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# What's New in Python

*Release 3.12.0b3*

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**Release** 3.12.0b3

**Date** July 11, 2023

This article explains the new features in Python 3.12, compared to 3.11.

For full details, see the changelog.

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**Note:** Prerelease users should be aware that this document is currently in draft form. It will be updated substantially as Python 3.12 moves towards release, so it's worth checking back even after reading earlier versions.

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# 1 Summary – Release highlights

New grammar features:

- **PEP 701**: Syntactic formalization of f-strings

New typing features:

- **PEP 688**: Making the buffer protocol accessible in Python
- *PEP 692: Using TypedDict for more precise **\*\*kwargs** typing*
- *PEP 695: Type Parameter Syntax*
- **PEP 698**: Override Decorator for Static Typing

Important deprecations, removals or restrictions:

- **PEP 623**: Remove `wstr` from Unicode
- **PEP 632**: Remove the `distutils` package

## 2 Improved Error Messages

- Modules from the standard library are now potentially suggested as part of the error messages displayed by the interpreter when a `NameError` is raised to the top level. Contributed by Pablo Galindo in [gh-98254](#).

```
>>> sys.version_info
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'sys' is not defined. Did you forget to import 'sys'?
```

- Improve the error suggestion for `NameError` exceptions for instances. Now if a `NameError` is raised in a method and the instance has an attribute that's exactly equal to the name in the exception, the suggestion will include `self.<NAME>` instead of the closest match in the method scope. Contributed by Pablo Galindo in [gh-99139](#).

```
>>> class A:
...     def __init__(self):
...         self.blech = 1
...
...     def foo(self):
...         somethin = blech
```

```
>>> A().foo()
File "<stdin>", line 1
    somethin = blech
              ^^^^^
NameError: name 'blech' is not defined. Did you mean: 'self.blech'?
```

- Improve the `SyntaxError` error message when the user types `import x from y` instead of `from y import x`. Contributed by Pablo Galindo in [gh-98931](#).

```
>>> import a.y.z from b.y.z
File "<stdin>", line 1
    import a.y.z from b.y.z
    ^^^^^^^^^^^^^^^^^^^^^^^
SyntaxError: Did you mean to use 'from ... import ...' instead?
```

- ```
>>> from collections import chainmap
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ImportError: cannot import name 'chainmap' from 'collections'. Did you mean:
↳ 'ChainMap'?
```

### 3.1 PEP 701: Syntactic formalization of f-strings

Quote reuse: in Python 3.11, reusing the same quotes as the containing f-string raises a `SyntaxError`, forcing the user to either use other available quotes (like using double quotes or triple quotes if the f-string uses single quotes). In Python 3.12, you can now do things like this:

Note that before this change there was no explicit limit in how f-strings can be nested, but the fact that string quotes cannot be reused inside the expression component of f-strings made it impossible to nest f-strings arbitrarily. In fact, this is the most nested f-string that could be written:

As now f-strings can contain any valid Python expression inside expression components, it is now possible to nest f-strings arbitrarily:

```
>>> f"This is the playlist: {"", ".join([
...     'Take me back to Eden',      # My, my, those eyes like fire
...     'Alkaline',                  # Not acid nor alkaline
...     'Ascensionism'               # Take to the broken skies at last
... ]})"
```

```
'This is the playlist: Take me back to Eden, Alkaline, Ascensionism'
```

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```
>>> print(f"This is the playlist: {\n".join(songs) }")
This is the playlist: Take me back to Eden
Alkaline
Ascensionism
>>> print(f"This is the playlist: {\N{BLACK HEART SUIT}}".join(songs) }")
This is the playlist: Take me back to Eden♥Alkaline♥Ascensionism
```

See **PEP 701** for more details.

As a positive side-effect of how this feature has been implemented (by parsing f-strings with the PEG parser (see **PEP 617**), now error messages for f-strings are more precise and include the exact location of the error. For example, in Python 3.11, the following f-string raises a `SyntaxError`:

```
>>> my_string = f"{x z y}" + f"{1 + 1}"
File "<stdin>", line 1
    (x z y)
    ^^^
SyntaxError: f-string: invalid syntax. Perhaps you forgot a comma?
```

but the error message doesn't include the exact location of the error within the line and also has the expression artificially surrounded by parentheses. In Python 3.12, as f-strings are parsed with the PEG parser, error messages can be more precise and show the entire line:

```
>>> my_string = f"{x z y}" + f"{1 + 1}"
File "<stdin>", line 1
    my_string = f"{x z y}" + f"{1 + 1}"
                  ^^^
SyntaxError: invalid syntax. Perhaps you forgot a comma?
```

(Contributed by Pablo Galindo, Batuhan Taskaya, Lysandros Nikolaou, Cristián Maureira-Fredes and Marta Gómez in [gh-102856](#). PEP written by Pablo Galindo, Batuhan Taskaya, Lysandros Nikolaou and Marta Gómez).

## 3.2 PEP 709: Comprehension inlining

Dictionary, list, and set comprehensions are now inlined, rather than creating a new single-use function object for each execution of the comprehension. This speeds up execution of a comprehension by up to 2x.

Comprehension iteration variables remain isolated; they don't overwrite a variable of the same name in the outer scope, nor are they visible after the comprehension. This isolation is now maintained via stack/locals manipulation, not via separate function scope.

Inlining does result in a few visible behavior changes:

- There is no longer a separate frame for the comprehension in tracebacks, and tracing/profiling no longer shows the comprehension as a function call.
- Calling `locals()` inside a comprehension now includes variables from outside the comprehension, and no longer includes the synthetic `.0` variable for the comprehension "argument".
- A comprehension iterating directly over `locals()` (e.g. `[k for k in locals()]`) may see "RuntimeError: dictionary changed size during iteration" when run under tracing (e.g. code coverage measurement). This is the same behavior already seen in e.g. `for k in locals():`. To avoid the error, first create a list of keys to iterate over: `keys = list(locals()); [k for k in keys]`.

Contributed by Carl Meyer and Vladimir Matveev in **PEP 709**.

### 3.3 PEP 688: Making the buffer protocol accessible in Python

**PEP 688** introduces a way to use the buffer protocol from Python code. Classes that implement the `__buffer__()` method are now usable as buffer types.

The new `collections.abc.Buffer` ABC provides a standard way to represent buffer objects, for example in type annotations. The new `inspect.BufferFlags` enum represents the flags that can be used to customize buffer creation. (Contributed by Jelle Zijlstra in [gh-102500](#).)

## 4 New Features Related to Type Hints

This section covers major changes affecting **PEP 484** type hints and the `typing` module.

### 4.1 PEP 692: Using TypedDict for more precise \*\*kwargs typing

Typing `**kwargs` in a function signature as introduced by **PEP 484** allowed for valid annotations only in cases where all of the `**kwargs` were of the same type.

This PEP specifies a more precise way of typing `**kwargs` by relying on typed dictionaries:

```
from typing import TypedDict, Unpack

class Movie(TypedDict):
    name: str
    year: int

def foo(**kwargs: Unpack[Movie]): ...
```

See **PEP 692** for more details.

(Contributed by Franek Magiera in [gh-103629](#).)

### 4.2 PEP 698: Override Decorator for Static Typing

A new decorator `typing.override()` has been added to the `typing` module. It indicates to type checkers that the method is intended to override a method in a superclass. This allows type checkers to catch mistakes where a method that is intended to override something in a base class does not in fact do so.

Example:

```
from typing import override

class Base:
    def get_color(self) -> str:
        return "blue"

class GoodChild(Base):
    @override # ok: overrides Base.get_color
    def get_color(self) -> str:
        return "yellow"

class BadChild(Base):
    @override # type checker error: does not override Base.get_color
```

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```
def get_colour(self) -> str:
    return "red"
```

(Contributed by Steven Troxler in [gh-101561](#).)

## 4.3 PEP 695: Type Parameter Syntax

Generic classes and functions under [PEP 484](#) were declared using a verbose syntax that left the scope of type parameters unclear and required explicit declarations of variance.

[PEP 695](#) introduces a new, more compact and explicit way to create generic classes and functions:

```
def max[T](args: Iterable[T]) -> T:
    ...

class list[T]:
    def __getitem__(self, index: int, /) -> T:
        ...

    def append(self, element: T) -> None:
        ...
```

In addition, the PEP introduces a new way to declare type aliases using the `type` statement, which creates an instance of `TypeAliasType`:

```
type Point = tuple[float, float]
```

Type aliases can also be generic:

```
type Point[T] = tuple[T, T]
```

The new syntax allows declaring `TypeVarTuple` and `ParamSpec` parameters, as well as `TypeVar` parameters with bounds or constraints:

```
type IntFunc[**P] = Callable[P, int] # ParamSpec
type LabeledTuple[*Ts] = tuple[str, *Ts] # TypeVarTuple
type HashableSequence[T: Hashable] = Sequence[T] # TypeVar with bound
type IntOrStrSequence[T: (int, str)] = Sequence[T] # TypeVar with constraints
```

The value of type aliases and the bound and constraints of type variables created through this syntax are evaluated only on demand (see lazy-evaluation). This means type aliases are able to refer to other types defined later in the file.

