
What's New in Python

Release 3.11.0a6

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This article explains the new features in Python 3.11, compared to 3.10.

For full details, see the changelog.

Note: Prerelease users should be aware that this document is currently in draft form. It will be updated substantially as Python 3.11 moves towards release, so it's worth checking back even after reading earlier versions.

1 Summary – Release highlights

New syntax features:

- **PEP 654:** Exception Groups and `except *`. (Contributed by Irit Katriel in [bpo-45292](#).)

New typing features:

- **PEP 673:** `Self` Type. (Contributed by James Hilton-Balfe and Pradeep Kumar in [bpo-30924](#).)

2 New Features

2.1 Enhanced error locations in tracebacks

When printing tracebacks, the interpreter will now point to the exact expression that caused the error instead of just the line. For example:

```
Traceback (most recent call last):
  File "distance.py", line 11, in <module>
    print(manhattan_distance(p1, p2))
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "distance.py", line 6, in manhattan_distance
    return abs(point_1.x - point_2.x) + abs(point_1.y - point_2.y)
           ^^^^^^^^^
AttributeError: 'NoneType' object has no attribute 'x'
```

Previous versions of the interpreter would point to just the line making it ambiguous which object was `None`. These enhanced errors can also be helpful when dealing with deeply nested dictionary objects and multiple function calls,

```

Traceback (most recent call last):
  File "query.py", line 37, in <module>
    magic_arithmetic('foo')
    ~~~~~^~~~~
  File "query.py", line 18, in magic_arithmetic
    return add_counts(x) / 25
    ~~~~~^~~~~
  File "query.py", line 24, in add_counts
    return 25 + query_user(user1) + query_user(user2)
    ~~~~~^~~~~
  File "query.py", line 32, in query_user
    return 1 + query_count(db, response['a']['b']['c']['user'], retry=True)
    ~~~~~^~~~~
TypeError: 'NoneType' object is not subscriptable

```

as well as complex arithmetic expressions:

```

Traceback (most recent call last):
  File "calculation.py", line 54, in <module>
    result = (x / y / z) * (a / b / c)
    ~~~~~^~~~
ZeroDivisionError: division by zero

```

See [PEP 657](#) for more details. (Contributed by Pablo Galindo, Batuhan Taskaya and Ammar Askar in [bpo-43950](#).)

Note: This feature requires storing column positions in code objects which may result in a small increase of disk usage of compiled Python files or interpreter memory usage. To avoid storing the extra information and/or deactivate printing the extra traceback information, the `-X no_debug_ranges` command line flag or the `PYTHONNODEBUGRANGES` environment variable can be used.

Column information for code objects

The information used by the enhanced traceback feature is made available as a general API that can be used to correlate bytecode instructions with source code. This information can be retrieved using:

- The `codeobject.co_positions()` method in Python.
- The `PyCode_Addr2Location()` function in the C-API.

The `-X no_debug_ranges` option and the environment variable `PYTHONNODEBUGRANGES` can be used to disable this feature.

See [PEP 657](#) for more details. (Contributed by Pablo Galindo, Batuhan Taskaya and Ammar Askar in [bpo-43950](#).)

Exceptions can be enriched with a string `__note__`

The `__note__` field was added to `BaseException`. It is `None` by default but can be set to a string which is added to the exception's traceback. (Contributed by Irit Katriel in [bpo-45607](#).)

3 Other Language Changes

- Starred expressions can be used in for statements. (See [bpo-46725](#) for more details.)
- Asynchronous comprehensions are now allowed inside comprehensions in asynchronous functions. Outer comprehensions implicitly become asynchronous. (Contributed by Serhiy Storchaka in [bpo-33346](#).)
- A `TypeError` is now raised instead of an `AttributeError` in `contextlib.ExitStack.enter_context()` and `contextlib.AsyncExitStack.enter_async_context()` for objects which do not support the context manager or asynchronous context manager protocols correspondingly. (Contributed by Serhiy Storchaka in [bpo-44471](#).)
- A `TypeError` is now raised instead of an `AttributeError` in `with` and `async with` statements for objects which do not support the context manager or asynchronous context manager protocols correspondingly. (Contributed by Serhiy Storchaka in [bpo-12022](#).)

4 Other CPython Implementation Changes

- Special methods `complex.__complex__()` and `bytes.__bytes__()` are implemented to support typing. `SupportsComplex` and `typing.SupportsBytes` protocols. (Contributed by Mark Dickinson and Dong-hee Na in [bpo-24234](#).)
- `siphash13` is added as a new internal hashing algorithms. It has similar security properties as `siphash24` but it is slightly faster for long inputs. `str`, `bytes`, and some other types now use it as default algorithm for `hash()`. **PEP 552** hash-based pyc files now use `siphash13`, too. (Contributed by Inada Naoki in [bpo-29410](#).)
- When an active exception is re-raised by a `raise` statement with no parameters, the traceback attached to this exception is now always `sys.exc_info()[1].__traceback__`. This means that changes made to the traceback in the current `except` clause are reflected in the re-raised exception. (Contributed by Irit Katriel in [bpo-45711](#).)
- The interpreter state's representation of handled exceptions (a.k.a `exc_info`, or `_PyErr_StackItem`) now has only the `exc_value` field, `exc_type` and `exc_traceback` have been removed as their values can be derived from `exc_value`. (Contributed by Irit Katriel in [bpo-45711](#).)
- A new command line option for the Windows installer `AppendPath` has been added. It behaves similar to `PrependPath` but appends the install and scripts directories instead of prepending them. (Contributed by Bastian Neuburger in [bpo-44934](#).)

