The Python Language Reference

Release 3.6.3

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October 03, 2017

CONTENTS

This reference manual describes the syntax and "core semantics" of the language. It is terse, but attempts to be exact and complete. The semantics of non-essential built-in object types and of the built-in functions and modules are described in library-index. For an informal introduction to the language, see tutorial-index. For C or C++ programmers, two additional manuals exist: extending-index describes the high-level picture of how to write a Python extension module, and the c-api-index describes the interfaces available to C/C++ programmers in detail.

INTRODUCTION

This reference manual describes the Python programming language. It is not intended as a tutorial.

While I am trying to be as precise as possible, I chose to use English rather than formal specifications for everything except syntax and lexical analysis. This should make the document more understandable to the average reader, but will leave room for ambiguities. Consequently, if you were coming from Mars and tried to re-implement Python from this document alone, you might have to guess things and in fact you would probably end up implementing quite a different language. On the other hand, if you are using Python and wonder what the precise rules about a particular area of the language are, you should definitely be able to find them here. If you would like to see a more formal definition of the language, maybe you could volunteer your time — or invent a cloning machine :-).

It is dangerous to add too many implementation details to a language reference document — the implementation may change, and other implementations of the same language may work differently. On the other hand, CPython is the one Python implementation in widespread use (although alternate implementations continue to gain support), and its particular quirks are sometimes worth being mentioned, especially where the implementation imposes additional limitations. Therefore, you'll find short "implementation notes" sprinkled throughout the text.

Every Python implementation comes with a number of built-in and standard modules. These are documented in library-index. A few built-in modules are mentioned when they interact in a significant way with the language definition.

1.1 Alternate Implementations

Though there is one Python implementation which is by far the most popular, there are some alternate implementations which are of particular interest to different audiences.

Known implementations include:

CPython This is the original and most-maintained implementation of Python, written in C. New language features generally appear here first.

Jython Python implemented in Java. This implementation can be used as a scripting language for Java applications, or can be used to create applications using the Java class libraries. It is also often used to create tests for Java libraries. More information can be found at the Jython website.

Python for .NET This implementation actually uses the CPython implementation, but is a managed .NET application and makes .NET libraries available. It was created by Brian Lloyd. For more information, see the Python for .NET home page.

IronPython An alternate Python for .NET. Unlike Python.NET, this is a complete Python implementation that generates IL, and compiles Python code directly to .NET assemblies. It was created by Jim Hugunin, the original creator of Jython. For more information, see the IronPython website.

PyPy An implementation of Python written completely in Python. It supports several advanced features not found in other implementations like stackless support and a Just in Time compiler. One of the goals of the project is to encourage experimentation with the language itself by making it easier to modify the interpreter (since it is written in Python). Additional information is available on the PyPy project's home page.

Each of these implementations varies in some way from the language as documented in this manual, or introduces specific information beyond what's covered in the standard Python documentation. Please refer to the implementation-specific documentation to determine what else you need to know about the specific implementation you're using.

1.2 Notation

The descriptions of lexical analysis and syntax use a modified BNF grammar notation. This uses the following style of definition:

name	::=	lc_letter (lc_letter | "_")*
lc_letter	::=	"a"..."z"

The first line says that a name is an lc_letter followed by a sequence of zero or more lc_letters and underscores. An lc_letter in turn is any of the single characters 'a' through 'z'. (This rule is actually adhered to for the names defined in lexical and grammar rules in this document.)

Each rule begins with a name (which is the name defined by the rule) and ::=. A vertical bar (|) is used to separate alternatives; it is the least binding operator in this notation. A star (*) means zero or more repetitions of the preceding item; likewise, a plus (+) means one or more repetitions, and a phrase enclosed in square brackets ([ ]) means zero or one occurrences (in other words, the enclosed phrase is optional). The * and + operators bind as tightly as possible; parentheses are used for grouping. Literal strings are enclosed in quotes. White space is only meaningful to separate tokens. Rules are normally contained on a single line; rules with many alternatives may be formatted alternatively with each line after the first beginning with a vertical bar.

In lexical definitions (as the example above), two more conventions are used: Two literal characters separated by three dots mean a choice of any single character in the given (inclusive) range of ASCII characters. A phrase between angular brackets (<...>) gives an informal description of the symbol defined; e.g., this could be used to describe the notion of 'control character' if needed.

Even though the notation used is almost the same, there is a big difference between the meaning of lexical and syntactic definitions: a lexical definition operates on the individual characters of the input source, while a syntax definition operates on the stream of tokens generated by the lexical analysis. All uses of BNF in the next chapter ("Lexical Analysis") are lexical definitions; uses in subsequent chapters are syntactic definitions.

LEXICAL ANALYSIS

A Python program is read by a parser. Input to the parser is a stream of tokens, generated by the lexical analyzer. This chapter describes how the lexical analyzer breaks a file into tokens.

Python reads program text as Unicode code points; the encoding of a source file can be given by an encoding declaration and defaults to UTF-8, see PEP 3120 for details. If the source file cannot be decoded, a SyntaxError is raised.

2.1 Line structure

A Python program is divided into a number of logical lines.

2.1.1 Logical lines

The end of a logical line is represented by the token NEWLINE. Statements cannot cross logical line boundaries except where NEWLINE is allowed by the syntax (e.g., between statements in compound statements). A logical line is constructed from one or more physical lines by following the explicit or implicit line joining rules.

2.1.2 Physical lines

A physical line is a sequence of characters terminated by an end-of-line sequence. In source files, any of the standard platform line termination sequences can be used - the Unix form using ASCII LF (linefeed), the Windows form using the ASCII sequence CR LF (return followed by linefeed), or the old Macintosh form using the ASCII CR (return) character. All of these forms can be used equally, regardless of platform.

When embedding Python, source code strings should be passed to Python APIs using the standard C conventions for newline characters (the \n character, representing ASCII LF, is the line terminator).

2.1.3 Comments

A comment starts with a hash character (#) that is not part of a string literal, and ends at the end of the physical line. A comment signifies the end of the logical line unless the implicit line joining rules are invoked. Comments are ignored by the syntax; they are not tokens.

2.1.4 Encoding declarations

If a comment in the first or second line of the Python script matches the regular expression coding[=:]\s*([-\w.]+), this comment is processed as an encoding declaration; the first group of this expression names the encoding of the source code file. The encoding declaration must appear on a line of its own. If it is the second line, the first line must also be a comment-only line. The recommended forms of an encoding expression are

```
# -*- coding: <encoding-name> -*-
```

which is recognized also by GNU Emacs, and

```
# vim:fileencoding=<encoding-name>
```

which is recognized by Bram Moolenaar's VIM.

If no encoding declaration is found, the default encoding is UTF-8. In addition, if the first bytes of the file are the UTF-8 byte-order mark (b'\xef\xbb\xbf'), the declared file encoding is UTF-8 (this is supported, among others, by Microsoft's notepad).

If an encoding is declared, the encoding name must be recognized by Python. The encoding is used for all lexical analysis, including string literals, comments and identifiers.

2.1.5 Explicit line joining

Two or more physical lines may be joined into logical lines using backslash characters (\), as follows: when a physical line ends in a backslash that is not part of a string literal or comment, it is joined with the following forming a single logical line, deleting the backslash and the following end-of-line character. For example:

```
if 1900 < year < 2100 and 1 <= month <= 12 \
   and 1 <= day <= 31 and 0 <= hour < 24 \
   and 0 <= minute < 60 and 0 <= second < 60:   # Looks like a valid date
       return 1
```

A line ending in a backslash cannot carry a comment. A backslash does not continue a comment. A backslash does not continue a token except for string literals (i.e., tokens other than string literals cannot be split across physical lines using a backslash). A backslash is illegal elsewhere on a line outside a string literal.

2.1.6 Implicit line joining

Expressions in parentheses, square brackets or curly braces can be split over more than one physical line without using backslashes. For example:

```
month_names = ['Januari', 'Februari', 'Maart',      # These are the
               'April',   'Mei',      'Juni',       # Dutch names
               'Juli',    'Augustus', 'September',  # for the months
               'Oktober', 'November', 'December']   # of the year
```

Implicitly continued lines can carry comments. The indentation of the continuation lines is not important. Blank continuation lines are allowed. There is no NEWLINE token between implicit continuation lines. Implicitly continued lines can also occur within triple-quoted strings (see below); in that case they cannot carry comments.

2.1.7 Blank lines

A logical line that contains only spaces, tabs, formfeeds and possibly a comment, is ignored (i.e., no NEW-LINE token is generated). During interactive input of statements, handling of a blank line may differ depending on the implementation of the read-eval-print loop. In the standard interactive interpreter, an entirely blank logical line (i.e. one containing not even whitespace or a comment) terminates a multi-line statement.