Type parameters declared through a type parameter list are visible within the scope of the declaration and any nested scopes, but not in the outer scope. For example, they can be used in the type annotations for the methods of a generic class or in the class body. However, they cannot be used in the module scope after the class is defined. See [type-params](#) for a detailed description of the runtime semantics of type parameters.

In order to support these scoping semantics, a new kind of scope is introduced, the annotation scope. Annotation scopes behave for the most part like function scopes, but interact differently with enclosing class scopes. In Python 3.13, annotations will also be evaluated in annotation scopes.

See [PEP 695](#) for more details.

(PEP written by Eric Traut. Implementation by Jelle Zijlstra, Eric Traut, and others in [gh-103764](#).)

## 5 Other Language Changes

- Add `perf_profiling` through the new environment variable `PYTHONPERFSUPPORT`, the new command-line option `-X perf`, as well as the new `sys.activate_stack_trampoline()`, `sys.deactivate_stack_trampoline()`, and `sys.is_stack_trampoline_active()` APIs. (Design by Pablo Galindo. Contributed by Pablo Galindo and Christian Heimes with contributions from Gregory P. Smith [Google] and Mark Shannon in [gh-96123](#).)
- The extraction methods in `tarfile`, and `shutil.unpack_archive()`, have a new *filter* argument that allows limiting tar features than may be surprising or dangerous, such as creating files outside the destination directory. See `tarfile-extraction-filter` for details. In Python 3.14, the default will switch to `'data'`. (Contributed by Petr Viktorin in [PEP 706](#).)
- `types.MappingProxyType` instances are now hashable if the underlying mapping is hashable. (Contributed by Serhiy Storchaka in [gh-87995](#).)
- `memoryview` now supports the half-float type (the `"e"` format code). (Contributed by Dong-hee Na and Antoine Pitrou in [gh-90751](#).)
- The parser now raises `SyntaxError` when parsing source code containing null bytes. (Contributed by Pablo Galindo in [gh-96670](#).)
- `ast.parse()` now raises `SyntaxError` instead of `ValueError` when parsing source code containing null bytes. (Contributed by Pablo Galindo in [gh-96670](#).)
- The Garbage Collector now runs only on the eval breaker mechanism of the Python bytecode evaluation loop instead of object allocations. The GC can also run when `PyErr_CheckSignals()` is called so C extensions that need to run for a long time without executing any Python code also have a chance to execute the GC periodically. (Contributed by Pablo Galindo in [gh-97922](#).)
- A backslash-character pair that is not a valid escape sequence now generates a `SyntaxWarning`, instead of `DeprecationWarning`. For example, `re.compile("\d+\.\d+")` now emits a `SyntaxWarning("\d" is an invalid escape sequence)`, use raw strings for regular expression: `re.compile(r"\d+\.\d+")`. In a future Python version, `SyntaxError` will eventually be raised, instead of `SyntaxWarning`. (Contributed by Victor Stinner in [gh-98401](#).)
- Octal escapes with value larger than `0o377` (ex: `"\477"`), deprecated in Python 3.11, now produce a `SyntaxWarning`, instead of `DeprecationWarning`. In a future Python version they will be eventually a `SyntaxError`. (Contributed by Victor Stinner in [gh-98401](#).)
- All builtin and extension callables expecting boolean parameters now accept arguments of any type instead of just `bool` and `int`. (Contributed by Serhiy Storchaka in [gh-60203](#).)
- Variables used in the target part of comprehensions that are not stored to can now be used in assignment expressions (`:=`). For example, in `[(b := 1) for a, b.prop in some_iter]`, the assignment to `b` is now allowed. Note that assigning to variables stored to in the target part of comprehensions (like `a`) is still disallowed, as per [PEP 572](#). (Contributed by Nikita Sobolev in [gh-100581](#).)
- `slice` objects are now hashable, allowing them to be used as dict keys and set items. (Contributed by Will Bradshaw, Furkan Onder, and Raymond Hettinger in [gh-101264](#).)
- `sum()` now uses Neumaier summation to improve accuracy when summing floats or mixed ints and floats. (Contributed by Raymond Hettinger in [gh-100425](#).)
- Exceptions raised in a typeobject's `__set_name__` method are no longer wrapped by a `RuntimeError`. Context information is added to the exception as a [PEP 678](#) note. (Contributed by Irit Katriel in [gh-77757](#).)
- When a `try-except*` construct handles the entire `ExceptionGroup` and raises one other exception, that exception is no longer wrapped in an `ExceptionGroup`. Also changed in version 3.11.4. (Contributed by Irit Katriel in [gh-103590](#).)



## 6 New Modules

- None yet.

## 7 Improved Modules

### 7.1 array

- The `array.array` class now supports subscripting, making it a generic type. (Contributed by Jelle Zijlstra in [gh-98658](#).)

### 7.2 asyncio

- The performance of writing to sockets in `asyncio` has been significantly improved. `asyncio` now avoids unnecessary copying when writing to sockets and uses `sendmsg()` if the platform supports it. (Contributed by Kumar Aditya in [gh-91166](#).)
- Added `asyncio.eager_task_factory()` and `asyncio.create_eager_task_factory()` functions to allow opting an event loop in to eager task execution, making some use-cases 2x to 5x faster. (Contributed by Jacob Bower & Itamar O in [gh-102853](#), [gh-104140](#), and [gh-104138](#))
- On Linux, `asyncio` uses `PidfdChildWatcher` by default if `os.pidfd_open()` is available and functional instead of `ThreadedChildWatcher`. (Contributed by Kumar Aditya in [gh-98024](#).)
- The `child_watcher` classes `MultiLoopChildWatcher`, `FastChildWatcher`, `AbstractChildWatcher` and `SafeChildWatcher` are deprecated and will be removed in Python 3.14. It is recommended to not manually configure a child watcher as the event loop now uses the best available child watcher for each platform (`PidfdChildWatcher` if supported and `ThreadedChildWatcher` otherwise). (Contributed by Kumar Aditya in [gh-94597](#).)
- `asyncio.set_child_watcher()`, `asyncio.get_child_watcher()`, `asyncio.AbstractEventLoopPolicy.set_child_watcher()` and `asyncio.AbstractEventLoopPolicy.get_child_watcher()` are deprecated and will be removed in Python 3.14. (Contributed by Kumar Aditya in [gh-94597](#).)
- Add `loop_factory` parameter to `asyncio.run()` to allow specifying a custom event loop factory. (Contributed by Kumar Aditya in [gh-99388](#).)
- Add C implementation of `asyncio.current_task()` for 4x-6x speedup. (Contributed by Itamar Ostricher and Pranav Thulasiram Bhat in [gh-100344](#).)
- `asyncio.iscoroutine()` now returns `False` for generators as `asyncio` does not support legacy generator-based coroutines. (Contributed by Kumar Aditya in [gh-102748](#).)
- `asyncio.wait()` and `asyncio.as_completed()` now accepts generators yielding tasks. (Contributed by Kumar Aditya in [gh-78530](#).)

## 7.3 calendar

- Add enums `Month` and `Day`. (Contributed by Prince Roshan in [gh-103636](#).)

## 7.4 csv

- Add `QUOTE_NOTNULL` and `QUOTE_STRINGS` flags to provide finer grained control of `None` and empty strings by `writer` objects.

## 7.5 dis

- Pseudo instruction opcodes (which are used by the compiler but do not appear in executable bytecode) are now exposed in the `dis` module. `HAVE_ARGUMENT` is still relevant to real opcodes, but it is not useful for pseudo instructions. Use the new `hasarg` collection instead. (Contributed by Irit Katriel in [gh-94216](#).)

## 7.6 email

- `email.utils.getaddresses()` and `email.utils.parseaddr()` now return `(' ', '')` 2-tuples in more situations where invalid email addresses are encountered instead of potentially inaccurate values. (Contributed by Thomas Dwyer for [gh-102988](#) to ameliorate CVE-2023-27043.)

## 7.7 fractions

- Objects of type `fractions.Fraction` now support float-style formatting. (Contributed by Mark Dickinson in [gh-100161](#).)

## 7.8 inspect

- Add `inspect.markcoroutinefunction()` to mark sync functions that return a coroutine for use with `inspect.iscoroutinefunction()`. (Contributed Carlton Gibson in [gh-99247](#).)
- Add `inspect.getasynccgenstate()` and `inspect.getasynccgenlocals()` for determining the current state of asynchronous generators. (Contributed by Thomas Krennwallner in [bpo-35759](#).)
- The performance of `inspect.getattr_static()` has been considerably improved. Most calls to the function should be at least 2x faster than they were in Python 3.11, and some may be 6x faster or more. (Contributed by Alex Waygood in [gh-103193](#).)

## 7.9 itertools

- Added `itertools.batched()` for collecting into even-sized tuples where the last batch may be shorter than the rest. (Contributed by Raymond Hettinger in [gh-98363](#).)

## 7.10 math

- Added `math.sumprod()` for computing a sum of products. (Contributed by Raymond Hettinger in [gh-100485](#).)
- Extended `math.nextafter()` to include a *steps* argument for moving up or down multiple steps at a time. (By Matthias Goergens, Mark Dickinson, and Raymond Hettinger in [gh-94906](#).)