5 New Modules

- A new module, `tomllib`, was added for parsing TOML. (Contributed by Taneli Hukkinen in [bpo-40059](#).)

6 Improved Modules

6.1 asyncio

- Add raw datagram socket functions to the event loop: `sock_sendto()`, `sock_recvfrom()` and `sock_recvfrom_into()`. (Contributed by Alex Grönholm in [bpo-46805](#).)

6.2 fractions

- Support **PEP 515**-style initialization of `Fraction` from string. (Contributed by Sergey B Kirpichev in [bpo-44258](#).)
- `Fraction` now implements an `__int__` method, so that an `isinstance(some_fraction, typing.SupportsInt)` check passes. (Contributed by Mark Dickinson in [bpo-44547](#).)

6.3 hashlib

- `hashlib.blake2b()` and `hashlib.blake2s()` now prefer [libb2](#) over Python's vendored copy. (Contributed by Christian Heimes in [bpo-47095](#).)
- The internal `_sha3` module with SHA3 and SHAKE algorithms now uses *tiny_sha3* instead of the *Keccak Code Package* to reduce code and binary size. The `hashlib` module prefers optimized SHA3 and SHAKE implementations from OpenSSL. The change affects only installations without OpenSSL support. (Contributed by Christian Heimes in [bpo-47098](#).)

6.4 IDLE and idlelib

- Apply syntax highlighting to `.pyi` files. (Contributed by Alex Waygood and Terry Jan Reedy in [bpo-45447](#).)

6.5 inspect

- Add `inspect.getmembers_static()`: return all members without triggering dynamic lookup via the descriptor protocol. (Contributed by Weipeng Hong in [bpo-30533](#).)
- Add `inspect.ismethodwrapper()` for checking if the type of an object is a `MethodWrapperType`. (Contributed by Hakan Çelik in [bpo-29418](#).)

6.6 math

- Add `math.exp2()`: return 2 raised to the power of x. (Contributed by Gideon Mitchell in [bpo-45917](#).)
- Add `math.cbrt()`: return the cube root of x. (Contributed by Ajith Ramachandran in [bpo-44357](#).)
- The behaviour of two `math.pow()` corner cases was changed, for consistency with the IEEE 754 specification. The operations `math.pow(0.0, -math.inf)` and `math.pow(-0.0, -math.inf)` now return `inf`. Previously they raised `ValueError`. (Contributed by Mark Dickinson in [bpo-44339](#).)
- The `math.nan` value is now always available. (Contributed by Victor Stinner in [bpo-46917](#).)

6.7 operator

- A new function `operator.call` has been added, such that `operator.call(obj, *args, **kwargs) == obj(*args, **kwargs)`. (Contributed by Antony Lee in [bpo-44019](#).)

6.8 os

- On Windows, `os.urandom()` now uses `BCryptGenRandom()`, instead of `CryptGenRandom()` which is deprecated. (Contributed by Dong-hee Na in [bpo-44611](#).)

6.9 re

- Atomic grouping `((?>...))` and possessive quantifiers `(*, ++, ?+, {m, n}+)` are now supported in regular expressions. (Contributed by Jeffrey C. Jacobs and Serhiy Storchaka in [bpo-433030](#).)

6.10 shutil

- Add optional parameter `dir_fd` in `shutil.rmtree()`. (Contributed by Serhiy Storchaka in [bpo-46245](#).)

6.11 socket

- Add CAN Socket support for NetBSD. (Contributed by Thomas Klausner in [bpo-30512](#).)

6.12 sqlite3

- You can now disable the authorizer by passing `None` to `set_authorizer()`. (Contributed by Erlend E. Aasland in [bpo-44491](#).)
- Collation name `create_collation()` can now contain any Unicode character. Collation names with invalid characters now raise `UnicodeEncodeError` instead of `sqlite3.ProgrammingError`. (Contributed by Erlend E. Aasland in [bpo-44688](#).)
- `sqlite3` exceptions now include the SQLite extended error code as `sqlite_errorcode` and the SQLite error name as `sqlite_errormsg`. (Contributed by Aviv Palivoda, Daniel Shahaf, and Erlend E. Aasland in [bpo-16379](#) and [bpo-24139](#).)
- Add `setlimit()` and `getlimit()` to `sqlite3.Connection` for setting and getting SQLite limits by connection basis. (Contributed by Erlend E. Aasland in [bpo-45243](#).)
- `sqlite3` now sets `sqlite3.thread_safety` based on the default threading mode the underlying SQLite library has been compiled with. (Contributed by Erlend E. Aasland in [bpo-45613](#).)
- `sqlite3` C callbacks now use `unraisable` exceptions if callback tracebacks are enabled. Users can now register an `unraisable` hook handler to improve their debug experience. (Contributed by Erlend E. Aasland in [bpo-45828](#).)
- Fetch across rollback no longer raises `InterfaceError`. Instead we leave it to the SQLite library to handle these cases. (Contributed by Erlend E. Aasland in [bpo-44092](#).)

6.13 sys

- `sys.exc_info()` now derives the `type` and `traceback` fields from the `value` (the exception instance), so when an exception is modified while it is being handled, the changes are reflected in the results of subsequent calls to `exc_info()`. (Contributed by Irit Katriel in [bpo-45711](#).)
- Add `sys.exception()` which returns the active exception instance (equivalent to `sys.exc_info()[1]`). (Contributed by Irit Katriel in [bpo-46328](#).)