2.1.8 Indentation

Leading whitespace (spaces and tabs) at the beginning of a logical line is used to compute the indentation level of the line, which in turn is used to determine the grouping of statements.

Tabs are replaced (from left to right) by one to eight spaces such that the total number of characters up to and including the replacement is a multiple of eight (this is intended to be the same rule as used by Unix). The total number of spaces preceding the first non-blank character then determines the line's indentation. Indentation cannot be split over multiple physical lines using backslashes; the whitespace up to the first backslash determines the indentation.

Indentation is rejected as inconsistent if a source file mixes tabs and spaces in a way that makes the meaning dependent on the worth of a tab in spaces; a TabError is raised in that case.

Cross-platform compatibility note: because of the nature of text editors on non-UNIX platforms, it is unwise to use a mixture of spaces and tabs for the indentation in a single source file. It should also be noted that different platforms may explicitly limit the maximum indentation level.

A formfeed character may be present at the start of the line; it will be ignored for the indentation calculations above. Formfeed characters occurring elsewhere in the leading whitespace have an undefined effect (for instance, they may reset the space count to zero).

The indentation levels of consecutive lines are used to generate INDENT and DEDENT tokens, using a stack, as follows.

Before the first line of the file is read, a single zero is pushed on the stack; this will never be popped off again. The numbers pushed on the stack will always be strictly increasing from bottom to top. At the beginning of each logical line, the line's indentation level is compared to the top of the stack. If it is equal, nothing happens. If it is larger, it is pushed on the stack, and one INDENT token is generated. If it is smaller, it must be one of the numbers occurring on the stack; all numbers on the stack that are larger are popped off, and for each number popped off a DEDENT token is generated. At the end of the file, a DEDENT token is generated for each number remaining on the stack that is larger than zero.

Here is an example of a correctly (though confusingly) indented piece of Python code:

```python
def perm(l):
        # Compute the list of all permutations of l
    if len(l) <= 1:
                return [l]
    r = []
    for i in range(len(l)):
            s = l[:i] + l[i+1:]
            p = perm(s)
            for x in p:
             r.append(l[i:i+1] + x)
    return r
```

The following example shows various indentation errors:

```
 def perm(l):                    # error: first line indented
for i in range(len(l)):         # error: not indented
   s = l[:i] + l[i+1:]
       p = perm(l[:i] + l[i+1:])   # error: unexpected indent
       for x in p:
             r.append(l[i:i+1] + x)
         return r               # error: inconsistent dedent
```

(Actually, the first three errors are detected by the parser; only the last error is found by the lexical analyzer
— the indentation of return r does not match a level popped off the stack.)

2.1.9 Whitespace between tokens

Except at the beginning of a logical line or in string literals, the whitespace characters space, tab and
formfeed can be used interchangeably to separate tokens. Whitespace is needed between two tokens only if
their concatenation could otherwise be interpreted as a different token (e.g., ab is one token, but a b is two
tokens).

2.2 Other tokens

Besides NEWLINE, INDENT and DEDENT, the following categories of tokens exist: identifiers, keywords,
literals, operators, and delimiters. Whitespace characters (other than line terminators, discussed earlier)
are not tokens, but serve to delimit tokens. Where ambiguity exists, a token comprises the longest possible
string that forms a legal token, when read from left to right.

2.3 Identifiers and keywords

Identifiers (also referred to as names) are described by the following lexical definitions.

The syntax of identifiers in Python is based on the Unicode standard annex UAX-31, with elaboration and
changes as defined below; see also PEP 3131 for further details.

Within the ASCII range (U+0001..U+007F), the valid characters for identifiers are the same as in Python
2.x: the uppercase and lowercase letters A through Z, the underscore _ and, except for the first character,
the digits 0 through 9.

Python 3.0 introduces additional characters from outside the ASCII range (see PEP 3131). For these char-
acters, the classification uses the version of the Unicode Character Database as included in the unicodedata
module.

Identifiers are unlimited in length. Case is significant.

```
identifier     ::=    xid_start xid_continue*
id_start       ::=    <all characters in general categories Lu, Ll, Lt, Lm, Lo, Nl, the underscore, and characters with the
id_continue    ::=    <all characters in id_start, plus characters in the categories Mn, Mc, Nd, Pc and others with the O
xid_start      ::=    <all characters in id_start whose NFKC normalization is in "id_start xid_continue*">
xid_continue   ::=    <all characters in id_continue whose NFKC normalization is in "id_continue*">
```

The Unicode category codes mentioned above stand for:

- Lu - uppercase letters

- Ll - lowercase letters

- Lt - titlecase letters

- Lm - modifier letters

- Lo - other letters

- Nl - letter numbers

- Mn - nonspacing marks

- Mc - spacing combining marks

- Nd - decimal numbers

- Pc - connector punctuations

- Other_ID_Start - explicit list of characters in PropList.txt to support backwards compatibility

- Other_ID_Continue - likewise

All identifiers are converted into the normal form NFKC while parsing; comparison of identifiers is based on NFKC.

A non-normative HTML file listing all valid identifier characters for Unicode 4.1 can be found at https://www.dcl.hpi.uni-potsdam.de/home/loewis/table-3131.html.

2.3.1 Keywords

The following identifiers are used as reserved words, or keywords of the language, and cannot be used as ordinary identifiers. They must be spelled exactly as written here:

```
False       class     finally    is         return
None        continue  for        lambda     try
True        def       from       nonlocal   while
and         del       global     not        with
as          elif      if         or         yield
assert      else      import     pass
break       except    in         raise
```

2.3.2 Reserved classes of identifiers

Certain classes of identifiers (besides keywords) have special meanings. These classes are identified by the patterns of leading and trailing underscore characters:

_* Not imported by from module import *. The special identifier _ is used in the interactive interpreter to store the result of the last evaluation; it is stored in the builtins module. When not in interactive mode, _ has no special meaning and is not defined. See section The import statement.

Note: The name _ is often used in conjunction with internationalization; refer to the documentation for the gettext module for more information on this convention.

__*__ System-defined names. These names are defined by the interpreter and its implementation (including the standard library). Current system names are discussed in the Special method names section and elsewhere. More will likely be defined in future versions of Python. Any use of __*__ names, in any context, that does not follow explicitly documented use, is subject to breakage without warning.

__* Class-private names. Names in this category, when used within the context of a class definition, are re-written to use a mangled form to help avoid name clashes between "private" attributes of base and derived classes. See section Identifiers (Names).

2.4 Literals

Literals are notations for constant values of some built-in types.

2.4.1 String and Bytes literals

String literals are described by the following lexical definitions:

stringliteral	::=	[stringprefix](shortstring | longstring)
stringprefix	::=	"r" | "u" | "R" | "U" | "f" | "F"
		| "fr" | "Fr" | "fR" | "FR" | "rf" | "rF" | "Rf" | "RF"
shortstring	::=	"'" shortstringitem* "'" | '"' shortstringitem* '"'
longstring	::=	"'''" longstringitem* "'''" | '"""' longstringitem* '"""'
shortstringitem	::=	shortstringchar | stringescapeseq
longstringitem	::=	longstringchar | stringescapeseq
shortstringchar	::=	<any source character except "\" or newline or the quote>
longstringchar	::=	<any source character except "\">
stringescapeseq	::=	"\" <any source character>

bytesliteral	::=	bytesprefix(shortbytes | longbytes)
bytesprefix	::=	"b" | "B" | "br" | "Br" | "bR" | "BR" | "rb" | "rB" | "Rb" | "RB"
shortbytes	::=	"'" shortbytesitem* "'" | '"' shortbytesitem* '"'
longbytes	::=	"'''" longbytesitem* "'''" | '"""' longbytesitem* '"""'
shortbytesitem	::=	shortbyteschar | bytesescapeseq
longbytesitem	::=	longbyteschar | bytesescapeseq
shortbyteschar	::=	<any ASCII character except "\" or newline or the quote>
longbyteschar	::=	<any ASCII character except "\">
bytesescapeseq	::=	"\" <any ASCII character>

One syntactic restriction not indicated by these productions is that whitespace is not allowed between the stringprefix or bytesprefix and the rest of the literal. The source character set is defined by the encoding declaration; it is UTF-8 if no encoding declaration is given in the source file; see section Encoding declarations.

In plain English: Both types of literals can be enclosed in matching single quotes (') or double quotes ("). They can also be enclosed in matching groups of three single or double quotes (these are generally referred to as triple-quoted strings). The backslash (\) character is used to escape characters that otherwise have a special meaning, such as newline, backslash itself, or the quote character.

Bytes literals are always prefixed with 'b' or 'B'; they produce an instance of the bytes type instead of the str type. They may only contain ASCII characters; bytes with a numeric value of 128 or greater must be expressed with escapes.

As of Python 3.3 it is possible again to prefix string literals with a u prefix to simplify maintenance of dual 2.x and 3.x codebases.