## 7.11 os

- Add `os.PIDFD_NONBLOCK` to open a file descriptor for a process with `os.pidfd_open()` in non-blocking mode. (Contributed by Kumar Aditya in [gh-93312](#).)
- `os.DirEntry` now includes an `os.DirEntry.is_junction()` method to check if the entry is a junction. (Contributed by Charles Machalow in [gh-99547](#).)
- Add `os.listdirrives()`, `os.listvolumes()` and `os.listmounts()` functions on Windows for enumerating drives, volumes and mount points. (Contributed by Steve Dower in [gh-102519](#).)
- `os.stat()` and `os.lstat()` are now more accurate on Windows. The `st_birthtime` field will now be filled with the creation time of the file, and `st_ctime` is deprecated but still contains the creation time (but in the future will return the last metadata change, for consistency with other platforms). `st_dev` may be up to 64 bits and `st_ino` up to 128 bits depending on your file system, and `st_rdev` is always set to zero rather than incorrect values. Both functions may be significantly faster on newer releases of Windows. (Contributed by Steve Dower in [gh-99726](#).)

## 7.12 os.path

- Add `os.path.isjunction()` to check if a given path is a junction. (Contributed by Charles Machalow in [gh-99547](#).)
- Add `os.path.splitroot()` to split a path into a triad (*drive*, *root*, *tail*). (Contributed by Barney Gale in [gh-101000](#).)

## 7.13 pathlib

- Add support for subclassing `pathlib.PurePath` and `Path`, plus their Posix- and Windows-specific variants. Subclasses may override the `with_segments()` method to pass information between path instances.
- Add `walk()` for walking the directory trees and generating all file or directory names within them, similar to `os.walk()`. (Contributed by Stanislav Zmiev in [gh-90385](#).)
- Add *walk\_up* optional parameter to `pathlib.PurePath.relative_to()` to allow the insertion of `..` entries in the result; this behavior is more consistent with `os.path.relpath()`. (Contributed by Domenico Ragusa in [bpo-40358](#).)
- Add `pathlib.Path.is_junction()` as a proxy to `os.path.isjunction()`. (Contributed by Charles Machalow in [gh-99547](#).)
- Add *case\_sensitive* optional parameter to `pathlib.Path.glob()`, `pathlib.Path.rglob()` and `pathlib.PurePath.match()` for matching the path's case sensitivity, allowing for more precise control over the matching process.

## 7.14 pdb

- Add convenience variables to hold values temporarily for debug session and provide quick access to values like the current frame or the return value. (Contributed by Tian Gao in [gh-103693](#).)

## 7.15 random

- Added `random.binomialvariate()`. (Contributed by Raymond Hettinger in [gh-81620](#).)
- Added a default of `lamb=1.0` to `random.expovariate()`. (Contributed by Raymond Hettinger in [gh-100234](#).)

## 7.16 shutil

- `shutil.make_archive()` now passes the `root_dir` argument to custom archivers which support it. In this case it no longer temporarily changes the current working directory of the process to `root_dir` to perform archiving. (Contributed by Serhiy Storchaka in [gh-74696](#).)
- `shutil.rmtree()` now accepts a new argument `onexc` which is an error handler like `onerror` but which expects an exception instance rather than a *(typ, val, tb)* triplet. `onerror` is deprecated and will be removed in Python 3.14. (Contributed by Irit Katriel in [gh-102828](#).)
- `shutil.which()` now consults the `PATHEXT` environment variable to find matches within `PATH` on Windows even when the given `cmd` includes a directory component. (Contributed by Charles Machalow in [gh-103179](#).)

`shutil.which()` will call `NeedCurrentDirectoryForExePathW` when querying for executables on Windows to determine if the current working directory should be prepended to the search path. (Contributed by Charles Machalow in [gh-103179](#).)

`shutil.which()` will return a path matching the `cmd` with a component from `PATHEXT` prior to a direct match elsewhere in the search path on Windows. (Contributed by Charles Machalow in [gh-103179](#).)

## 7.17 sqlite3

- Add a command-line interface. (Contributed by Erlend E. Aasland in [gh-77617](#).)
- Add the `autocommit` attribute to `Connection` and the `autocommit` parameter to `connect()` to control **PEP 249**-compliant transaction handling. (Contributed by Erlend E. Aasland in [gh-83638](#).)
- Add `entrypoint` keyword-only parameter to `load_extension()`, for overriding the SQLite extension entry point. (Contributed by Erlend E. Aasland in [gh-103015](#).)
- Add `getConfig()` and `setconfig()` to `Connection` to make configuration changes to a database connection. (Contributed by Erlend E. Aasland in [gh-103489](#).)

## 7.18 statistics

- Extended `statistics.correlation()` to include as a ranked method for computing the Spearman correlation of ranked data. (Contributed by Raymond Hettinger in [gh-95861](#).)

## 7.19 sys

- Add `sys.activate_stack_trampoline()` and `sys.deactivate_stack_trampoline()` for activating and deactivating stack profiler trampolines, and `sys.is_stack_trampoline_active()` for querying if stack profiler trampolines are active. (Contributed by Pablo Galindo and Christian Heimes with contributions from Gregory P. Smith [Google] and Mark Shannon in [gh-96123](#).)
- Add `sys.last_exc` which holds the last unhandled exception that was raised (for post-mortem debugging use cases). Deprecate the three fields that have the same information in its legacy form: `sys.last_type`, `sys.last_value` and `sys.last_traceback`. (Contributed by Irit Katriel in [gh-102778](#).)
- `sys._current_exceptions()` now returns a mapping from thread-id to an exception instance, rather than to a `(typ, exc, tb)` tuple. (Contributed by Irit Katriel in [gh-103176](#).)

## 7.20 tempfile

- The `tempfile.NamedTemporaryFile` function has a new optional parameter `delete_on_close` (Contributed by Evgeny Zorin in [gh-58451](#).)
- `tempfile.mkdtemp()` now always returns an absolute path, even if the argument provided to the `dir` parameter is a relative path.

## 7.21 threading

- Add `threading.settrace_all_threads()` and `threading.setprofile_all_threads()` that allow to set tracing and profiling functions in all running threads in addition to the calling one. (Contributed by Pablo Galindo in [gh-93503](#).)

## 7.22 tkinter

- `tkinter.Canvas.coords()` now flattens its arguments. It now accepts not only coordinates as separate arguments (`x1, y1, x2, y2, ...`) and a sequence of coordinates (`[x1, y1, x2, y2, ...]`), but also coordinates grouped in pairs (`(x1, y1), (x2, y2), ...` and `[(x1, y1), (x2, y2), ...]`), like `create_*()` methods. (Contributed by Serhiy Storchaka in [gh-94473](#).)

## 7.23 tokenize

- The `tokenize` module includes the changes introduced in **PEP 701**. (Contributed by Marta Gómez Macías and Pablo Galindo in [gh-102856](#).) See *Porting to Python 3.12* for more information on the changes to the `tokenize` module.

## 7.24 types

- Add `types.get_original_bases()` to allow for further introspection of user-defined-generics when subclassed. (Contributed by James Hilton-Balfe and Alex Waygood in [gh-101827](#).)

## 7.25 typing

- `isinstance()` checks against runtime-checkable protocols now use `inspect.getattr_static()` rather than `hasattr()` to lookup whether attributes exist. This means that descriptors and `__getattr__()` methods are no longer unexpectedly evaluated during `isinstance()` checks against runtime-checkable protocols. However, it may also mean that some objects which used to be considered instances of a runtime-checkable protocol may no longer be considered instances of that protocol on Python 3.12+, and vice versa. Most users are unlikely to be affected by this change. (Contributed by Alex Waygood in [gh-102433](#).)
- The members of a runtime-checkable protocol are now considered “frozen” at runtime as soon as the class has been created. Monkey-patching attributes onto a runtime-checkable protocol will still work, but will have no impact on `isinstance()` checks comparing objects to the protocol. For example:

```
>>> from typing import Protocol, runtime_checkable
>>> @runtime_checkable
... class HasX(Protocol):
...     x = 1
...
>>> class Foo: ...
...
>>> f = Foo()
>>> isinstance(f, HasX)
False
>>> f.x = 1
>>> isinstance(f, HasX)
True
>>> HasX.y = 2
>>> isinstance(f, HasX) # unchanged, even though HasX now also has a "y"
↪attribute
True
```

This change was made in order to speed up `isinstance()` checks against runtime-checkable protocols.

- The performance profile of `isinstance()` checks against runtime-checkable protocols has changed significantly. Most `isinstance()` checks against protocols with only a few members should be at least 2x faster than in 3.11, and some may be 20x faster or more. However, `isinstance()` checks against protocols with fourteen or more members may be slower than in Python 3.11. (Contributed by Alex Waygood in [gh-74690](#) and [gh-103193](#).)
- All `typing.TypedDict` and `typing.NamedTuple` classes now have the `__orig_bases__` attribute. (Contributed by Adrian Garcia Badaracco in [gh-103699](#).)
- Add `frozen_default` parameter to `typing.dataclass_transform()`. (Contributed by Erik De Bonte in [gh-99957](#).)

## 7.26 unicodedata

- The Unicode database has been updated to version 15.0.0. (Contributed by Benjamin Peterson in [gh-96734](#)).