6.14 sysconfig

- Two new installation schemes (*posix_venv*, *nt_venv* and *venv*) were added and are used when Python creates new virtual environments or when it is running from a virtual environment. The first two schemes (*posix_venv* and *nt_venv*) are OS-specific for non-Windows and Windows, the *venv* is essentially an alias to one of them according to the OS Python runs on. This is useful for downstream distributors who modify `sysconfig.get_preferred_scheme()`. Third party code that creates new virtual environments should use the new *venv* installation scheme to determine the paths, as does `venv`. (Contributed by Miro Hrončok in [bpo-45413](#).)

6.15 threading

- On Unix, if the `sem_clockwait()` function is available in the C library (glibc 2.30 and newer), the `threading.Lock.acquire()` method now uses the monotonic clock (`time.CLOCK_MONOTONIC`) for the timeout, rather than using the system clock (`time.CLOCK_REALTIME`), to not be affected by system clock changes. (Contributed by Victor Stinner in [bpo-41710](#).)

6.16 time

- On Unix, `time.sleep()` now uses the `clock_nanosleep()` or `nanosleep()` function, if available, which has a resolution of 1 nanosecond (10^{-9} seconds), rather than using `select()` which has a resolution of 1 microsecond (10^{-6} seconds). (Contributed by Benjamin Szőke and Victor Stinner in [bpo-21302](#).)
- On Windows 8.1 and newer, `time.sleep()` now uses a waitable timer based on [high-resolution timers](#) which has a resolution of 100 nanoseconds (10^{-7} seconds). Previously, it had a resolution of 1 millisecond (10^{-3} seconds). (Contributed by Benjamin Szőke, Dong-hee Na, Eryk Sun and Victor Stinner in [bpo-21302](#) and [bpo-45429](#).)

6.17 unicodedata

- The Unicode database has been updated to version 14.0.0. ([bpo-45190](#)).

6.18 venv

- When new Python virtual environments are created, the *venv* sysconfig installation scheme is used to determine the paths inside the environment. When Python runs in a virtual environment, the same installation scheme is the default. That means that downstream distributors can change the default sysconfig install scheme without changing behavior of virtual environments. Third party code that also creates new virtual environments should do the same. (Contributed by Miro Hrončok in [bpo-45413](#).)

6.19 zipfile

- Added support for specifying member name encoding for reading metadata in the zipfile's directory and file headers. (Contributed by Stephen J. Turnbull and Serhiy Storchaka in [bpo-28080](#).)

6.20 fcntl

- On FreeBSD, the `F_DUP2FD` and `F_DUP2FD_CLOEXEC` flags respectively are supported, the former equals to `dup2` usage while the latter set the `FD_CLOEXEC` flag in addition.

7 Optimizations

- Compiler now optimizes simple C-style formatting with literal format containing only format codes `%s`, `%r` and `%a` and makes it as fast as corresponding f-string expression. (Contributed by Serhiy Storchaka in [bpo-28307](#).)
- “Zero-cost” exceptions are implemented. The cost of `try` statements is almost eliminated when no exception is raised. (Contributed by Mark Shannon in [bpo-40222](#).)
- Method calls with keywords are now faster due to bytecode changes which avoid creating bound method instances. Previously, this optimization was applied only to method calls with purely positional arguments. (Contributed by Ken Jin and Mark Shannon in [bpo-26110](#), based on ideas implemented in PyPy.)
- Pure ASCII strings are now normalized in constant time by `unicodedata.normalize()`. (Contributed by Dong-hee Na in [bpo-44987](#).)
- `math` functions `comb()` and `perm()` are now up to 10 times or more faster for large arguments (the speed up is larger for larger k). (Contributed by Serhiy Storchaka in [bpo-37295](#).)
- Dict don’t store hash value when all inserted keys are Unicode objects. This reduces dict size. For example, `sys.getsizeof(dict.fromkeys("abcdefg"))` becomes 272 bytes from 352 bytes on 64bit platform. (Contributed by Inada Naoki in [bpo-46845](#).)

8 CPython bytecode changes

- Replaced all numeric `BINARY_*` and `INPLACE_*` instructions with a single `BINARY_OP` implementation.
- Replaced the three call instructions: `CALL_FUNCTION`, `CALL_FUNCTION_KW` and `CALL_METHOD` with `PUSH_NULL`, `PRECALL`, `CALL`, and `KW_NAMES`. This decouples the argument shifting for methods from the handling of keyword arguments and allows better specialization of calls.
- Removed `COPY_DICT_WITHOUT_KEYS` and `GEN_START`.
- `MATCH_CLASS` and `MATCH_KEYS` no longer push an additional boolean value indicating whether the match succeeded or failed. Instead, they indicate failure with `None` (where a tuple of extracted values would otherwise be).
- Replace several stack manipulation instructions (`DUP_TOP`, `DUP_TOP_TWO`, `ROT_TWO`, `ROT_THREE`, `ROT_FOUR`, and `ROT_N`) with new `COPY` and `SWAP` instructions.
- Add `POP_JUMP_IF_NOT_NONE` and `POP_JUMP_IF_NONE` opcodes to speed up conditional jumps.
- Replaced `JUMP_IF_NOT_EXC_MATCH` by `CHECK_EXC_MATCH` which performs the check but does not jump.
- Replaced `JUMP_ABSOLUTE` by the relative `JUMP_BACKWARD`.