Both string and bytes literals may optionally be prefixed with a letter 'r' or 'R'; such strings are called raw strings and treat backslashes as literal characters. As a result, in string literals, '\U' and '\u' escapes

in raw strings are not treated specially. Given that Python 2.x's raw unicode literals behave differently than Python 3.x's the `'ur'` syntax is not supported.

New in version 3.3: The `'rb'` prefix of raw bytes literals has been added as a synonym of `'br'`.

New in version 3.3: Support for the unicode legacy literal (u'value') was reintroduced to simplify the maintenance of dual Python 2.x and 3.x codebases. See PEP 414 for more information.

A string literal with `'f'` or `'F'` in its prefix is a formatted string literal; see Formatted string literals. The `'f'` may be combined with `'r'`, but not with `'b'` or `'u'`, therefore raw formatted strings are possible, but formatted bytes literals are not.

In triple-quoted literals, unescaped newlines and quotes are allowed (and are retained), except that three unescaped quotes in a row terminate the literal. (A "quote" is the character used to open the literal, i.e. either `'` or `"`.)

Unless an `'r'` or `'R'` prefix is present, escape sequences in string and bytes literals are interpreted according to rules similar to those used by Standard C. The recognized escape sequences are:

Escape Sequence	Meaning	Notes
\newline	Backslash and newline ignored	
\\	Backslash (\)	
\'	Single quote (')	
\"	Double quote (")	
\a	ASCII Bell (BEL)	
\b	ASCII Backspace (BS)	
\f	ASCII Formfeed (FF)	
\n	ASCII Linefeed (LF)	
\r	ASCII Carriage Return (CR)	
\t	ASCII Horizontal Tab (TAB)	
\v	ASCII Vertical Tab (VT)	
\ooo	Character with octal value ooo	(1,3)
\xhh	Character with hex value hh	(2,3)

Escape sequences only recognized in string literals are:

Escape Sequence	Meaning	Notes
\N{name}	Character named name in the Unicode database	(4)
\uxxxx	Character with 16-bit hex value xxxx	(5)
\Uxxxxxxxx	Character with 32-bit hex value xxxxxxxx	(6)

Notes:

1. As in Standard C, up to three octal digits are accepted.

2. Unlike in Standard C, exactly two hex digits are required.

3. In a bytes literal, hexadecimal and octal escapes denote the byte with the given value. In a string literal, these escapes denote a Unicode character with the given value.

4. Changed in version 3.3: Support for name aliases[1] has been added.

5. Exactly four hex digits are required.

6. Any Unicode character can be encoded this way. Exactly eight hex digits are required.

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[1] http://www.unicode.org/Public/9.0.0/ucd/NameAliases.txt

Unlike Standard C, all unrecognized escape sequences are left in the string unchanged, i.e., the backslash is left in the result. (This behavior is useful when debugging: if an escape sequence is mistyped, the resulting output is more easily recognized as broken.) It is also important to note that the escape sequences only recognized in string literals fall into the category of unrecognized escapes for bytes literals.

> Changed in version 3.6: Unrecognized escape sequences produce a DeprecationWarning. In some future version of Python they will be a SyntaxError.

Even in a raw literal, quotes can be escaped with a backslash, but the backslash remains in the result; for example, r"\"" is a valid string literal consisting of two characters: a backslash and a double quote; r"\" is not a valid string literal (even a raw string cannot end in an odd number of backslashes). Specifically, a raw literal cannot end in a single backslash (since the backslash would escape the following quote character). Note also that a single backslash followed by a newline is interpreted as those two characters as part of the literal, not as a line continuation.

2.4.2 String literal concatenation

Multiple adjacent string or bytes literals (delimited by whitespace), possibly using different quoting conventions, are allowed, and their meaning is the same as their concatenation. Thus, "hello" 'world' is equivalent to "helloworld". This feature can be used to reduce the number of backslashes needed, to split long strings conveniently across long lines, or even to add comments to parts of strings, for example:

```
re.compile("[A-Za-z_]"       # letter or underscore
           "[A-Za-z0-9_]*"   # letter, digit or underscore
          )
```

Note that this feature is defined at the syntactical level, but implemented at compile time. The '+' operator must be used to concatenate string expressions at run time. Also note that literal concatenation can use different quoting styles for each component (even mixing raw strings and triple quoted strings), and formatted string literals may be concatenated with plain string literals.

2.4.3 Formatted string literals

New in version 3.6.

A formatted string literal or f-string is a string literal that is prefixed with 'f' or 'F'. These strings may contain replacement fields, which are expressions delimited by curly braces {}. While other string literals always have a constant value, formatted strings are really expressions evaluated at run time.

Escape sequences are decoded like in ordinary string literals (except when a literal is also marked as a raw string). After decoding, the grammar for the contents of the string is:

```
f_string          ::=  (literal_char | "{{" | "}}" | replacement_field)*
replacement_field ::=  "{" f_expression ["!" conversion] [":" format_spec] "}"
f_expression      ::=  (conditional_expression | "*" or_expr)
                       ("," conditional_expression | "," "*" or_expr)* [","]
                       | yield_expression
conversion        ::=  "s" | "r" | "a"
format_spec       ::=  (literal_char | NULL | replacement_field)*
literal_char      ::=  <any code point except "{", "}" or NULL>
```

The parts of the string outside curly braces are treated literally, except that any doubled curly braces '{{' or '}}' are replaced with the corresponding single curly brace. A single opening curly bracket '{' marks a replacement field, which starts with a Python expression. After the expression, there may be a conversion

field, introduced by an exclamation point '!'. A format specifier may also be appended, introduced by a colon ':'. A replacement field ends with a closing curly bracket '}'.

Expressions in formatted string literals are treated like regular Python expressions surrounded by parentheses, with a few exceptions. An empty expression is not allowed, and a lambda expression must be surrounded by explicit parentheses. Replacement expressions can contain line breaks (e.g. in triple-quoted strings), but they cannot contain comments. Each expression is evaluated in the context where the formatted string literal appears, in order from left to right.

If a conversion is specified, the result of evaluating the expression is converted before formatting. Conversion '!s' calls str() on the result, '!r' calls repr(), and '!a' calls ascii().

The result is then formatted using the format() protocol. The format specifier is passed to the __format__() method of the expression or conversion result. An empty string is passed when the format specifier is omitted. The formatted result is then included in the final value of the whole string.

Top-level format specifiers may include nested replacement fields. These nested fields may include their own conversion fields and format specifiers, but may not include more deeply-nested replacement fields.

Formatted string literals may be concatenated, but replacement fields cannot be split across literals.

Some examples of formatted string literals:

```
>>> name = "Fred"
>>> f"He said his name is {name!r}."
"He said his name is 'Fred'."
>>> f"He said his name is {repr(name)}."  # repr() is equivalent to !r
"He said his name is 'Fred'."
>>> width = 10
>>> precision = 4
>>> value = decimal.Decimal("12.34567")
>>> f"result: {value:{width}.{precision}}"  # nested fields
'result:      12.35'
>>> today = datetime(year=2017, month=1, day=27)
>>> f"{today:%b %d, %Y}"  # using date format specifier
'January 27, 2017'
>>> number = 1024
>>> f"{number:#0x}"  # using integer format specifier
'0x400'
```

A consequence of sharing the same syntax as regular string literals is that characters in the replacement fields must not conflict with the quoting used in the outer formatted string literal:

```
f"abc {a["x"]} def"    # error: outer string literal ended prematurely
f"abc {a['x']} def"    # workaround: use different quoting
```

Backslashes are not allowed in format expressions and will raise an error:

```
f"newline: {ord('\n')}"  # raises SyntaxError
```

To include a value in which a backslash escape is required, create a temporary variable.

```
>>> newline = ord('\n')
>>> f"newline: {newline}"
'newline: 10'
```

Formatted string literals cannot be used as docstrings, even if they do not include expressions.

```
>>> def foo():
...     f"Not a docstring"
```

```
...
>>> foo.__doc__ is None
True
```

See also PEP 498 for the proposal that added formatted string literals, and str.format(), which uses a related format string mechanism.

2.4.4 Numeric literals

There are three types of numeric literals: integers, floating point numbers, and imaginary numbers. There are no complex literals (complex numbers can be formed by adding a real number and an imaginary number).

Note that numeric literals do not include a sign; a phrase like -1 is actually an expression composed of the unary operator '-' and the literal 1.

2.4.5 Integer literals

Integer literals are described by the following lexical definitions:

integer	::=	decinteger	bininteger	octinteger	hexinteger
decinteger	::=	nonzerodigit (["_"] digit)*	"0"+ (["_"] "0")*
bininteger	::=	"0" ("b" | "B") (["_"] bindigit)+
octinteger	::=	"0" ("o" | "O") (["_"] octdigit)+
hexinteger	::=	"0" ("x" | "X") (["_"] hexdigit)+
nonzerodigit	::=	"1"..."9"
digit	::=	"0"..."9"
bindigit	::=	"0"	"1"
octdigit	::=	"0"..."7"
hexdigit	::=	digit	"a"..."f"	"A"..."F"

There is no limit for the length of integer literals apart from what can be stored in available memory.