## 7.27 unittest

Added `--durations` command line option, showing the N slowest test cases:

```
python3 -m unittest --durations=3 lib.tests.test_threading
.....
Slowest test durations
-----
1.210s      test_timeout (Lib.test.test_threading.BarrierTests)
1.003s      test_default_timeout (Lib.test.test_threading.BarrierTests)
0.518s      test_timeout (Lib.test.test_threading.EventTests)

(0.000 durations hidden.  Use -v to show these durations.)
-----
Ran 158 tests in 9.869s

OK (skipped=3)
```

(Contributed by Giampaolo Rodola in [bpo-4080](#))

## 7.28 uuid

- Add a command-line interface. (Contributed by Adam Chhina in [gh-88597](#).)

# 8 Optimizations

- Removed `wstr` and `wstr_length` members from Unicode objects. It reduces object size by 8 or 16 bytes on 64bit platform. (**PEP 623**) (Contributed by Inada Naoki in [gh-92536](#).)
- Added experimental support for using the BOLT binary optimizer in the build process, which improves performance by 1-5%. (Contributed by Kevin Modzelewski in [gh-90536](#) and tuned by Dong-hee Na in [gh-101525](#))
- Speed up the regular expression substitution (functions `re.sub()` and `re.subn()` and corresponding `re.Pattern` methods) for replacement strings containing group references by 2–3 times. (Contributed by Serhiy Storchaka in [gh-91524](#).)
- Speed up `asyncio.Task` creation by deferring expensive string formatting. (Contributed by Itamar O in [gh-103793](#).)
- The `tokenize.tokenize()` and `tokenize.generate_tokens()` functions are up to 64% faster as a side effect of the changes required to cover **PEP 701** in the `tokenize` module. (Contributed by Marta Gómez Macías and Pablo Galindo in [gh-102856](#).)
- Speed up `super()` method calls and attribute loads via the new `LOAD_SUPER_ATTR` instruction. (Contributed by Carl Meyer and Vladimir Matveev in [gh-103497](#).)

## 9 CPython bytecode changes

- Remove the `LOAD_METHOD` instruction. It has been merged into `LOAD_ATTR`. `LOAD_ATTR` will now behave like the old `LOAD_METHOD` instruction if the low bit of its `oparg` is set. (Contributed by Ken Jin in [gh-93429](#).)
- Remove the `JUMP_IF_FALSE_OR_POP` and `JUMP_IF_TRUE_OR_POP` instructions. (Contributed by Irit Katriel in [gh-102859](#).)
- Add the `LOAD_FAST_AND_CLEAR` instruction as part of the implementation of **PEP 709**. (Contributed by Carl Meyer in [gh-101441](#).)
- Add the `LOAD_FROM_DICT_OR_DEREF`, `LOAD_FROM_DICT_OR_GLOBALS`, and `LOAD_LOCALS` opcodes as part of the implementation of **PEP 695**. Remove the `LOAD_CLASSDEREF` opcode, which can be replaced with `LOAD_LOCALS` plus `LOAD_FROM_DICT_OR_DEREF`. (Contributed by Jelle Zijlstra in [gh-103764](#).)
- Add the `LOAD_SUPER_ATTR` instruction. (Contributed by Carl Meyer and Vladimir Matveev in [gh-103497](#).)

## 10 Demos and Tools

- Remove the `Tools/demo/` directory which contained old demo scripts. A copy can be found in the [old-demos project](#). (Contributed by Victor Stinner in [gh-97681](#).)
- Remove outdated example scripts of the `Tools/scripts/` directory. A copy can be found in the [old-demos project](#). (Contributed by Victor Stinner in [gh-97669](#).)

## 11 Deprecated

- `typing.Hashable` and `typing.Sized` aliases for `collections.abc.Hashable` and `collections.abc.Sized`. ([gh-94309](#).)
- The `sqlite3` default adapters and converters are now deprecated. Instead, use the `sqlite3-adaptor-converter-recipes` and tailor them to your needs. (Contributed by Erlend E. Aasland in [gh-90016](#).)
- In `execute()`, `DeprecationWarning` is now emitted when named placeholders are used together with parameters supplied as a sequence instead of as a dict. Starting from Python 3.14, using named placeholders with parameters supplied as a sequence will raise a `ProgrammingError`. (Contributed by Erlend E. Aasland in [gh-101698](#).)
- The 3-arg signatures (`type`, `value`, `traceback`) of `throw()`, `throw()` and `athrow()` are deprecated and may be removed in a future version of Python. Use the single-arg versions of these functions instead. (Contributed by Ofey Chan in [gh-89874](#).)
- `DeprecationWarning` is now raised when `__package__` on a module differs from `__spec__.parent` (previously it was `ImportWarning`). (Contributed by Brett Cannon in [gh-65961](#).)
- The `get_event_loop()` method of the default event loop policy now emits a `DeprecationWarning` if there is no current event loop set and it decides to create one. (Contributed by Serhiy Storchaka and Guido van Rossum in [gh-100160](#).)
- The `xml.etree.ElementTree` module now emits `DeprecationWarning` when testing the truth value of an `xml.etree.ElementTree.Element`. Before, the Python implementation emitted `FutureWarning`, and the C implementation emitted nothing.
- In accordance with **PEP 699**, the `ma_version_tag` field in `PyDictObject` is deprecated for extension modules. Accessing this field will generate a compiler warning at compile time. This field will be removed in Python 3.14. (Contributed by Ramvikrams and Kumar Aditya in [gh-101193](#). PEP by Ken Jin.)



- The `st_ctime` fields return by `os.stat()` and `os.lstat()` on Windows are deprecated. In a future release, they will contain the last metadata change time, consistent with other platforms. For now, they still contain the creation time, which is also available in the new `st_birthtime` field. (Contributed by Steve Dower in [gh-99726](#).)
- The `sys.last_type`, `sys.last_value` and `sys.last_traceback` fields are deprecated. Use `sys.last_exc` instead. (Contributed by Irit Katriel in [gh-102778](#).)
- The `onerror` argument of `shutil.rmtree()` is deprecated as will be removed in Python 3.14. Use `onexc` instead. (Contributed by Irit Katriel in [gh-102828](#).)
- Extracting tar archives without specifying `filter` is deprecated until Python 3.14, when `'data'` filter will become the default. See [tarfile-extraction-filter](#) for details.
- `calendar.January` and `calendar.February` constants are deprecated and replaced by `calendar.Month.JANUARY` and `calendar.Month.FEBRUARY`. (Contributed by Prince Roshan in [gh-103636](#).)
- The bitwise inversion operator (`~`) on `bool` is deprecated. It will throw an error in Python 3.14. Use `not` for logical negation of bools instead. In the rare case that you really need the bitwise inversion of the underlying `int`, convert to `int` explicitly with `~int(x)`. (Contributed by Tim Hoffmann in [gh-103487](#).)
- `datetime.datetime.utcnow()` and `datetime.datetime.fromtimestamp()` are deprecated and will be removed in a future version. Instead, use timezone-aware objects to represent datetimes in UTC: respectively, call `datetime.now()` and `datetime.fromtimestamp()` with the `tz` parameter set to `datetime.UTC`. (Contributed by Paul Ganssle in [gh-103857](#).)

## 11.1 Pending Removal in Python 3.13

The following modules and APIs have been deprecated in earlier Python releases, and will be removed in Python 3.13.

Modules (see [PEP 594](#)):

- `aifc`
- `audioop`
- `cgi`
- `cgitb`
- `chunk`
- `crypt`
- `imghdr`
- `mailcap`
- `msilib`
- `nis`
- `nntplib`
- `ossaudiodev`
- `pipes`
- `sndhdr`
- `spwd`
- `sunau`
- `telnetlib`

- uu
- xdrlib

APIs:

- `configparser.LegacyInterpolation` ([gh-90765](#))
- `locale.getdefaultlocale()` ([gh-90817](#))
- `turtle.RawTurtle.settiltangle()` ([gh-50096](#))
- `unittest.findTestCases()` ([gh-50096](#))
- `unittest.getTestCaseNames()` ([gh-50096](#))
- `unittest.makeSuite()` ([gh-50096](#))
- `unittest.TestProgram.usageExit()` ([gh-67048](#))
- `webbrowser.MacOSX` ([gh-86421](#))
- classmethod descriptor chaining ([gh-89519](#))

## 11.2 Pending Removal in Python 3.14

- Deprecated the following `importlib.abc` classes, scheduled for removal in Python 3.14:

- `importlib.abc.ResourceReader`
- `importlib.abc.Traversable`
- `importlib.abc.TraversableResources`

Use `importlib.resources.abc` classes instead:

- `importlib.resources.abc.Traversable`
- `importlib.resources.abc.TraversableResources`

(Contributed by Jason R. Coombs and Hugo van Kemenade in [gh-93963](#).)