9 Deprecated

- The `lib2to3` package and `2to3` tool are now deprecated and may not be able to parse Python 3.10 or newer. See the [PEP 617](#) (New PEG parser for CPython). (Contributed by Victor Stinner in [bpo-40360](#).)
- Undocumented modules `sre_compile`, `sre_constants` and `sre_parse` are now deprecated. (Contributed by Serhiy Storchaka in [bpo-47152](#).)
- `webbrowser.MacOSX` is deprecated and will be removed in Python 3.13. It is untested and undocumented and also not used by `webbrowser` itself. (Contributed by Dong-hee Na in [bpo-42255](#).)
- The behavior of returning a value from a `TestCase` and `IsolatedAsyncioTestCase` test methods (other than the default `None` value), is now deprecated.
- Deprecated the following `unittest` functions, scheduled for removal in Python 3.13:

- `unittest.findTestCases()`
- `unittest.makeSuite()`
- `unittest.getTestCaseNames()`

Use `TestLoader` method instead:

- `unittest.TestLoader.loadTestsFromModule()`
- `unittest.TestLoader.loadTestsFromTestCase()`
- `unittest.TestLoader.getTestCaseNames()`

(Contributed by Erlend E. Aasland in [bpo-5846](#).)

- The `turtle.RawTurtle.settiltangle()` is deprecated since Python 3.1, it now emits a deprecation warning and will be removed in Python 3.13. Use `turtle.RawTurtle.tiltangle()` instead (it was earlier incorrectly marked as deprecated, its docstring is now corrected). (Contributed by Hugo van Kemenade in [bpo-45837](#).)
- The delegation of `int()` to `__trunc__()` is now deprecated. Calling `int(a)` when `type(a)` implements `__trunc__()` but not `__int__()` or `__index__()` now raises a `DeprecationWarning`. (Contributed by Zackery Spytz in [bpo-44977](#).)
- The following have been deprecated in `configparser` since Python 3.2. Their deprecation warnings have now been updated to note they will be removed in Python 3.12:
 - the `configparser.SafeConfigParser` class
 - the `configparser.ParsingError.filename` property
 - the `configparser.ParsingError.readfp()` method

(Contributed by Hugo van Kemenade in [bpo-45173](#).)

- The `locale.getdefaultlocale()` function is deprecated and will be removed in Python 3.13. Use `locale.setlocale()`, `locale.getpreferredencoding(False)` and `locale.getlocale()` functions instead. (Contributed by Victor Stinner in [bpo-46659](#).)
- The `asynchat`, `asyncore` and `smtplib` modules have been deprecated since at least Python 3.6. Their documentation and deprecation warnings have now been updated to note they will be removed in Python 3.12 ([PEP 594](#)). (Contributed by Hugo van Kemenade in [bpo-47022](#).)

10 Removed

- `smtplib.MailmanProxy` is now removed as it is unusable without an external module, `mailman`. (Contributed by Dong-hee Na in [bpo-35800](#).)
- The `binhex` module, deprecated in Python 3.9, is now removed. The following `binascii` functions, deprecated in Python 3.9, are now also removed:

- `a2b_hqx()`, `b2a_hqx()`;
- `rlecode_hqx()`, `rledecode_hqx()`.

The `binascii.crc_hqx()` function remains available.

(Contributed by Victor Stinner in [bpo-45085](#).)

- The `distutils.bdist_msi` command, deprecated in Python 3.9, is now removed. Use `bdist_wheel` (wheel packages) instead. (Contributed by Hugo van Kemenade in [bpo-45124](#).)
- Due to significant security concerns, the `reuse_address` parameter of `asyncio.loop.create_datagram_endpoint()`, disabled in Python 3.9, is now entirely removed. This is because of the behavior of the socket option `SO_REUSEADDR` in UDP. (Contributed by Hugo van Kemenade in [bpo-45129](#).)
- Removed `__getitem__()` methods of `xml.dom.pulldom.DOMEventStream`, `wsgiref.util.FileWrapper` and `fileinput.FileInput`, deprecated since Python 3.9. (Contributed by Hugo van Kemenade in [bpo-45132](#).)
- The following deprecated functions and methods are removed in the `gettext` module: `lgettext()`, `ldgettext()`, `lngettext()` and `ldngettext()`.

Function `bind_textdomain_codeset()`, methods `output_charset()` and `set_output_charset()`, and the `codeset` parameter of functions `translation()` and `install()` are also removed, since they are only used for the `l*gettext()` functions. (Contributed by Dong-hee Na and Serhiy Storchaka in [bpo-44235](#).)
- The `@asyncio.coroutine` decorator enabling legacy generator-based coroutines to be compatible with `async/await` code. The function has been deprecated since Python 3.8 and the removal was initially scheduled for Python 3.10. Use `async def` instead. (Contributed by Illia Volochii in [bpo-43216](#).)
- `asyncio.coroutines CoroWrapper` used for wrapping legacy generator-based coroutine objects in the debug mode. (Contributed by Illia Volochii in [bpo-43216](#).)
- Removed the deprecated `split()` method of `_tkinter.TkappType`. (Contributed by Erlend E. Aasland in [bpo-38371](#).)
- Removed from the `inspect` module:

- the `getargspec` function, deprecated since Python 3.0; use `inspect.signature()` or `inspect.getfullargspec()` instead.
- the `formatargspec` function, deprecated since Python 3.5; use the `inspect.signature()` function and `Signature` object directly.
- the undocumented `Signature.from_builtin` and `Signature.from_function` functions, deprecated since Python 3.5; use the `Signature.from_callable()` method instead.