Underscores are ignored for determining the numeric value of the literal. They can be used to group digits for enhanced readability. One underscore can occur between digits, and after base specifiers like 0x.

Note that leading zeros in a non-zero decimal number are not allowed. This is for disambiguation with C-style octal literals, which Python used before version 3.0.

Some examples of integer literals:

```
7     2147483647                  0o177    0b100110111
3     79228162514264337593543950336     0o377    0xdeadbeef
      100_000_000_000              0b_1110_0101
```

Changed in version 3.6: Underscores are now allowed for grouping purposes in literals.

2.4.6 Floating point literals

Floating point literals are described by the following lexical definitions:

floatnumber	::=	pointfloat	exponentfloat

pointfloat	::=	[digitpart] fraction | digitpart "."
exponentfloat	::=	(digitpart | pointfloat) exponent
digitpart	::=	digit (["_"] digit)*
fraction	::=	"." digitpart
exponent	::=	("e" | "E") ["+" | "-"] digitpart

Note that the integer and exponent parts are always interpreted using radix 10. For example, 077e010 is legal, and denotes the same number as 77e10. The allowed range of floating point literals is implementation-dependent. As in integer literals, underscores are supported for digit grouping.

Some examples of floating point literals:

```
3.14    10.    .001    1e100    3.14e-10    0e0    3.14_15_93
```

Note that numeric literals do not include a sign; a phrase like -1 is actually an expression composed of the unary operator - and the literal 1.

Changed in version 3.6: Underscores are now allowed for grouping purposes in literals.

2.4.7 Imaginary literals

Imaginary literals are described by the following lexical definitions:

imagnumber	::=	(floatnumber | digitpart) ("j" | "J")

An imaginary literal yields a complex number with a real part of 0.0. Complex numbers are represented as a pair of floating point numbers and have the same restrictions on their range. To create a complex number with a nonzero real part, add a floating point number to it, e.g., (3+4j). Some examples of imaginary literals:

```
3.14j    10.j    10j    .001j    1e100j    3.14e-10j    3.14_15_93j
```

2.5 Operators

The following tokens are operators:

```
+       -       *       **      /       //      %       @
<<      >>      &       |       ^       ~
<       >       <=      >=      ==      !=
```

2.6 Delimiters

The following tokens serve as delimiters in the grammar:

```
(       )       [       ]       {       }
,       :       .       ;       @       =       ->
+=      -=      *=      /=      //=     %=      @=
&=      |=      ^=      >>=     <<=     **=
```

The period can also occur in floating-point and imaginary literals. A sequence of three periods has a special meaning as an ellipsis literal. The second half of the list, the augmented assignment operators, serve lexically as delimiters, but also perform an operation.

The following printing ASCII characters have special meaning as part of other tokens or are otherwise significant to the lexical analyzer:

```
'       "       #       \
```

The following printing ASCII characters are not used in Python. Their occurrence outside string literals and comments is an unconditional error:

```
$       ?       `
```

DATA MODEL

3.1 Objects, values and types

Objects are Python's abstraction for data. All data in a Python program is represented by objects or by relations between objects. (In a sense, and in conformance to Von Neumann's model of a "stored program computer," code is also represented by objects.)

Every object has an identity, a type and a value. An object's identity never changes once it has been created; you may think of it as the object's address in memory. The 'is' operator compares the identity of two objects; the id() function returns an integer representing its identity.

CPython implementation detail: For CPython, id(x) is the memory address where x is stored.

An object's type determines the operations that the object supports (e.g., "does it have a length?") and also defines the possible values for objects of that type. The type() function returns an object's type (which is an object itself). Like its identity, an object's type is also unchangeable.[1]

The value of some objects can change. Objects whose value can change are said to be mutable; objects whose value is unchangeable once they are created are called immutable. (The value of an immutable container object that contains a reference to a mutable object can change when the latter's value is changed; however the container is still considered immutable, because the collection of objects it contains cannot be changed. So, immutability is not strictly the same as having an unchangeable value, it is more subtle.) An object's mutability is determined by its type; for instance, numbers, strings and tuples are immutable, while dictionaries and lists are mutable.

Objects are never explicitly destroyed; however, when they become unreachable they may be garbage-collected. An implementation is allowed to postpone garbage collection or omit it altogether — it is a matter of implementation quality how garbage collection is implemented, as long as no objects are collected that are still reachable.

CPython implementation detail: CPython currently uses a reference-counting scheme with (optional) delayed detection of cyclically linked garbage, which collects most objects as soon as they become unreachable, but is not guaranteed to collect garbage containing circular references. See the documentation of the gc module for information on controlling the collection of cyclic garbage. Other implementations act differently and CPython may change. Do not depend on immediate finalization of objects when they become unreachable (so you should always close files explicitly).

Note that the use of the implementation's tracing or debugging facilities may keep objects alive that would normally be collectable. Also note that catching an exception with a 'try... except' statement may keep objects alive.

Some objects contain references to "external" resources such as open files or windows. It is understood that these resources are freed when the object is garbage-collected, but since garbage collection is not guaranteed

---

[1] It is possible in some cases to change an object's type, under certain controlled conditions. It generally isn't a good idea though, since it can lead to some very strange behaviour if it is handled incorrectly.

to happen, such objects also provide an explicit way to release the external resource, usually a close() method. Programs are strongly recommended to explicitly close such objects. The 'try... finally' statement and the 'with' statement provide convenient ways to do this.

Some objects contain references to other objects; these are called containers. Examples of containers are tuples, lists and dictionaries. The references are part of a container's value. In most cases, when we talk about the value of a container, we imply the values, not the identities of the contained objects; however, when we talk about the mutability of a container, only the identities of the immediately contained objects are implied. So, if an immutable container (like a tuple) contains a reference to a mutable object, its value changes if that mutable object is changed.

Types affect almost all aspects of object behavior. Even the importance of object identity is affected in some sense: for immutable types, operations that compute new values may actually return a reference to any existing object with the same type and value, while for mutable objects this is not allowed. E.g., after a = 1; b = 1, a and b may or may not refer to the same object with the value one, depending on the implementation, but after c = []; d = [], c and d are guaranteed to refer to two different, unique, newly created empty lists. (Note that c = d = [] assigns the same object to both c and d.)

3.2 The standard type hierarchy

Below is a list of the types that are built into Python. Extension modules (written in C, Java, or other languages, depending on the implementation) can define additional types. Future versions of Python may add types to the type hierarchy (e.g., rational numbers, efficiently stored arrays of integers, etc.), although such additions will often be provided via the standard library instead.

Some of the type descriptions below contain a paragraph listing 'special attributes.' These are attributes that provide access to the implementation and are not intended for general use. Their definition may change in the future.

None This type has a single value. There is a single object with this value. This object is accessed through the built-in name None. It is used to signify the absence of a value in many situations, e.g., it is returned from functions that don't explicitly return anything. Its truth value is false.

NotImplemented This type has a single value. There is a single object with this value. This object is accessed through the built-in name NotImplemented. Numeric methods and rich comparison methods should return this value if they do not implement the operation for the operands provided. (The interpreter will then try the reflected operation, or some other fallback, depending on the operator.) Its truth value is true.

See implementing-the-arithmetic-operations for more details.

Ellipsis This type has a single value. There is a single object with this value. This object is accessed through the literal ... or the built-in name Ellipsis. Its truth value is true.

numbers.Number These are created by numeric literals and returned as results by arithmetic operators and arithmetic built-in functions. Numeric objects are immutable; once created their value never changes. Python numbers are of course strongly related to mathematical numbers, but subject to the limitations of numerical representation in computers.

Python distinguishes between integers, floating point numbers, and complex numbers:

numbers.Integral These represent elements from the mathematical set of integers (positive and negative).

There are two types of integers:

Integers (int)

These represent numbers in an unlimited range, subject to available (virtual) memory only. For the purpose of shift and mask operations, a binary representation is assumed, and negative numbers are represented in a variant of 2's complement which gives the illusion of an infinite string of sign bits extending to the left.

Booleans (bool) These represent the truth values False and True. The two objects representing the values False and True are the only Boolean objects. The Boolean type is a subtype of the integer type, and Boolean values behave like the values 0 and 1, respectively, in almost all contexts, the exception being that when converted to a string, the strings "False" or "True" are returned, respectively.