- Deprecated `collections.abc.ByteString`. Prefer `Sequence` or `collections.abc.Buffer`. For use in typing, prefer a union, like `bytes | bytearray`, or `collections.abc.Buffer`. (Contributed by Shantanu Jain in [gh-91896](#).)
- `typing.ByteString`, deprecated since Python 3.9, now causes a `DeprecationWarning` to be emitted when it is used.
- Creating immutable types (`Py_TPFLAGS_IMMUTABLETYPE`) with mutable bases using the C API.
- Deprecated the `isdst` parameter in `email.utils.localtime()`. (Contributed by Alan Williams in [gh-72346](#).)
- `__package__` and `__cached__` will cease to be set or taken into consideration by the import system ([gh-97879](#)).
- Testing the truth value of an `xml.etree.ElementTree.Element` is deprecated and will raise an exception in Python 3.14.
- The default multiprocessing start method will change to a safer one on Linux, BSDs, and other non-macOS POSIX platforms where `'fork'` is currently the default ([gh-84559](#)). Adding a runtime warning about this was deemed too disruptive as the majority of code is not expected to care. Use the `get_context()` or `set_start_method()` APIs to explicitly specify when your code *requires* `'fork'`. See `multiprocessing-start-methods`.

- `pty` has two undocumented `master_open()` and `slave_open()` functions that have been deprecated since Python 2 but only gained a proper `DeprecationWarning` in 3.12. Remove them in 3.14.
- `itertools` had undocumented, inefficient, historically buggy, and inconsistent support for `copy`, `deepcopy`, and `pickle` operations. This will be removed in 3.14 for a significant reduction in code volume and maintenance burden. (Contributed by Raymond Hettinger in [gh-101588](#).)
- Accessing `co_notab` was deprecated in [PEP 626](#) since 3.10 and was planned to be removed in 3.12 but it only got a proper `DeprecationWarning` in 3.12. May be removed in 3.14. (Contributed by Nikita Sobolev in [gh-101866](#).)
- The `onerror` argument of `shutil.rmtree()` is deprecated in 3.12, and will be removed in 3.14.
- The `type`, `choices`, and `metavar` parameters of `argparse.BooleanOptionalAction` are deprecated and will be removed in 3.14. (Contributed by Nikita Sobolev in [gh-92248](#).)
- `pkgutil.find_loader()` and `pkgutil.get_loader()` now raise `DeprecationWarning`; use `importlib.util.find_spec()` instead. (Contributed by Nikita Sobolev in [gh-97850](#).)
- The following `ast` features have been deprecated in documentation since Python 3.8, now cause a `DeprecationWarning` to be emitted at runtime when they are accessed or used, and will be removed in Python 3.14:

- `ast.Num`
- `ast.Str`
- `ast.Bytes`
- `ast.NameConstant`
- `ast.Ellipsis`

Use `ast.Constant` instead. (Contributed by Serhiy Storchaka in [gh-90953](#).)

## 11.3 Pending Removal in Future Versions

The following APIs were deprecated in earlier Python versions and will be removed, although there is currently no date scheduled for their removal.

- `typing.Text` ([gh-92332](#))
- Currently Python accepts numeric literals immediately followed by keywords, for example `0in x, 1or x, 0if 1else 2`. It allows confusing and ambiguous expressions like `[0x1for x in y]` (which can be interpreted as `[0x1 for x in y]` or `[0x1f or x in y]`). A syntax warning is raised if the numeric literal is immediately followed by one of keywords `and`, `else`, `for`, `if`, `in`, `is` and `or`. In a future release it will be changed to a syntax error. ([gh-87999](#))

## 12 Removed

- Remove the `distutils` package. It was deprecated in Python 3.10 by [PEP 632](#) “Deprecate `distutils` module”. For projects still using `distutils` and cannot be updated to something else, the `setuptools` project can be installed: it still provides `distutils`. (Contributed by Victor Stinner in [gh-92584](#).)
- Remove the bundled `setuptools` wheel from `ensurepip`, and stop installing `setuptools` in environments created by `venv`.

`pip (>= 22.1)` does not require `setuptools` to be installed in the environment. `setuptools`-based (and `distutils`-based) packages can still be used with `pip install`, since `pip` will provide `setuptools` in the build environment it uses for building a package.

`easy_install`, `pkg_resources`, `setuptools` and `distutils` are no longer provided by default in environments created with `venv` or bootstrapped with `ensurepip`, since they are part of the `setuptools` package. For projects relying on these at runtime, the `setuptools` project should be declared as a dependency and installed separately (typically, using `pip`).

(Contributed by Pradyun Gedam in [gh-95299](#).)

- Removed many old deprecated `unittest` features:
  - A number of `TestCase` method aliases:

| Deprecated alias                    | Method Name                         | Deprecated in |
|-------------------------------------|-------------------------------------|---------------|
| <code>failUnless</code>             | <code>assertTrue()</code>           | 3.1           |
| <code>failIf</code>                 | <code>assertFalse()</code>          | 3.1           |
| <code>failUnlessEqual</code>        | <code>assertEqual()</code>          | 3.1           |
| <code>failIfEqual</code>            | <code>assertNotEqual()</code>       | 3.1           |
| <code>failUnlessAlmostEqual</code>  | <code>assertAlmostEqual()</code>    | 3.1           |
| <code>failIfAlmostEqual</code>      | <code>assertNotAlmostEqual()</code> | 3.1           |
| <code>failUnlessRaises</code>       | <code>assertRaises()</code>         | 3.1           |
| <code>assert_</code>                | <code>assertTrue()</code>           | 3.2           |
| <code>assertEquals</code>           | <code>assertEqual()</code>          | 3.2           |
| <code>assertNotEquals</code>        | <code>assertNotEqual()</code>       | 3.2           |
| <code>assertAlmostEquals</code>     | <code>assertAlmostEqual()</code>    | 3.2           |
| <code>assertNotAlmostEquals</code>  | <code>assertNotAlmostEqual()</code> | 3.2           |
| <code>assertRegexpMatches</code>    | <code>assertRegex()</code>          | 3.2           |
| <code>assertRaisesRegexp</code>     | <code>assertRaisesRegex()</code>    | 3.2           |
| <code>assertNotRegexpMatches</code> | <code>assertNotRegex()</code>       | 3.5           |

You can use <https://github.com/isidentical/teyit> to automatically modernise your unit tests.

- Undocumented and broken `TestCase` method `assertDictContainsSubset` (deprecated in Python 3.2).
- Undocumented `TestLoader.loadTestsFromModule` parameter `use_load_tests` (deprecated and ignored since Python 3.2).
- An alias of the `TextTestResult` class: `_TextTestResult` (deprecated in Python 3.2).

(Contributed by Serhiy Storchaka in [bpo-45162](#).)

- Several names deprecated in the `configparser` way back in 3.2 have been removed per [gh-89336](#):
  - `configparser.ParsingError` no longer has a `filename` attribute or argument. Use the `source` attribute and argument instead.
  - `configparser` no longer has a `SafeConfigParser` class. Use the shorter `ConfigParser` name instead.
  - `configparser.ConfigParser` no longer has a `readfp` method. Use `read_file()` instead.
- The following undocumented `sqlite3` features, deprecated in Python 3.10, are now removed:
  - `sqlite3.enable_shared_cache()`
  - `sqlite3.OptimizedUnicode`

If a shared cache must be used, open the database in URI mode using the `cache=shared` query parameter.

The `sqlite3.OptimizedUnicode` text factory has been an alias for `str` since Python 3.3. Code that previously set the text factory to `OptimizedUnicode` can either use `str` explicitly, or rely on the default value which is also `str`.

(Contributed by Erlend E. Aasland in [gh-92548](#).)

- `smtpd` has been removed according to the schedule in [PEP 594](#), having been deprecated in Python 3.4.7 and 3.5.4. Use `aiosmtpd` PyPI module or any other `asyncio`-based server instead. (Contributed by Oleg Iarygin in [gh-93243](#).)
- `asynchat` and `asyncore` have been removed according to the schedule in [PEP 594](#), having been deprecated in Python 3.6. Use `asyncio` instead. (Contributed by Nikita Sobolev in [gh-96580](#).)
- Remove `io.OpenWrapper` and `_pyio.OpenWrapper`, deprecated in Python 3.10: just use `open()` instead. The `open()` (`io.open()`) function is a built-in function. Since Python 3.10, `_pyio.open()` is also a static method. (Contributed by Victor Stinner in [gh-94169](#).)
- Remove the `ssl.RAND_pseudo_bytes()` function, deprecated in Python 3.6: use `os.urandom()` or `ssl.RAND_bytes()` instead. (Contributed by Victor Stinner in [gh-94199](#).)
- `gzip`: Remove the `filename` attribute of `gzip.GzipFile`, deprecated since Python 2.6, use the `name` attribute instead. In write mode, the `filename` attribute added `'.gz'` file extension if it was not present. (Contributed by Victor Stinner in [gh-94196](#).)
- Remove the `ssl.match_hostname()` function. It was deprecated in Python 3.7. OpenSSL performs host-name matching since Python 3.7, Python no longer uses the `ssl.match_hostname()` function. (Contributed by Victor Stinner in [gh-94199](#).)
- Remove the `locale.format()` function, deprecated in Python 3.7: use `locale.format_string()` instead. (Contributed by Victor Stinner in [gh-94226](#).)
- `hashlib`: Remove the pure Python implementation of `hashlib.pbkdf2_hmac()`, deprecated in Python 3.10. Python 3.10 and newer requires OpenSSL 1.1.1 ([PEP 644](#)): this OpenSSL version provides a C implementation of `pbkdf2_hmac()` which is faster. (Contributed by Victor Stinner in [gh-94199](#).)
- `xml.etree.ElementTree`: Remove the `ElementTree.Element.copy()` method of the pure Python implementation, deprecated in Python 3.10, use the `copy.copy()` function instead. The C implementation of `xml.etree.ElementTree` has no `copy()` method, only a `__copy__()` method. (Contributed by Victor Stinner in [gh-94383](#).)
- `zipimport`: Remove `find_loader()` and `find_module()` methods, deprecated in Python 3.10: use the `find_spec()` method instead. See [PEP 451](#) for the rationale. (Contributed by Victor Stinner in [gh-94379](#).)
- Remove the `ssl.wrap_socket()` function, deprecated in Python 3.7: instead, create a `ssl.SSLContext` object and call its `ssl.SSLContext.wrap_socket` method. Any package that still uses `ssl.wrap_socket()` is broken and insecure. The function neither sends a SNI TLS extension nor validates server hostname. Code is subject to [CWE-295](#): Improper Certificate Validation. (Contributed by Victor Stinner in [gh-94199](#).)
- Many previously deprecated cleanups in `importlib` have now been completed:
  - References to, and support for `module_repr()` has been removed. (Contributed by Barry Warsaw in [gh-97850](#).)
  - `importlib.util.set_package` has been removed. (Contributed by Brett Cannon in [gh-65961](#).)
  - Support for `find_loader()` and `find_module()` APIs have been removed. (Contributed by Barry Warsaw in [gh-98040](#).)
  - `importlib.abc.Finder`, `pkgutil.ImpImporter`, and `pkgutil.ImpLoader` have been removed. (Contributed by Barry Warsaw in [gh-98040](#).)