(Contributed by Hugo van Kemenade in [bpo-45320](#).)

- Remove namespace package support from `unittest` discovery. It was introduced in Python 3.4 but has been broken since Python 3.7. (Contributed by Inada Naoki in [bpo-23882](#).)
- Remove `__class_getitem__` method from `pathlib.PurePath`, because it was not used and added by mistake in previous versions. (Contributed by Nikita Sobolev in [bpo-46483](#).)
- Remove the undocumented private `float.__set_format__()` method, previously known as `float.__setformat__()` in Python 3.7. Its docstring said: “You probably don’t want to use this function. It exists mainly to be used in Python’s test suite.” (Contributed by Victor Stinner in [bpo-46852](#).)

11 Porting to Python 3.11

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

11.1 Changes in the Python API

- Prohibited passing `non-concurrent.futures.ThreadPoolExecutor` executors to `loop.set_default_executor()` following a deprecation in Python 3.8. (Contributed by Illia Volochii in [bpo-43234](#).)
- `open()`, `io.open()`, `codecs.open()` and `fileinput.FileInput` no longer accept 'U' (“universal newline”) in the file mode. This flag was deprecated since Python 3.3. In Python 3, the “universal newline” is used by default when a file is open in text mode. The `newline` parameter of `open()` controls how universal newlines works. (Contributed by Victor Stinner in [bpo-37330](#).)
- The `pdb` module now reads the `.pdbrc` configuration file with the 'utf-8' encoding. (Contributed by Srinivas Reddy Thatiparthi ([@sreenivasreddy](#)) in [bpo-41137](#).)
- When sorting using tuples as keys, the order of the result may differ from earlier releases if the tuple elements don't define a total ordering (see [expressions-value-comparisons](#) for information on total ordering). It's generally true that the result of sorting simply isn't well-defined in the absence of a total ordering on list elements.
- `calendar`: The `calendar.LocaleTextCalendar` and `calendar.LocaleHTMLCalendar` classes now use `locale.getlocale()`, instead of using `locale.getdefaultlocale()`, if no locale is specified. (Contributed by Victor Stinner in [bpo-46659](#).)
- Global inline flags (e.g. `(?i)`) can now only be used at the start of the regular expressions. Using them not at the start of expression was deprecated since Python 3.6. (Contributed by Serhiy Storchaka in [bpo-47066](#).)
- `re` module: Fix a few long-standing bugs where, in rare cases, capturing group could get wrong result. So the result may be different than before. (Contributed by Ma Lin in [bpo-35859](#).)
- The `population` parameter of `random.sample()` must be a sequence. Automatic conversion of sets to lists is no longer supported. If the sample size is larger than the population size, a `ValueError` is raised. (Contributed by Raymond Hettinger in [bpo-40465](#).)

12 Build Changes

- Building Python now requires a C11 compiler without optional C11 features. (Contributed by Victor Stinner in [bpo-46656](#).)
- Building Python now requires support of IEEE 754 floating point numbers. (Contributed by Victor Stinner in [bpo-46917](#).)
- CPython can now be built with the ThinLTO option via `--with-lto=thin`. (Contributed by Dong-hee Na and Brett Holman in [bpo-44340](#).)
- `libpython` is no longer linked against `libcrypt`. (Contributed by Mike Gilbert in [bpo-45433](#).)
- Building Python now requires a C99 `<math.h>` header file providing the following functions: `copysign()`, `hypot()`, `isfinite()`, `isinf()`, `isnan()`, `round()`. (Contributed by Victor Stinner in [bpo-45440](#).)
- Building Python now requires a C99 `<math.h>` header file providing a NAN constant, or the `__builtin_nan()` built-in function. (Contributed by Victor Stinner in [bpo-46640](#).)
- Building Python now requires support for floating point Not-a-Number (NaN): remove the `Py_NO_NAN` macro. (Contributed by Victor Stinner in [bpo-46656](#).)
- Freelists for object structs can now be disabled. A new **configure** option `--without-freelists` can be used to disable all freelists except empty tuple singleton. (Contributed by Christian Heimes in [bpo-45522](#).)

- `Modules/Setup` and `Modules/makesetup` have been improved and tied up. Extension modules can now be built through `makesetup`. All except some test modules can be linked statically into main binary or library. (Contributed by Brett Cannon and Christian Heimes in [bpo-45548](#), [bpo-45570](#), [bpo-45571](#), and [bpo-43974](#).)
- Build dependencies, compiler flags, and linker flags for most stdlib extension modules are now detected by **configure**. `libffi`, `libnsl`, `libsqlite3`, `zlib`, `bzip2`, `liblzma`, `libcrypt`, `Tcl/Tk` libs, and `uuid` flags are detected by `pkg-config` (when available). (Contributed by Christian Heimes and Erlend Egeberg Aasland in [bpo-45847](#), [bpo-45747](#), and [bpo-45763](#).)

Note: Use the environment variables `TCLTK_CFLAGS` and `TCLTK_LIBS` to manually specify the location of `Tcl/Tk` headers and libraries. The **configure** options `--with-tcltk-includes` and `--with-tcltk-libs` have been removed.