The rules for integer representation are intended to give the most meaningful interpretation of shift and mask operations involving negative integers.

numbers.Real (float) These represent machine-level double precision floating point numbers. You are at the mercy of the underlying machine architecture (and C or Java implementation) for the accepted range and handling of overflow. Python does not support single-precision floating point numbers; the savings in processor and memory usage that are usually the reason for using these are dwarfed by the overhead of using objects in Python, so there is no reason to complicate the language with two kinds of floating point numbers.

numbers.Complex (complex) These represent complex numbers as a pair of machine-level double precision floating point numbers. The same caveats apply as for floating point numbers. The real and imaginary parts of a complex number z can be retrieved through the read-only attributes z.real and z.imag.

Sequences These represent finite ordered sets indexed by non-negative numbers. The built-in function len() returns the number of items of a sequence. When the length of a sequence is n, the index set contains the numbers 0, 1, ..., n-1. Item i of sequence a is selected by a[i].

Sequences also support slicing: a[i:j] selects all items with index k such that i <= k < j. When used as an expression, a slice is a sequence of the same type. This implies that the index set is renumbered so that it starts at 0.

Some sequences also support "extended slicing" with a third "step" parameter: a[i:j:k] selects all items of a with index x where x = i + n*k, n >= 0 and i <= x < j.

Sequences are distinguished according to their mutability:

Immutable sequences An object of an immutable sequence type cannot change once it is created. (If the object contains references to other objects, these other objects may be mutable and may be changed; however, the collection of objects directly referenced by an immutable object cannot change.)

The following types are immutable sequences:

Strings A string is a sequence of values that represent Unicode code points. All the code points in the range U+0000 - U+10FFFF can be represented in a string. Python doesn't have a char type; instead, every code point in the string is represented as a string object with length 1. The built-in function ord() converts a code point from its string form to an integer in the range 0 - 10FFFF; chr() converts an integer in the range 0 - 10FFFF to the corresponding length 1 string object. str.encode() can be used to convert a str to bytes using the given text encoding, and bytes.decode() can be used to achieve the opposite.

Tuples The items of a tuple are arbitrary Python objects. Tuples of two or more items are formed by comma-separated lists of expressions. A tuple of one item (a 'singleton') can be formed by affixing a comma to an expression (an expression by itself does not create a tuple, since parentheses must be usable for grouping of expressions). An empty tuple can be formed by an empty pair of parentheses.

Bytes A bytes object is an immutable array. The items are 8-bit bytes, represented by integers in the range 0 <= x < 256. Bytes literals (like b'abc') and the built-in bytes() constructor can be used to create bytes objects. Also, bytes objects can be decoded to strings via the decode() method.

Mutable sequences Mutable sequences can be changed after they are created. The subscription and slicing notations can be used as the target of assignment and del (delete) statements.

There are currently two intrinsic mutable sequence types:

Lists The items of a list are arbitrary Python objects. Lists are formed by placing a comma-separated list of expressions in square brackets. (Note that there are no special cases needed to form lists of length 0 or 1.)

Byte Arrays A bytearray object is a mutable array. They are created by the built-in bytearray() constructor. Aside from being mutable (and hence unhashable), byte arrays otherwise provide the same interface and functionality as immutable bytes objects.

The extension module array provides an additional example of a mutable sequence type, as does the collections module.

Set types These represent unordered, finite sets of unique, immutable objects. As such, they cannot be indexed by any subscript. However, they can be iterated over, and the built-in function len() returns the number of items in a set. Common uses for sets are fast membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference.

For set elements, the same immutability rules apply as for dictionary keys. Note that numeric types obey the normal rules for numeric comparison: if two numbers compare equal (e.g., 1 and 1.0), only one of them can be contained in a set.

There are currently two intrinsic set types:

Sets These represent a mutable set. They are created by the built-in set() constructor and can be modified afterwards by several methods, such as add().

Frozen sets These represent an immutable set. They are created by the built-in frozenset() constructor. As a frozenset is immutable and hashable, it can be used again as an element of another set, or as a dictionary key.

Mappings These represent finite sets of objects indexed by arbitrary index sets. The subscript notation a[k] selects the item indexed by k from the mapping a; this can be used in expressions and as the target of assignments or del statements. The built-in function len() returns the number of items in a mapping.

There is currently a single intrinsic mapping type:

Dictionaries These represent finite sets of objects indexed by nearly arbitrary values. The only types of values not acceptable as keys are values containing lists or dictionaries or other mutable types that are compared by value rather than by object identity, the reason being that the efficient implementation of dictionaries requires a key's hash value to remain constant. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (e.g., 1 and 1.0) then they can be used interchangeably to index the same dictionary entry.

Dictionaries are mutable; they can be created by the {...} notation (see section Dictionary displays).

The extension modules dbm.ndbm and dbm.gnu provide additional examples of mapping types, as does the collections module.

Callable types These are the types to which the function call operation (see section Calls) can be applied:

User-defined functions A user-defined function object is created by a function definition (see section Function definitions). It should be called with an argument list containing the same number of items as the function's formal parameter list.

Special attributes:

Attribute	Meaning	
__doc__	The function's documentation string, or None if unavailable; not inherited by subclasses	Writable
__name__	The function's name	Writable
__qualname__	The function's qualified name New in version 3.3.	Writable
__module__	The name of the module the function was defined in, or None if unavailable.	Writable
__defaults__	A tuple containing default argument values for those arguments that have defaults, or None if no arguments have a default value	Writable
__code__	The code object representing the compiled function body.	Writable
__globals__	A reference to the dictionary that holds the function's global variables — the global namespace of the module in which the function was defined.	Read-only
__dict__	The namespace supporting arbitrary function attributes.	Writable
__closure__	None or a tuple of cells that contain bindings for the function's free variables.	Read-only
__annotations__	A dict containing annotations of parameters. The keys of the dict are the parameter names, and `'return'` for the return annotation, if provided.	Writable
__kwdefaults__	A dict containing defaults for keyword-only parameters.	Writable

Most of the attributes labelled "Writable" check the type of the assigned value.

Function objects also support getting and setting arbitrary attributes, which can be used, for example, to attach metadata to functions. Regular attribute dot-notation is used to get and set such attributes. Note that the current implementation only supports function attributes on user-defined functions. Function attributes on built-in functions may be supported in the future.

Additional information about a function's definition can be retrieved from its code object; see the description of internal types below.

Instance methods An instance method object combines a class, a class instance and any callable object (normally a user-defined function).

Special read-only attributes: __self__ is the class instance object, __func__ is the function object; __doc__ is the method's documentation (same as __func__.__doc__); __name__ is the method name (same as __func__.__name__); __module__ is the name of the module the method was defined in, or None if unavailable.

Methods also support accessing (but not setting) the arbitrary function attributes on the underlying function object.

User-defined method objects may be created when getting an attribute of a class (perhaps via an instance of that class), if that attribute is a user-defined function object or a class method object.

When an instance method object is created by retrieving a user-defined function object from a class via one of its instances, its __self__ attribute is the instance, and the method object is said to be bound. The new method's __func__ attribute is the original function object.

When a user-defined method object is created by retrieving another method object from a class or instance, the behaviour is the same as for a function object, except that the __func__ attribute of the new instance is not the original method object but its __func__ attribute.

When an instance method object is created by retrieving a class method object from a class or instance, its __self__ attribute is the class itself, and its __func__ attribute is the function object underlying the class method.

When an instance method object is called, the underlying function (__func__) is called, inserting the class instance (__self__) in front of the argument list. For instance, when C is a class which contains a definition for a function f(), and x is an instance of C, calling x.f(1) is equivalent to calling C.f(x, 1).

When an instance method object is derived from a class method object, the "class instance" stored in __self__ will actually be the class itself, so that calling either x.f(1) or C.f(1) is equivalent to calling f(C,1) where f is the underlying function.

Note that the transformation from function object to instance method object happens each time the attribute is retrieved from the instance. In some cases, a fruitful optimization is to assign the attribute to a local variable and call that local variable. Also notice that this transformation only happens for user-defined functions; other callable objects (and all non-callable objects) are retrieved without transformation. It is also important to note that user-defined functions which are attributes of a class instance are not converted to bound methods; this only happens when the function is an attribute of the class.

Generator functions A function or method which uses the yield statement (see section The yield statement) is called a generator function. Such a function, when called, always returns an iterator object which can be used to execute the body of the function: calling the iterator's iterator. __next__() method will cause the function to execute until it provides a value using the yield statement. When the function executes a return statement or falls off the end, a StopIteration exception is raised and the iterator will have reached the end of the set of values to be returned.

Coroutine functions A function or method which is defined using async def is called a coroutine function. Such a function, when called, returns a coroutine object. It may contain await expressions, as well as async with and async for statements. See also the Coroutine Objects section.

Asynchronous generator functions A function or method which is defined using async def and which uses the yield statement is called a asynchronous generator function. Such a function, when called, returns an asynchronous iterator object which can be used in an async for statement to execute the body of the function.