- The `imp` module has been removed. (Contributed by Barry Warsaw in [gh-98040](#).)
- Replace removed `imp` functions with `importlib` functions:

| <code>imp</code>                     | <code>importlib</code>                                                                                                                                          |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>imp.NullImporter</code>        | Insert None into <code>sys.path_importer_cache</code>                                                                                                           |
| <code>imp.cache_from_source()</code> | <code>importlib.util.cache_from_source()</code>                                                                                                                 |
| <code>imp.find_module()</code>       | <code>importlib.util.find_spec()</code>                                                                                                                         |
| <code>imp.get_magic()</code>         | <code>importlib.util.MAGIC_NUMBER</code>                                                                                                                        |
| <code>imp.get_suffixes()</code>      | <code>importlib.machinery.SOURCE_SUFFIXES</code> , <code>importlib.machinery.EXTENSION_SUFFIXES</code> , and <code>importlib.machinery.BYTECODE_SUFFIXES</code> |
| <code>imp.get_tag()</code>           | <code>sys.implementation.cache_tag</code>                                                                                                                       |
| <code>imp.load_module()</code>       | <code>importlib.import_module()</code>                                                                                                                          |
| <code>imp.new_module(name)</code>    | <code>types.ModuleType(name)</code>                                                                                                                             |
| <code>imp.reload()</code>            | <code>importlib.reload()</code>                                                                                                                                 |
| <code>imp.source_from_cache()</code> | <code>importlib.util.source_from_cache()</code>                                                                                                                 |

- Replace `imp.load_source()` with:

```
import importlib.util
import importlib.machinery

def load_source(modname, filename):
    loader = importlib.machinery.SourceFileLoader(modname, filename)
    spec = importlib.util.spec_from_file_location(modname, filename,
↪ loader=loader)
    module = importlib.util.module_from_spec(spec)
    # The module is always executed and not cached in sys.modules.
    # Uncomment the following line to cache the module.
    # sys.modules[module.__name__] = module
    loader.exec_module(module)
    return module
```

- Removed `imp` functions and attributes with no replacements:

\* undocumented functions:

- `imp.init_builtin()`
- `imp.load_compiled()`
- `imp.load_dynamic()`
- `imp.load_package()`

\* `imp.lock_held()`, `imp.acquire_lock()`, `imp.release_lock()`: the locking scheme has changed in Python 3.3 to per-module locks.

```
* imp.find_module()    constants:    SEARCH_ERROR,  PY_SOURCE,  PY_COMPILED,
    C_EXTENSION,  PY_RESOURCE,  PKG_DIRECTORY,  C_BUILTIN,  PY_FROZEN,
    PY_CODERESOURCE, IMP_HOOK.
```

- Removed the `suspicious` rule from the documentation Makefile, and removed `Doc/tools/rstlint.py`, both in favor of [sphinx-lint](#). (Contributed by Julien Palard in [gh-98179](#).)
- Remove the `keyfile` and `certfile` parameters from the `ftplib`, `imaplib`, `poplib` and `smtplib` modules, and the `key_file`, `cert_file` and `check_hostname` parameters from the `http.client` module, all deprecated since Python 3.6. Use the `context` parameter (`ssl_context` in `imaplib`) instead. (Contributed by Victor Stinner in [gh-94172](#).)
- `ftplib`: Remove the `FTP_TLS.ssl_version` class attribute: use the `context` parameter instead. (Contributed by Victor Stinner in [gh-94172](#).)
- Remove support for obsolete browsers from `webbrowser`. Removed browsers include: Grail, Mosaic, Netscape, Galeon, Skipstone, Iceape, Firebird, and Firefox versions 35 and below ([gh-102871](#)).

## 13 Porting to Python 3.12

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

### 13.1 Changes in the Python API

- More strict rules are now applied for numerical group references and group names in regular expressions. Only sequence of ASCII digits is now accepted as a numerical reference. The group name in bytes patterns and replacement strings can now only contain ASCII letters and digits and underscore. (Contributed by Serhiy Storchaka in [gh-91760](#).)
- Removed `randrange()` functionality deprecated since Python 3.10. Formerly, `randrange(10.0)` losslessly converted to `randrange(10)`. Now, it raises a `TypeError`. Also, the exception raised for non-integral values such as `randrange(10.5)` or `randrange('10')` has been changed from `ValueError` to `TypeError`. This also prevents bugs where `randrange(1e25)` would silently select from a larger range than `randrange(10**25)`. (Originally suggested by Serhiy Storchaka [gh-86388](#).)
- `argparse.ArgumentParser` changed encoding and error handler for reading arguments from file (e.g. `fromfile_prefix_chars` option) from default text encoding (e.g. `locale.getpreferredencoding(False)`) to filesystem encoding and error handler. Argument files should be encoded in UTF-8 instead of ANSI Codepage on Windows.
- Removed the `asyncore`-based `smtpd` module deprecated in Python 3.4.7 and 3.5.4. A recommended replacement is the `asyncio`-based [aiosmtpd](#) PyPI module.
- `shlex.split()`: Passing `None` for `s` argument now raises an exception, rather than reading `sys.stdin`. The feature was deprecated in Python 3.9. (Contributed by Victor Stinner in [gh-94352](#).)
- The `os` module no longer accepts bytes-like paths, like `bytearray` and `memoryview` types: only the exact `bytes` type is accepted for bytes strings. (Contributed by Victor Stinner in [gh-98393](#).)
- `syslog.openlog()` and `syslog.closelog()` now fail if used in subinterpreters. `syslog.syslog()` may still be used in subinterpreters, but now only if `syslog.openlog()` has already been called in the main interpreter. These new restrictions do not apply to the main interpreter, so only a very small set of users might be affected. This change helps with interpreter isolation. Furthermore, `syslog` is a wrapper around process-global resources, which are best managed from the main interpreter. (Contributed by Dong-hee Na in [gh-99127](#).)
- The undocumented locking behavior of `cached_property()` is removed, because it locked across all instances of the class, leading to high lock contention. This means that a cached property getter function could now run

more than once for a single instance, if two threads race. For most simple cached properties (e.g. those that are idempotent and simply calculate a value based on other attributes of the instance) this will be fine. If synchronization is needed, implement locking within the cached property getter function or around multi-threaded access points.

- `sys._current_exceptions()` now returns a mapping from thread-id to an exception instance, rather than to a `(typ, exc, tb)` tuple. (Contributed by Irit Katriel in [gh-103176](#).)
- When extracting tar files using `tarfile` or `shutil.unpack_archive()`, pass the *filter* argument to limit features that may be surprising or dangerous. See [tarfile-extraction-filter](#) for details.
- The output of the `tokenize.tokenize()` and `tokenize.generate_tokens()` functions is now changed due to the changes introduced in [PEP 701](#). This means that `STRING` tokens are not emitted any more for f-strings and the tokens described in [PEP 701](#) are now produced instead: `FSTRING_START`, `FSTRING_MIDDLE` and `FSTRING_END` are now emitted for f-string “string” parts in addition to the appropriate tokens for the tokenization in the expression components. For example for the f-string `f"start {1+1} end"` the old version of the tokenizer emitted:

|                          |                     |                                   |
|--------------------------|---------------------|-----------------------------------|
| <code>1, 0-1, 18:</code> | <code>STRING</code> | <code>'f"start {1+1} end"'</code> |
|--------------------------|---------------------|-----------------------------------|

while the new version emits:

|                           |                             |                       |
|---------------------------|-----------------------------|-----------------------|
| <code>1, 0-1, 2:</code>   | <code>FSTRING_START</code>  | <code>'f''</code>     |
| <code>1, 2-1, 8:</code>   | <code>FSTRING_MIDDLE</code> | <code>'start '</code> |
| <code>1, 8-1, 9:</code>   | <code>OP</code>             | <code>'{'</code>      |
| <code>1, 9-1, 10:</code>  | <code>NUMBER</code>         | <code>'1'</code>      |
| <code>1, 10-1, 11:</code> | <code>OP</code>             | <code>'+'</code>      |
| <code>1, 11-1, 12:</code> | <code>NUMBER</code>         | <code>'1'</code>      |
| <code>1, 12-1, 13:</code> | <code>OP</code>             | <code>'}'</code>      |
| <code>1, 13-1, 17:</code> | <code>FSTRING_MIDDLE</code> | <code>' end'</code>   |
| <code>1, 17-1, 18:</code> | <code>FSTRING_END</code>    | <code>'''</code>      |

Additionally, there may be some minor behavioral changes as a consequence of the changes required to support [PEP 701](#). Some of these changes include:

- The `type` attribute of the tokens emitted when tokenizing some invalid Python characters such as `!` has changed from `ERRORTOKEN` to `OP`.
- Incomplete single-line strings now also raise `tokenize.TokenError` as incomplete multiline strings do.
- Some incomplete or invalid Python code now raises `tokenize.TokenError` instead of returning arbitrary `ERRORTOKEN` tokens when tokenizing it.
- Mixing tabs and spaces as indentation in the same file is not supported anymore and will raise a `TabError`.