- CPython now has experimental support for cross compiling to WebAssembly platform `wasm32-emscripten`. The effort is inspired by previous work like `Pyodide`. (Contributed by Christian Heimes and Ethan Smith in [bpo-40280](#).)
- CPython will now use 30-bit digits by default for the Python `int` implementation. Previously, the default was to use 30-bit digits on platforms with `SIZEOF_VOID_P >= 8`, and 15-bit digits otherwise. It's still possible to explicitly request use of 15-bit digits via either the `--enable-big-digits` option to the `configure` script or (for Windows) the `PYLONG_BITS_IN_DIGIT` variable in `PC/pyconfig.h`, but this option may be removed at some point in the future. (Contributed by Mark Dickinson in [bpo-45569](#).)
- The `tkinter` package now requires `Tcl/Tk` version 8.5.12 or newer. (Contributed by Serhiy Storchaka in [bpo-46996](#).)

13 C API Changes

- `PyErr_SetExcInfo()` no longer uses the `type` and `traceback` arguments, the interpreter now derives those values from the exception instance (the `value` argument). The function still steals references of all three arguments. (Contributed by Irit Katriel in [bpo-45711](#).)
- `PyErr_GetExcInfo()` now derives the `type` and `traceback` fields of the result from the exception instance (the `value` field). (Contributed by Irit Katriel in [bpo-45711](#).)
- `_frozen` has a new `is_package` field to indicate whether or not the frozen module is a package. Previously, a negative value in the `size` field was the indicator. Now only non-negative values be used for `size`. (Contributed by Kumar Aditya in [bpo-46608](#).)

13.1 New Features

- Add a new `PyType_GetName()` function to get type's short name. (Contributed by Hai Shi in [bpo-42035](#).)
- Add a new `PyType_GetQualName()` function to get type's qualified name. (Contributed by Hai Shi in [bpo-42035](#).)
- Add new `PyThreadState_EnterTracing()` and `PyThreadState_LeaveTracing()` functions to the limited C API to suspend and resume tracing and profiling. (Contributed by Victor Stinner in [bpo-43760](#).)
- Added the `Py_Version` constant which bears the same value as `PY_VERSION_HEX`. (Contributed by Gabriele N. Tornetta in [bpo-43931](#).)
- `Py_buffer` and APIs are now part of the limited API and the stable ABI:
 - `PyObject_CheckBuffer()`
 - `PyObject_GetBuffer()`
 - `PyBuffer_GetPointer()`

- `PyBuffer_SizeFromFormat()`
- `PyBuffer_ToContiguous()`
- `PyBuffer_FromContiguous()`
- `PyBuffer_CopyData()`
- `PyBuffer_IsContiguous()`
- `PyBuffer_FillContiguousStrides()`
- `PyBuffer_FillInfo()`
- `PyBuffer_Release()`
- `PyMemoryView_FromBuffer()`
- `bf_getbuffer` and `bf_releasebuffer` type slots

(Contributed by Christian Heimes in [bpo-45459](#).)

- Added the `PyType_GetModuleByDef` function, used to get the module in which a method was defined, in cases where this information is not available directly (via `PyCMethod`). (Contributed by Petr Viktorin in [bpo-46613](#).)
- Add new functions to pack and unpack C double (serialize and deserialize): `PyFloat_Pack2()`, `PyFloat_Pack4()`, `PyFloat_Pack8()`, `PyFloat_Unpack2()`, `PyFloat_Unpack4()` and `PyFloat_Unpack8()`. (Contributed by Victor Stinner in [bpo-46906](#).)
- Add new functions to get frame object attributes: `PyFrame_GetBuiltins()`, `PyFrame_GetGenerator()`, `PyFrame_GetGlobals()`.

13.2 Porting to Python 3.11

- The old trashcan macros (`Py_TRASHCAN_SAFE_BEGIN/Py_TRASHCAN_SAFE_END`) are now deprecated. They should be replaced by the new macros `Py_TRASHCAN_BEGIN` and `Py_TRASHCAN_END`.

A `tp_dealloc` function that has the old macros, such as:

```
static void
mytype_dealloc(mytype *p)
{
    PyObject_GC_UnTrack(p);
    Py_TRASHCAN_SAFE_BEGIN(p);
    ...
    Py_TRASHCAN_SAFE_END
}
```

should migrate to the new macros as follows:

```
static void
mytype_dealloc(mytype *p)
{
    PyObject_GC_UnTrack(p);
    Py_TRASHCAN_BEGIN(p, mytype_dealloc)
    ...
    Py_TRASHCAN_END
}
```

Note that `Py_TRASHCAN_BEGIN` has a second argument which should be the deallocation function it is in.

To support older Python versions in the same codebase, you can define the following macros and use them throughout the code (credit: these were copied from the `mypy` codebase):

```

#if PY_MAJOR_VERSION >= 3 && PY_MINOR_VERSION >= 8
# define CPy_TRASHCAN_BEGIN(op, dealloc) Py_TRASHCAN_BEGIN(op, dealloc)
# define CPy_TRASHCAN_END(op) Py_TRASHCAN_END
#else
# define CPy_TRASHCAN_BEGIN(op, dealloc) Py_TRASHCAN_SAFE_BEGIN(op)
# define CPy_TRASHCAN_END(op) Py_TRASHCAN_SAFE_END(op)
#endif