Calling the asynchronous iterator's aiterator.__anext__() method will return an awaitable which when awaited will execute until it provides a value using the yield expression. When the function executes an empty return statement or falls off the end, a StopAsyncIteration exception is raised and the asynchronous iterator will have reached the end of the set of values to be yielded.

Built-in functions A built-in function object is a wrapper around a C function. Examples of built-in functions are len() and math.sin() (math is a standard built-in module). The number and type of the arguments are determined by the C function. Special read-only attributes: __doc__ is the function's documentation string, or None if unavailable; __name__ is the function's name; __self__ is set to None (but see the next item); __module__ is the name of the module the function was defined in or None if unavailable.

Built-in methods This is really a different disguise of a built-in function, this time containing an object passed to the C function as an implicit extra argument. An example of a built-in method is alist. append(), assuming alist is a list object. In this case, the special read-only attribute __self__ is set to the object denoted by alist.

Classes Classes are callable. These objects normally act as factories for new instances of themselves,

but variations are possible for class types that override __new__(). The arguments of the call are passed to __new__() and, in the typical case, to __init__() to initialize the new instance.

Class Instances Instances of arbitrary classes can be made callable by defining a __call__() method in their class.

Modules Modules are a basic organizational unit of Python code, and are created by the import system as invoked either by the import statement (see import), or by calling functions such as importlib. import_module() and built-in __import__(). A module object has a namespace implemented by a dictionary object (this is the dictionary referenced by the __globals__ attribute of functions defined in the module). Attribute references are translated to lookups in this dictionary, e.g., m.x is equivalent to m.__dict__["x"]. A module object does not contain the code object used to initialize the module (since it isn't needed once the initialization is done).

Attribute assignment updates the module's namespace dictionary, e.g., m.x = 1 is equivalent to m.__dict__["x"] = 1.

Predefined (writable) attributes: __name__ is the module's name; __doc__ is the module's documentation string, or None if unavailable; __annotations__ (optional) is a dictionary containing variable annotations collected during module body execution; __file__ is the pathname of the file from which the module was loaded, if it was loaded from a file. The __file__ attribute may be missing for certain types of modules, such as C modules that are statically linked into the interpreter; for extension modules loaded dynamically from a shared library, it is the pathname of the shared library file.

Special read-only attribute: __dict__ is the module's namespace as a dictionary object.

CPython implementation detail: Because of the way CPython clears module dictionaries, the module dictionary will be cleared when the module falls out of scope even if the dictionary still has live references. To avoid this, copy the dictionary or keep the module around while using its dictionary directly.

Custom classes Custom class types are typically created by class definitions (see section Class definitions). A class has a namespace implemented by a dictionary object. Class attribute references are translated to lookups in this dictionary, e.g., C.x is translated to C.__dict__["x"] (although there are a number of hooks which allow for other means of locating attributes). When the attribute name is not found there, the attribute search continues in the base classes. This search of the base classes uses the C3 method resolution order which behaves correctly even in the presence of 'diamond' inheritance structures where there are multiple inheritance paths leading back to a common ancestor. Additional details on the C3 MRO used by Python can be found in the documentation accompanying the 2.3 release at https://www.python.org/download/releases/2.3/mro/.

When a class attribute reference (for class C, say) would yield a class method object, it is transformed into an instance method object whose __self__ attributes is C. When it would yield a static method object, it is transformed into the object wrapped by the static method object. See section Implementing Descriptors for another way in which attributes retrieved from a class may differ from those actually contained in its __dict__.

Class attribute assignments update the class's dictionary, never the dictionary of a base class.

A class object can be called (see above) to yield a class instance (see below).

Special attributes: __name__ is the class name; __module__ is the module name in which the class was defined; __dict__ is the dictionary containing the class's namespace; __bases__ is a tuple containing the base classes, in the order of their occurrence in the base class list; __doc__ is the class's documentation string, or None if undefined; __annotations__ (optional) is a dictionary containing variable annotations collected during class body execution.

Class instances A class instance is created by calling a class object (see above). A class instance has a namespace implemented as a dictionary which is the first place in which attribute references are searched.

When an attribute is not found there, and the instance's class has an attribute by that name, the search continues with the class attributes. If a class attribute is found that is a user-defined function object, it is transformed into an instance method object whose __self__ attribute is the instance. Static method and class method objects are also transformed; see above under "Classes". See section Implementing Descriptors for another way in which attributes of a class retrieved via its instances may differ from the objects actually stored in the class's __dict__. If no class attribute is found, and the object's class has a __getattr__() method, that is called to satisfy the lookup.

Attribute assignments and deletions update the instance's dictionary, never a class's dictionary. If the class has a __setattr__() or __delattr__() method, this is called instead of updating the instance dictionary directly.

Class instances can pretend to be numbers, sequences, or mappings if they have methods with certain special names. See section Special method names.

Special attributes: __dict__ is the attribute dictionary; __class__ is the instance's class.

I/O objects (also known as file objects) A file object represents an open file. Various shortcuts are available to create file objects: the open() built-in function, and also os.popen(), os.fdopen(), and the makefile() method of socket objects (and perhaps by other functions or methods provided by extension modules).

The objects sys.stdin, sys.stdout and sys.stderr are initialized to file objects corresponding to the interpreter's standard input, output and error streams; they are all open in text mode and therefore follow the interface defined by the io.TextIOBase abstract class.

Internal types A few types used internally by the interpreter are exposed to the user. Their definitions may change with future versions of the interpreter, but they are mentioned here for completeness.

Code objects Code objects represent byte-compiled executable Python code, or bytecode. The difference between a code object and a function object is that the function object contains an explicit reference to the function's globals (the module in which it was defined), while a code object contains no context; also the default argument values are stored in the function object, not in the code object (because they represent values calculated at run-time). Unlike function objects, code objects are immutable and contain no references (directly or indirectly) to mutable objects.

Special read-only attributes: co_name gives the function name; co_argcount is the number of positional arguments (including arguments with default values); co_nlocals is the number of local variables used by the function (including arguments); co_varnames is a tuple containing the names of the local variables (starting with the argument names); co_cellvars is a tuple containing the names of local variables that are referenced by nested functions; co_freevars is a tuple containing the names of free variables; co_code is a string representing the sequence of bytecode instructions; co_consts is a tuple containing the literals used by the bytecode; co_names is a tuple containing the names used by the bytecode; co_filename is the filename from which the code was compiled; co_firstlineno is the first line number of the function; co_lnotab is a string encoding the mapping from bytecode offsets to line numbers (for details see the source code of the interpreter); co_stacksize is the required stack size (including local variables); co_flags is an integer encoding a number of flags for the interpreter.

The following flag bits are defined for co_flags: bit 0x04 is set if the function uses the *arguments syntax to accept an arbitrary number of positional arguments; bit 0x08 is set if the function uses the **keywords syntax to accept arbitrary keyword arguments; bit 0x20 is set if the function is a generator.

Future feature declarations (from __future__ import division) also use bits in co_flags to indicate whether a code object was compiled with a particular feature enabled: bit 0x2000 is set if the function was compiled with future division enabled; bits 0x10 and 0x1000 were used in earlier versions of Python.

Other bits in co_flags are reserved for internal use.

If a code object represents a function, the first item in co_consts is the documentation string of the function, or None if undefined.

Frame objects Frame objects represent execution frames. They may occur in traceback objects (see below).

Special read-only attributes: f_back is to the previous stack frame (towards the caller), or None if this is the bottom stack frame; f_code is the code object being executed in this frame; f_locals is the dictionary used to look up local variables; f_globals is used for global variables; f_builtins is used for built-in (intrinsic) names; f_lasti gives the precise instruction (this is an index into the bytecode string of the code object).

Special writable attributes: f_trace, if not None, is a function called at the start of each source code line (this is used by the debugger); f_lineno is the current line number of the frame — writing to this from within a trace function jumps to the given line (only for the bottom-most frame). A debugger can implement a Jump command (aka Set Next Statement) by writing to f_lineno.

Frame objects support one method:

frame.clear()
    This method clears all references to local variables held by the frame. Also, if the frame belonged to a generator, the generator is finalized. This helps break reference cycles involving frame objects (for example when catching an exception and storing its traceback for later use).

    RuntimeError is raised if the frame is currently executing.

    New in version 3.4.

Traceback objects Traceback objects represent a stack trace of an exception. A traceback object is created when an exception occurs. When the search for an exception handler unwinds the execution stack, at each unwound level a traceback object is inserted in front of the current traceback. When an exception handler is entered, the stack trace is made available to the program. (See section The try statement.) It is accessible as the third item of the tuple returned by sys. exc_info(). When the program contains no suitable handler, the stack trace is written (nicely formatted) to the standard error stream; if the interpreter is interactive, it is also made available to the user as sys.last_traceback.