## 14 Build Changes

- Python no longer uses `setup.py` to build shared C extension modules. Build parameters like headers and libraries are detected in `configure` script. Extensions are built by `Makefile`. Most extensions use `pkg-config` and fall back to manual detection. (Contributed by Christian Heimes in [gh-93939](#).)
- `va_start()` with two parameters, like `va_start(args, format)`, is now required to build Python. `va_start()` is no longer called with a single parameter. (Contributed by Kumar Aditya in [gh-93207](#).)
- CPython now uses the `ThinLTO` option as the default link time optimization policy if the Clang compiler accepts the flag. (Contributed by Dong-hee Na in [gh-89536](#).)
- Add `COMPILEALL_OPTS` variable in `Makefile` to override `compileall` options (default: `-j0`) in `make install`. Also merged the 3 `compileall` commands into a single command to build `.pyc` files for all optimization levels (0, 1, 2) at once. (Contributed by Victor Stinner in [gh-99289](#).)



- Add platform triplets for 64-bit LoongArch:
  - loongarch64-linux-gnuf
  - loongarch64-linux-gnuf32
  - loongarch64-linux-gnu
 (Contributed by Zhang Na in [gh-90656](#).)
- PYTHON\_FOR\_REGEN now require Python 3.10 or newer.
- Autoconf 2.71 and aclocal 1.16.4 is now required to regenerate `!configure`. (Contributed by Christian Heimes in [gh-89886](#).)

## 15 C API Changes

### 15.1 New Features

- **PEP 697**: Introduced the Unstable C API tier, intended for low-level tools like debuggers and JIT compilers. This API may change in each minor release of CPython without deprecation warnings. Its contents are marked by the `PyUnstable_` prefix in names.

Code object constructors:

- `PyUnstable_Code_New()` (renamed from `PyCode_New`)
- `PyUnstable_Code_NewWithPosOnlyArgs()` (renamed from `PyCode_NewWithPosOnlyArgs`)

Extra storage for code objects (**PEP 523**):

- `PyUnstable_Eval_RequestCodeExtraIndex()` (renamed from `_PyEval_RequestCodeExtraIndex`)
- `PyUnstable_Code_GetExtra()` (renamed from `_PyCode_GetExtra`)
- `PyUnstable_Code_SetExtra()` (renamed from `_PyCode_SetExtra`)

The original names will continue to be available until the respective API changes.

(Contributed by Petr Viktorin in [gh-101101](#).)

- **PEP 697**: Added API for extending types whose instance memory layout is opaque:
  - `PyType_Spec.basicsize` can be zero or negative to specify inheriting or extending the base class size.
  - `PyObject_GetTypeData()` and `PyType_GetTypeDataSize()` added to allow access to subclass-specific instance data.
  - `Py_TPFLAGS_ITEMS_AT_END` and `PyObject_GetItemData()` added to allow safely extending certain variable-sized types, including `PyType_Type`.
  - `Py_RELATIVE_OFFSET` added to allow defining members in terms of a subclass-specific struct.

(Contributed by Petr Viktorin in [gh-103509](#).)

- Added the new limited C API function `PyType_FromMetaclass()`, which generalizes the existing `PyType_FromModuleAndSpec()` using an additional metaclass argument. (Contributed by Wenzel Jakob in [gh-93012](#).)
- API for creating objects that can be called using the vectorcall protocol was added to the Limited API:
  - `Py_TPFLAGS_HAVE_VECTORCALL`

- `PyVectorcall_NARGS()`
- `PyVectorcall_Call()`
- `vectorcallfunc`

The `Py_TPFLAGS_HAVE_VECTORCALL` flag is now removed from a class when the class's `__call__()` method is reassigned. This makes vectorcall safe to use with mutable types (i.e. heap types without the immutable flag, `Py_TPFLAGS_IMMUTABLETYPE`). Mutable types that do not override `tp_call` now inherit the `Py_TPFLAGS_HAVE_VECTORCALL` flag. (Contributed by Petr Viktorin in [gh-93274](#).)

The `Py_TPFLAGS_MANAGED_DICT` and `Py_TPFLAGS_MANAGED_WEAKREF` flags have been added. This allows extension classes to support object `__dict__` and weakrefs with less bookkeeping, using less memory and with faster access.

- API for performing calls using the vectorcall protocol was added to the Limited API:

- `PyObject_Vectorcall()`
- `PyObject_VectorcallMethod()`
- `Py_VECTORCALL_ARGUMENTS_OFFSET`

This means that both the incoming and outgoing ends of the vector call protocol are now available in the Limited API. (Contributed by Wenzel Jakob in [gh-98586](#).)

- Added two new public functions, `PyEval_SetProfileAllThreads()` and `PyEval_SetTraceAllThreads()`, that allow to set tracing and profiling functions in all running threads in addition to the calling one. (Contributed by Pablo Galindo in [gh-93503](#).)
- Added new function `PyFunction_SetVectorcall()` to the C API which sets the vectorcall field of a given `PyFunctionObject`. (Contributed by Andrew Frost in [gh-92257](#).)
- The C API now permits registering callbacks via `PyDict_AddWatcher()`, `PyDict_Watch()` and related APIs to be called whenever a dictionary is modified. This is intended for use by optimizing interpreters, JIT compilers, or debuggers. (Contributed by Carl Meyer in [gh-91052](#).)
- Added `PyType_AddWatcher()` and `PyType_Watch()` API to register callbacks to receive notification on changes to a type. (Contributed by Carl Meyer in [gh-91051](#).)
- Added `PyCode_AddWatcher()` and `PyCode_ClearWatcher()` APIs to register callbacks to receive notification on creation and destruction of code objects. (Contributed by Itamar Ostricher in [gh-91054](#).)
- Add `PyFrame_GetVar()` and `PyFrame_GetVarString()` functions to get a frame variable by its name. (Contributed by Victor Stinner in [gh-91248](#).)
- Add `PyErr_GetRaisedException()` and `PyErr_SetRaisedException()` for saving and restoring the current exception. These functions return and accept a single exception object, rather than the triple arguments of the now-deprecated `PyErr_Fetch()` and `PyErr_Restore()`. This is less error prone and a bit more efficient. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `_PyErr_ChainExceptions1`, which takes an exception instance, to replace the legacy-API `_PyErr_ChainExceptions`, which is now deprecated. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `PyException_GetArgs()` and `PyException_SetArgs()` as convenience functions for retrieving and modifying the `args` passed to the exception's constructor. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `PyErr_DisplayException()`, which takes an exception instance, to replace the legacy-api `PyErr_Display()`. (Contributed by Irit Katriel in [gh-102755](#).)
- **PEP 683**: Introduced Immortal Objects to Python which allows objects to bypass reference counts and introduced changes to the C-API:
  - **`_Py_IMMORTAL_REFCNT`**: The reference count that defines an object as immortal.

- `_Py_IsImmortal` Checks if an object has the immortal reference count.
- `PyObject_HEAD_INIT` This will now initialize reference count to `_Py_IMMORTAL_REFCNT` when used with `Py_BUILD_CORE`.
- `SSTATE_INTERNED_IMMORTAL` An identifier for interned unicode objects that are immortal.
- `SSTATE_INTERNED_IMMORTAL_STATIC` An identifier for interned unicode objects that are immortal and static
- `sys.getunicodeinternedsize` This returns the total number of unicode objects that have been interned. This is now needed for `refleak.py` to correctly track reference counts and allocated blocks

(Contributed by Eddie Elizondo in [gh-84436](#).)

- In the limited C API version 3.12, `Py_INCREF()` and `Py_DECREF()` functions are now implemented as opaque function calls to hide implementation details. (Contributed by Victor Stinner in [gh-105387](#).)