```

- The `PyType_Ready()` function now raises an error if a type is defined with the `Py_TPFLAGS_HAVE_GC` flag set but has no traverse function (`PyTypeObject.tp_traverse`). (Contributed by Victor Stinner in [bpo-44263](#).)
- Heap types with the `Py_TPFLAGS_IMMUTABLETYPE` flag can now inherit the **PEP 590** vectorcall protocol. Previously, this was only possible for static types. (Contributed by Erlend E. Aasland in [bpo-43908](#))
- Since `Py_TYPE()` is changed to an inline static function, `Py_TYPE(obj) = new_type` must be replaced with `Py_SET_TYPE(obj, new_type)`: see the `Py_SET_TYPE()` function (available since Python 3.9). For backward compatibility, this macro can be used:

```

#if PY_VERSION_HEX < 0x030900A4 && !defined(Py_SET_TYPE)
static inline void _Py_SET_TYPE(PyObject *ob, PyTypeObject *type)
{ ob->ob_type = type; }
#define Py_SET_TYPE(ob, type) _Py_SET_TYPE((PyObject*)(ob), type)
#endif

```

(Contributed by Victor Stinner in [bpo-39573](#).)

- Since `Py_SIZE()` is changed to an inline static function, `Py_SIZE(obj) = new_size` must be replaced with `Py_SET_SIZE(obj, new_size)`: see the `Py_SET_SIZE()` function (available since Python 3.9). For backward compatibility, this macro can be used:

```

#if PY_VERSION_HEX < 0x030900A4 && !defined(Py_SET_SIZE)
static inline void _Py_SET_SIZE(PyVarObject *ob, Py_ssize_t size)
{ ob->ob_size = size; }
#define Py_SET_SIZE(ob, size) _Py_SET_SIZE((PyVarObject*)(ob), size)
#endif

```

(Contributed by Victor Stinner in [bpo-39573](#).)

- `<Python.h>` no longer includes the header files `<stdlib.h>`, `<stdio.h>`, `<errno.h>` and `<string.h>` when the `Py_LIMITED_API` macro is set to `0x030b0000` (Python 3.11) or higher. C extensions should explicitly include the header files after `#include <Python.h>`. (Contributed by Victor Stinner in [bpo-45434](#).)
- The non-limited API files `cellobject.h`, `classobject.h`, `context.h`, `funcobject.h`, `genobject.h` and `longintrepr.h` have been moved to the `Include/cpython` directory. Moreover, the `eval.h` header file was removed. These files must not be included directly, as they are already included in `Python.h`: Include Files. If they have been included directly, consider including `Python.h` instead. (Contributed by Victor Stinner in [bpo-35134](#).)
- The `PyUnicode_CHECK_INTERNED()` macro has been excluded from the limited C API. It was never usable there, because it used internal structures which are not available in the limited C API. (Contributed by Victor Stinner in [bpo-46007](#).)
- The `PyFrameObject` structure member has been moved to the internal C API headers.

While the documentation notes that the `PyFrameObject` fields are subject to change at any time, they have been stable for a long time and were used in several popular extensions.

In Python 3.11, the frame struct was reorganized to allow performance optimizations. Some fields were removed entirely, as they were details of the old implementation.

`PyFrameObject` fields:

- `f_back`: use `PyFrame_GetBack()`.

- f_blockstack: removed.
- f_builtins: use PyFrame_GetBuiltins().
- f_code: use PyFrame_GetCode().
- f_gen: use PyFrame_GetGenerator().
- f_globals: use PyFrame_GetGlobals().
- f_iblock: removed.
- f_lasti: use PyObject_GetAttrString((PyObject*)frame, "f_lasti"). Code using f_lasti with PyCode_Addr2Line() should use PyFrame_GetLineNumber() instead.
- f_lineno: use PyFrame_GetLineNumber().
- f_locals: use PyFrame_GetLocals().
- f_stackdepth: removed.
- f_state: no public API (renamed to f_frame.f_state).
- f_trace: no public API.
- f_trace_lines: use PyObject_GetAttrString((PyObject*)frame, "f_trace_lines").
- f_trace_opcodes: use PyObject_GetAttrString((PyObject*)frame, "f_trace_opcodes").
- f_localsplus: no public API (renamed to f_frame.localsplus).
- f_valuestack: removed.

The Python frame object is now created lazily. A side effect is that the `f_back` member must not be accessed directly, since its value is now also computed lazily. The `PyFrame_GetBack()` function must be called instead.

Debuggers that accessed the `f_locals` directly *must* call `PyFrame_GetLocals()` instead. They no longer need to call `PyFrame_FastToLocalsWithError()` or `PyFrame_LocalsToFast()`, in fact they should not call those functions. The necessary updating of the frame is now managed by the virtual machine.

Code defining `PyFrame_GetCode()` on Python 3.8 and older:

```
#if PY_VERSION_HEX < 0x030900B1
static inline PyCodeObject* PyFrame_GetCode(PyFrameObject *frame)
{
    Py_INCREF(frame->f_code);
    return frame->f_code;
}
#endif
```

Code defining `PyFrame_GetBack()` on Python 3.8 and older:

```
#if PY_VERSION_HEX < 0x030900B1
static inline PyFrameObject* PyFrame_GetBack(PyFrameObject *frame)
{
    Py_XINCRREF(frame->f_back);
    return frame->f_back;
}
#endif
```

Or use the [pythoncapi_compat](#) project to get these two functions on older Python versions.