Special read-only attributes: tb_next is the next level in the stack trace (towards the frame where the exception occurred), or None if there is no next level; tb_frame points to the execution frame of the current level; tb_lineno gives the line number where the exception occurred; tb_lasti indicates the precise instruction. The line number and last instruction in the traceback may differ from the line number of its frame object if the exception occurred in a try statement with no matching except clause or with a finally clause.

Slice objects Slice objects are used to represent slices for __getitem__() methods. They are also created by the built-in slice() function.

Special read-only attributes: start is the lower bound; stop is the upper bound; step is the step value; each is None if omitted. These attributes can have any type.

Slice objects support one method:

slice.indices(self, length)
    This method takes a single integer argument length and computes information about the slice that the slice object would describe if applied to a sequence of length items. It returns a tuple of three integers; respectively these are the start and stop indices and the step or stride length of the slice. Missing or out-of-bounds indices are handled in a manner consistent with regular slices.

Static method objects Static method objects provide a way of defeating the transformation of function objects to method objects described above. A static method object is a wrapper around any other

object, usually a user-defined method object. When a static method object is retrieved from a class or a class instance, the object actually returned is the wrapped object, which is not subject to any further transformation. Static method objects are not themselves callable, although the objects they wrap usually are. Static method objects are created by the built-in staticmethod() constructor.

Class method objects A class method object, like a static method object, is a wrapper around another object that alters the way in which that object is retrieved from classes and class instances. The behaviour of class method objects upon such retrieval is described above, under "User-defined methods". Class method objects are created by the built-in classmethod() constructor.

3.3 Special method names

A class can implement certain operations that are invoked by special syntax (such as arithmetic operations or subscripting and slicing) by defining methods with special names. This is Python's approach to operator overloading, allowing classes to define their own behavior with respect to language operators. For instance, if a class defines a method named __getitem__(), and x is an instance of this class, then x[i] is roughly equivalent to type(x).__getitem__(x, i). Except where mentioned, attempts to execute an operation raise an exception when no appropriate method is defined (typically AttributeError or TypeError).

Setting a special method to None indicates that the corresponding operation is not available. For example, if a class sets __iter__() to None, the class is not iterable, so calling iter() on its instances will raise a TypeError (without falling back to __getitem__()).[2]

When implementing a class that emulates any built-in type, it is important that the emulation only be implemented to the degree that it makes sense for the object being modelled. For example, some sequences may work well with retrieval of individual elements, but extracting a slice may not make sense. (One example of this is the NodeList interface in the W3C's Document Object Model.)

3.3.1 Basic customization

object.__new__(cls[, ...])

Called to create a new instance of class cls. __new__() is a static method (special-cased so you need not declare it as such) that takes the class of which an instance was requested as its first argument. The remaining arguments are those passed to the object constructor expression (the call to the class). The return value of __new__() should be the new object instance (usually an instance of cls).

Typical implementations create a new instance of the class by invoking the superclass's __new__() method using super().__new__(cls[, ...]) with appropriate arguments and then modifying the newly-created instance as necessary before returning it.

If __new__() returns an instance of cls, then the new instance's __init__() method will be invoked like __init__(self[, ...]), where self is the new instance and the remaining arguments are the same as were passed to __new__().

If __new__() does not return an instance of cls, then the new instance's __init__() method will not be invoked.

__new__() is intended mainly to allow subclasses of immutable types (like int, str, or tuple) to customize instance creation. It is also commonly overridden in custom metaclasses in order to customize class creation.

---

[2] The __hash__(), __iter__(), __reversed__(), and __contains__() methods have special handling for this; others will still raise a TypeError, but may do so by relying on the behavior that None is not callable.

object.__init__(self[, ...])
> Called after the instance has been created (by __new__()), but before it is returned to the caller. The arguments are those passed to the class constructor expression. If a base class has an __init__() method, the derived class's __init__() method, if any, must explicitly call it to ensure proper initialization of the base class part of the instance; for example: super().__init__([args...]).

> Because __new__() and __init__() work together in constructing objects (__new__() to create it, and __init__() to customize it), no non-None value may be returned by __init__(); doing so will cause a TypeError to be raised at runtime.

object.__del__(self)
> Called when the instance is about to be destroyed. This is also called a destructor. If a base class has a __del__() method, the derived class's __del__() method, if any, must explicitly call it to ensure proper deletion of the base class part of the instance. Note that it is possible (though not recommended!) for the __del__() method to postpone destruction of the instance by creating a new reference to it. It may then be called at a later time when this new reference is deleted. It is not guaranteed that __del__() methods are called for objects that still exist when the interpreter exits.

> Note: del x doesn't directly call x.__del__() — the former decrements the reference count for x by one, and the latter is only called when x's reference count reaches zero. Some common situations that may prevent the reference count of an object from going to zero include: circular references between objects (e.g., a doubly-linked list or a tree data structure with parent and child pointers); a reference to the object on the stack frame of a function that caught an exception (the traceback stored in sys. exc_info()[2] keeps the stack frame alive); or a reference to the object on the stack frame that raised an unhandled exception in interactive mode (the traceback stored in sys.last_traceback keeps the stack frame alive). The first situation can only be remedied by explicitly breaking the cycles; the second can be resolved by freeing the reference to the traceback object when it is no longer useful, and the third can be resolved by storing None in sys.last_traceback. Circular references which are garbage are detected and cleaned up when the cyclic garbage collector is enabled (it's on by default). Refer to the documentation for the gc module for more information about this topic.

> Warning: Due to the precarious circumstances under which __del__() methods are invoked, exceptions that occur during their execution are ignored, and a warning is printed to sys.stderr instead. Also, when __del__() is invoked in response to a module being deleted (e.g., when execution of the program is done), other globals referenced by the __del__() method may already have been deleted or in the process of being torn down (e.g. the import machinery shutting down). For this reason, __del__() methods should do the absolute minimum needed to maintain external invariants. Starting with version 1.5, Python guarantees that globals whose name begins with a single underscore are deleted from their module before other globals are deleted; if no other references to such globals exist, this may help in assuring that imported modules are still available at the time when the __del__() method is called.

object.__repr__(self)
> Called by the repr() built-in function to compute the "official" string representation of an object. If at all possible, this should look like a valid Python expression that could be used to recreate an object with the same value (given an appropriate environment). If this is not possible, a string of the form <...some useful description...> should be returned. The return value must be a string object. If a class defines __repr__() but not __str__(), then __repr__() is also used when an "informal" string representation of instances of that class is required.

> This is typically used for debugging, so it is important that the representation is information-rich and unambiguous.

---

object.__str__(self)
> Called by str(object) and the built-in functions format() and print() to compute the "informal" or nicely printable string representation of an object. The return value must be a string object.

> This method differs from object.__repr__() in that there is no expectation that __str__() return a valid Python expression: a more convenient or concise representation can be used.

> The default implementation defined by the built-in type object calls object.__repr__().

object.__bytes__(self)
> Called by bytes to compute a byte-string representation of an object. This should return a bytes object.

object.__format__(self, format_spec)
> Called by the format() built-in function, and by extension, evaluation of formatted string literals and the str.format() method, to produce a "formatted" string representation of an object. The format_spec argument is a string that contains a description of the formatting options desired. The interpretation of the format_spec argument is up to the type implementing __format__(), however most classes will either delegate formatting to one of the built-in types, or use a similar formatting option syntax.

> See formatspec for a description of the standard formatting syntax.

> The return value must be a string object.

> Changed in version 3.4: The __format__ method of object itself raises a TypeError if passed any non-empty string.

object.__lt__(self, other)
object.__le__(self, other)
object.__eq__(self, other)
object.__ne__(self, other)
object.__gt__(self, other)
object.__ge__(self, other)
> These are the so-called "rich comparison" methods. The correspondence between operator symbols and method names is as follows: x<y calls x.__lt__(y), x<=y calls x.__le__(y), x==y calls x.__eq__(y), x!=y calls x.__ne__(y), x>y calls x.__gt__(y), and x>=y calls x.__ge__(y).

> A rich comparison method may return the singleton NotImplemented if it does not implement the operation for a given pair of arguments. By convention, False and True are returned for a successful comparison. However, these methods can return any value, so if the comparison operator is used in a Boolean context (e.g., in the condition of an if statement), Python will call bool() on the value to determine if the result is true or false.

> By default, __ne__() delegates to __eq__() and inverts the result unless it is NotImplemented. There are no other implied relationships among the comparison operators, for example, the truth of (x<y or x==y) does not imply x<=y. To automatically generate ordering operations from a single root operation, see functools.total_ordering().

> See the paragraph on __hash__() for some important notes on creating hashable objects which support custom comparison operations and are usable as dictionary keys.