## 15.2 Porting to Python 3.12

- Legacy Unicode APIs based on `Py_UNICODE*` representation has been removed. Please migrate to APIs based on UTF-8 or `wchar_t*`.
- Argument parsing functions like `PyArg_ParseTuple()` doesn't support `Py_UNICODE*` based format (e.g. `u, Z`) anymore. Please migrate to other formats for Unicode like `s, z, es, and U`.
- `tp_weaklist` for all static builtin types is always `NULL`. This is an internal-only field on `PyTypeObject` but we're pointing out the change in case someone happens to be accessing the field directly anyway. To avoid breakage, consider using the existing public C-API instead, or, if necessary, the (internal-only) `_PyObject_GET_WEAKREFS_LISTPTR()` macro.
- This internal-only `PyTypeObject.tp_subclasses` may now not be a valid object pointer. Its type was changed to `void*` to reflect this. We mention this in case someone happens to be accessing the internal-only field directly.

To get a list of subclasses, call the Python method `__subclasses__()` (using `PyObject_CallMethod()`, for example).

- Add support of more formatting options (left aligning, octals, uppercase hexadecimals, `intmax_t`, `ptrdiff_t`, `wchar_t` C strings, variable width and precision) in `PyUnicode_FromFormat()` and `PyUnicode_FromFormatV()`. (Contributed by Serhiy Storchaka in [gh-98836](#).)
- An unrecognized format character in `PyUnicode_FromFormat()` and `PyUnicode_FromFormatV()` now sets a `SystemError`. In previous versions it caused all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded. (Contributed by Serhiy Storchaka in [gh-95781](#).)
- Fixed wrong sign placement in `PyUnicode_FromFormat()` and `PyUnicode_FromFormatV()`. (Contributed by Philip Georgi in [gh-95504](#).)
- Extension classes wanting to add a `__dict__` or weak reference slot should use `Py_TPFLAGS_MANAGED_DICT` and `Py_TPFLAGS_MANAGED_WEAKREF` instead of `tp_dictoffset` and `tp_weaklistoffset`, respectively. The use of `tp_dictoffset` and `tp_weaklistoffset` is still supported, but does not fully support multiple inheritance ([gh-95589](#)), and performance may be worse. Classes declaring `Py_TPFLAGS_MANAGED_DICT` should call `_PyObject_VisitManagedDict()` and `_PyObject_ClearManagedDict()` to traverse and clear their instance's dictionaries. To clear weakrefs, call `PyObject_ClearWeakRefs()`, as before.
- The `PyUnicode_FSDecoder()` function no longer accepts bytes-like paths, like `bytearray` and `memoryview` types: only the exact `bytes` type is accepted for bytes strings. (Contributed by Victor Stinner in [gh-98393](#).)

- The `Py_CLEAR`, `Py_SETREF` and `Py_XSETREF` macros now only evaluate their arguments once. If an argument has side effects, these side effects are no longer duplicated. (Contributed by Victor Stinner in [gh-98724](#).)
- The interpreter's error indicator is now always normalized. This means that `PyErr_SetObject()`, `PyErr_SetString()` and the other functions that set the error indicator now normalize the exception before storing it. (Contributed by Mark Shannon in [gh-101578](#).)
- `_Py_RefTotal` is no longer authoritative and only kept around for ABI compatibility. Note that it is an internal global and only available on debug builds. If you happen to be using it then you'll need to start using `_Py_GetGlobalRefTotal()`.
- The following functions now select an appropriate metaclass for the newly created type:
  - `PyType_FromSpec()`
  - `PyType_FromSpecWithBases()`
  - `PyType_FromModuleAndSpec()`

Creating classes whose metaclass overrides `tp_new` is deprecated, and in Python 3.14+ it will be disallowed. Note that these functions ignore `tp_new` of the metaclass, possibly allowing incomplete initialization.

Note that `PyType_FromMetaclass()` (added in Python 3.12) already disallows creating classes whose metaclass overrides `tp_new`.

- `PyOS_InputHook` and `PyOS_ReadlineFunctionPointer` are no longer called in subinterpreters. This is because clients generally rely on process-wide global state (since these callbacks have no way of recovering extension module state).

This also avoids situations where extensions may find themselves running in a subinterpreter that they don't support (or haven't yet been loaded in). See [gh-104668](#) for more info.

## 15.3 Deprecated

- Deprecate global configuration variable:
  - `Py_DebugFlag`: use `PyConfig.parser_debug`
  - `Py_VerboseFlag`: use `PyConfig.verbose`
  - `Py_QuietFlag`: use `PyConfig.quiet`
  - `Py_InteractiveFlag`: use `PyConfig.interactive`
  - `Py_InspectFlag`: use `PyConfig.inspect`
  - `Py_OptimizeFlag`: use `PyConfig.optimization_level`
  - `Py_NoSiteFlag`: use `PyConfig.site_import`
  - `Py_BytesWarningFlag`: use `PyConfig.bytes_warning`
  - `Py_FrozenFlag`: use `PyConfig.pathconfig_warnings`
  - `Py_IgnoreEnvironmentFlag`: use `PyConfig.use_environment`
  - `Py_DontWriteBytecodeFlag`: use `PyConfig.write_bytecode`
  - `Py_NoUserSiteDirectory`: use `PyConfig.user_site_directory`
  - `Py_UnbufferedStdioFlag`: use `PyConfig.buffered_stdio`
  - `Py_HashRandomizationFlag`: use `PyConfig.use_hash_seed` and `PyConfig.hash_seed`
  - `Py_IsolatedFlag`: use `PyConfig.isolated`

- `Py_LegacyWindowsFSEncodingFlag`: use `PyPreConfig.legacy_windows_fs_encoding`
- `Py_LegacyWindowsStdioFlag`: use `PyConfig.legacy_windows_stdio`
- `Py_FileSystemDefaultEncoding`: use `PyConfig.filesystem_encoding`
- `Py_HasFileSystemDefaultEncoding`: use `PyConfig.filesystem_encoding`
- `Py_FileSystemDefaultEncodeErrors`: use `PyConfig.filesystem_errors`
- `Py_UTF8Mode`: use `PyPreConfig.utf8_mode` (see `Py_PreInitialize()`)

The `Py_InitializeFromConfig()` API should be used with `PyConfig` instead. (Contributed by Victor Stinner in [gh-77782](#).)

- Creating immutable types (`Py_TPFLAGS_IMMUTABLETYPE`) with mutable bases is deprecated and will be disabled in Python 3.14.
- The `structmember.h` header is deprecated, though it continues to be available and there are no plans to remove it.

Its contents are now available just by including `Python.h`, with a `Py` prefix added if it was missing:

- `PyMemberDef`, `PyMember_GetOne()` and `PyMember_SetOne()`
- Type macros like `Py_T_INT`, `Py_T_DOUBLE`, etc. (previously `T_INT`, `T_DOUBLE`, etc.)
- The flags `Py_READONLY` (previously `READONLY`) and `Py_AUDIT_READ` (previously all uppercase)

Several items are not exposed from `Python.h`:

- `T_OBJECT` (use `Py_T_OBJECT_EX`)
- `T_NONE` (previously undocumented, and pretty quirky)
- The macro `WRITE_RESTRICTED` which does nothing.
- The macros `RESTRICTED` and `READ_RESTRICTED`, equivalents of `Py_AUDIT_READ`.
- In some configurations, `<stddef.h>` is not included from `Python.h`. It should be included manually when using `offsetof()`.

The deprecated header continues to provide its original contents under the original names. Your old code can stay unchanged, unless the extra include and non-namespaced macros bother you greatly.

(Contributed in [gh-47146](#) by Petr Viktorin, based on earlier work by Alexander Belopolsky and Matthias Braun.)

- `PyErr_Fetch()` and `PyErr_Restore()` are deprecated. Use `PyErr_GetRaisedException()` and `PyErr_SetRaisedException()` instead. (Contributed by Mark Shannon in [gh-101578](#).)
- `PyErr_Display()` is deprecated. Use `PyErr_DisplayException()` instead. (Contributed by Irit Katriel in [gh-102755](#).)
- `_PyErr_ChainExceptions` is deprecated. Use `_PyErr_ChainExceptions1` instead. (Contributed by Irit Katriel in [gh-102192](#).)
- Using `PyType_FromSpec()`, `PyType_FromSpecWithBases()` or `PyType_FromModuleAndSpec()` to create a class whose metaclass overrides `tp_new` is deprecated. Call the metaclass instead.

## 15.4 Removed

- Remove the `token.h` header file. There was never any public tokenizer C API. The `token.h` header file was only designed to be used by Python internals. (Contributed by Victor Stinner in [gh-92651](#).)
- Legacy Unicode APIs have been removed. See [PEP 623](#) for detail.
  - `PyUnicode_WCHAR_KIND`
  - `PyUnicode_AS_UNICODE()`
  - `PyUnicode_AsUnicode()`
  - `PyUnicode_AsUnicodeAndSize()`
  - `PyUnicode_AS_DATA()`
  - `PyUnicode_FromUnicode()`
  - `PyUnicode_GET_SIZE()`
  - `PyUnicode_GetSize()`
  - `PyUnicode_GET_DATA_SIZE()`
- Remove the `PyUnicode_InternImmortal()` function macro. (Contributed by Victor Stinner in [gh-85858](#).)
- Remove Jython compatibility hacks from several stdlib modules and tests. (Contributed by Nikita Sobolev in [gh-99482](#).)
- Remove `_use_broken_old_ctypes_structure_semantics_` flag from `ctypes` module. (Contributed by Nikita Sobolev in [gh-99285](#).)

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