- Changes of the `PyThreadState` structure members:

- frame: removed, use `PyThreadState_GetFrame()` (function added to Python 3.9 by [bpo-40429](#)). Warning: the function returns a strong reference, need to call `Py_XDECREF()`.
- tracing: changed, use `PyThreadState_EnterTracing()` and `PyThreadState_LeaveTracing()` (functions added to Python 3.11 by [bpo-43760](#)).
- recursion_depth: removed, use `(tstate->recursion_limit - tstate->recursion_remaining)` instead.
- stackcheck_counter: removed.

Code defining `PyThreadState_GetFrame()` on Python 3.8 and older:

```
#if PY_VERSION_HEX < 0x030900B1
static inline PyFrameObject* PyThreadState_GetFrame(PyThreadState *tstate)
{
    Py_XINCREF(tstate->frame);
    return tstate->frame;
}
#endif
```

Code defining `PyThreadState_EnterTracing()` and `PyThreadState_LeaveTracing()` on Python 3.10 and older:

```
#if PY_VERSION_HEX < 0x030B00A2
static inline void PyThreadState_EnterTracing(PyThreadState *tstate)
{
    tstate->tracing++;
    #if PY_VERSION_HEX >= 0x030A00A1
    tstate->cframe->use_tracing = 0;
    #else
    tstate->use_tracing = 0;
    #endif
}

static inline void PyThreadState_LeaveTracing(PyThreadState *tstate)
{
    int use_tracing = (tstate->c_tracefunc != NULL || tstate->c_profilefunc !=
↳ NULL);
    tstate->tracing--;
    #if PY_VERSION_HEX >= 0x030A00A1
    tstate->cframe->use_tracing = use_tracing;
    #else
    tstate->use_tracing = use_tracing;
    #endif
}
#endif
```

Or use the [pythoncapi_compat](#) project to get these functions on old Python functions.

- Distributors are encouraged to build Python with the optimized Blake2 library [libb2](#).
- Move the private undocumented `_PyEval_EvalFrameDefault()` function to the internal C API. The function now uses the `_PyInterpreterFrame` type which is part of the internal C API. (Contributed by Victor Stinner in [bpo-46850](#).)
- Move the private `_PyFrameEvalFunction` type, and private `_PyInterpreterState_GetEvalFrameFunc()` and `_PyInterpreterState_SetEvalFrameFunc()` functions to the internal C API. The `_PyFrameEvalFunction` callback function type now uses the `_PyInterpreterFrame` type which is part of the internal C API. (Contributed by Victor Stinner in [bpo-46850](#).)

13.3 Deprecated

- Deprecate the following functions to configure the Python initialization:

- `PySys_AddWarnOptionUnicode()`
- `PySys_AddWarnOption()`
- `PySys_AddXOption()`
- `PySys_HasWarnOptions()`
- `Py_SetPath()`
- `Py_SetProgramName()`
- `Py_SetPythonHome()`
- `Py_SetStandardStreamEncoding()`
- `_Py_SetProgramFullPath()`

Use the new `PyConfig` API of the Python Initialization Configuration instead ([PEP 587](#)). (Contributed by Victor Stinner in [bpo-44113](#).)

- Deprecate the `ob_shash` member of the `PyBytesObject`. Use `PyObject_Hash()` instead. (Contributed by Inada Naoki in [bpo-46864](#).)

13.4 Removed

- `PyFrame_BlockSetup()` and `PyFrame_BlockPop()` have been removed. (Contributed by Mark Shannon in [bpo-40222](#).)

- Remove the following math macros using the `errno` variable:

- `Py_ADJUST_ERANGE1()`
- `Py_ADJUST_ERANGE2()`
- `Py_OVERFLOWED()`
- `Py_SET_ERANGE_IF_OVERFLOW()`
- `Py_SET_ERRNO_ON_MATH_ERROR()`

(Contributed by Victor Stinner in [bpo-45412](#).)

- Remove `Py_UNICODE_COPY()` and `Py_UNICODE_FILL()` macros, deprecated since Python 3.3. Use `PyUnicode_CopyCharacters()` or `memcpy()` (`wchar_t*` string), and `PyUnicode_Fill()` functions instead. (Contributed by Victor Stinner in [bpo-41123](#).)
- Remove the `pystrhex.h` header file. It only contains private functions. C extensions should only include the main `<Python.h>` header file. (Contributed by Victor Stinner in [bpo-45434](#).)
- Remove the `Py_FORCE_DOUBLE()` macro. It was used by the `Py_IS_INFINITY()` macro. (Contributed by Victor Stinner in [bpo-45440](#).)
- The following items are no longer available when `Py_LIMITED_API` is defined:

- `PyMarshal_WriteLongToFile()`
- `PyMarshal_WriteObjectToFile()`
- `PyMarshal_ReadObjectFromString()`
- `PyMarshal_WriteObjectToString()`
- the `Py_MARSHAL_VERSION` macro

These are not part of the limited API.

(Contributed by Victor Stinner in [bpo-45474](#).)

- Exclude `PyWeakref_GET_OBJECT()` from the limited C API. It never worked since the `PyWeakReference` structure is opaque in the limited C API. (Contributed by Victor Stinner in [bpo-35134](#).)
- Remove the `PyHeapType_GET_MEMBERS()` macro. It was exposed in the public C API by mistake, it must only be used by Python internally. Use the `PyTypeObject.tp_members` member instead. (Contributed by Victor Stinner in [bpo-40170](#).)
- Remove the `HAVE_PY_SET_53BIT_PRECISION` macro (moved to the internal C API). (Contributed by Victor Stinner in [bpo-45412](#).)

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