> There are no swapped-argument versions of these methods (to be used when the left argument does not support the operation but the right argument does); rather, __lt__() and __gt__() are each other's reflection, __le__() and __ge__() are each other's reflection, and __eq__() and __ne__() are their own reflection. If the operands are of different types, and right operand's type is a direct or indirect subclass of the left operand's type, the reflected method of the right operand has priority, otherwise the left operand's method has priority. Virtual subclassing is not considered.

object.__hash__(self)
> Called by built-in function hash() and for operations on members of hashed collections including set, frozenset, and dict. __hash__() should return an integer. The only required property is that objects

which compare equal have the same hash value; it is advised to mix together the hash values of the components of the object that also play a part in comparison of objects by packing them into a tuple and hashing the tuple. Example:

```python
def __hash__(self):
    return hash((self.name, self.nick, self.color))
```

Note: hash() truncates the value returned from an object's custom `__hash__()` method to the size of a Py_ssize_t. This is typically 8 bytes on 64-bit builds and 4 bytes on 32-bit builds. If an object's `__hash__()` must interoperate on builds of different bit sizes, be sure to check the width on all supported builds. An easy way to do this is with python -c "import sys; print(sys.hash_info.width)".

If a class does not define an `__eq__()` method it should not define a `__hash__()` operation either; if it defines `__eq__()` but not `__hash__()`, its instances will not be usable as items in hashable collections. If a class defines mutable objects and implements an `__eq__()` method, it should not implement `__hash__()`, since the implementation of hashable collections requires that a key's hash value is immutable (if the object's hash value changes, it will be in the wrong hash bucket).

User-defined classes have `__eq__()` and `__hash__()` methods by default; with them, all objects compare unequal (except with themselves) and x.`__hash__()` returns an appropriate value such that x == y implies both that x is y and hash(x) == hash(y).

A class that overrides `__eq__()` and does not define `__hash__()` will have its `__hash__()` implicitly set to None. When the `__hash__()` method of a class is None, instances of the class will raise an appropriate TypeError when a program attempts to retrieve their hash value, and will also be correctly identified as unhashable when checking isinstance(obj, collections.Hashable).

If a class that overrides `__eq__()` needs to retain the implementation of `__hash__()` from a parent class, the interpreter must be told this explicitly by setting `__hash__` = <ParentClass>.`__hash__`.

If a class that does not override `__eq__()` wishes to suppress hash support, it should include `__hash__` = None in the class definition. A class which defines its own `__hash__()` that explicitly raises a TypeError would be incorrectly identified as hashable by an isinstance(obj, collections.Hashable) call.

Note: By default, the `__hash__()` values of str, bytes and datetime objects are "salted" with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

This is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict insertion, O(n^2) complexity. See http://www.ocert.org/advisories/ocert-2011-003.html for details.

Changing hash values affects the iteration order of dicts, sets and other mappings. Python has never made guarantees about this ordering (and it typically varies between 32-bit and 64-bit builds).

See also PYTHONHASHSEED.

Changed in version 3.3: Hash randomization is enabled by default.

object.`__bool__`(self)
Called to implement truth value testing and the built-in operation bool(); should return False or True. When this method is not defined, `__len__()` is called, if it is defined, and the object is considered true if its result is nonzero. If a class defines neither `__len__()` nor `__bool__()`, all its instances are considered true.

3.3.2 Customizing attribute access

The following methods can be defined to customize the meaning of attribute access (use of, assignment to, or deletion of x.name) for class instances.

object.__getattr__(self, name)

Called when an attribute lookup has not found the attribute in the usual places (i.e. it is not an instance attribute nor is it found in the class tree for self). name is the attribute name. This method should return the (computed) attribute value or raise an AttributeError exception.

Note that if the attribute is found through the normal mechanism, __getattr__() is not called. (This is an intentional asymmetry between __getattr__() and __setattr__().) This is done both for efficiency reasons and because otherwise __getattr__() would have no way to access other attributes of the instance. Note that at least for instance variables, you can fake total control by not inserting any values in the instance attribute dictionary (but instead inserting them in another object). See the __getattribute__() method below for a way to actually get total control over attribute access.

object.__getattribute__(self, name)

Called unconditionally to implement attribute accesses for instances of the class. If the class also defines __getattr__(), the latter will not be called unless __getattribute__() either calls it explicitly or raises an AttributeError. This method should return the (computed) attribute value or raise an AttributeError exception. In order to avoid infinite recursion in this method, its implementation should always call the base class method with the same name to access any attributes it needs, for example, object.__getattribute__(self, name).

Note: This method may still be bypassed when looking up special methods as the result of implicit invocation via language syntax or built-in functions. See Special method lookup.

---

object.__setattr__(self, name, value)

Called when an attribute assignment is attempted. This is called instead of the normal mechanism (i.e. store the value in the instance dictionary). name is the attribute name, value is the value to be assigned to it.

If __setattr__() wants to assign to an instance attribute, it should call the base class method with the same name, for example, object.__setattr__(self, name, value).

object.__delattr__(self, name)

Like __setattr__() but for attribute deletion instead of assignment. This should only be implemented if del obj.name is meaningful for the object.

object.__dir__(self)

Called when dir() is called on the object. A sequence must be returned. dir() converts the returned sequence to a list and sorts it.

Implementing Descriptors

The following methods only apply when an instance of the class containing the method (a so-called descriptor class) appears in an owner class (the descriptor must be in either the owner's class dictionary or in the class dictionary for one of its parents). In the examples below, "the attribute" refers to the attribute whose name is the key of the property in the owner class' __dict__.

object.__get__(self, instance, owner)

Called to get the attribute of the owner class (class attribute access) or of an instance of that class (instance attribute access). owner is always the owner class, while instance is the instance that the attribute was accessed through, or None when the attribute is accessed through the owner. This method should return the (computed) attribute value or raise an AttributeError exception.

object.__set__(self, instance, value)
>   Called to set the attribute on an instance instance of the owner class to a new value, value.

object.__delete__(self, instance)
>   Called to delete the attribute on an instance instance of the owner class.

object.__set_name__(self, owner, name)
>   Called at the time the owning class owner is created. The descriptor has been assigned to name.

>   New in version 3.6.

The attribute __objclass__ is interpreted by the inspect module as specifying the class where this object was defined (setting this appropriately can assist in runtime introspection of dynamic class attributes). For callables, it may indicate that an instance of the given type (or a subclass) is expected or required as the first positional argument (for example, CPython sets this attribute for unbound methods that are implemented in C).

Invoking Descriptors

In general, a descriptor is an object attribute with "binding behavior", one whose attribute access has been overridden by methods in the descriptor protocol: __get__(), __set__(), and __delete__(). If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object's dictionary. For instance, a.x has a lookup chain starting with a.__dict__['x'], then type(a).__dict__['x'], and continuing through the base classes of type(a) excluding metaclasses.

However, if the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined and how they were called.

The starting point for descriptor invocation is a binding, a.x. How the arguments are assembled depends on a:

Direct Call The simplest and least common call is when user code directly invokes a descriptor method: x.__get__(a).

Instance Binding If binding to an object instance, a.x is transformed into the call: type(a).__dict__['x'].__get__(a, type(a)).

Class Binding If binding to a class, A.x is transformed into the call: A.__dict__['x'].__get__(None, A).

Super Binding If a is an instance of super, then the binding super(B, obj).m() searches obj.__class__.__mro__ for the base class A immediately preceding B and then invokes the descriptor with the call: A.__dict__['m'].__get__(obj, obj.__class__).

For instance bindings, the precedence of descriptor invocation depends on the which descriptor methods are defined. A descriptor can define any combination of __get__(), __set__() and __delete__(). If it does not define __get__(), then accessing the attribute will return the descriptor object itself unless there is a value in the object's instance dictionary. If the descriptor defines __set__() and/or __delete__(), it is a data descriptor; if it defines neither, it is a non-data descriptor. Normally, data descriptors define both __get__() and __set__(), while non-data descriptors have just the __get__() method. Data descriptors with __set__() and __get__() defined always override a redefinition in an instance dictionary. In contrast, non-data descriptors can be overridden by instances.

Python methods (including staticmethod() and classmethod()) are implemented as non-data descriptors. Accordingly, instances can redefine and override methods. This allows individual instances to acquire behaviors that differ from other instances of the same class.

The property() function is implemented as a data descriptor. Accordingly, instances cannot override the behavior of a property.

__slots__

By default, instances of classes have a dictionary for attribute storage. This wastes space for objects having very few instance variables. The space consumption can become acute when creating large numbers of instances.

The default can be overridden by defining __slots__ in a class definition. The __slots__ declaration takes a sequence of instance variables and reserves just enough space in each instance to hold a value for each variable. Space is saved because __dict__ is not created for each instance.

object.__slots__
    This class variable can be assigned a string, iterable, or sequence of strings with variable names used by instances. __slots__ reserves space for the declared variables and prevents the automatic creation of __dict__ and __weakref__ for each instance.

Notes on using __slots__

- When inheriting from a class without __slots__, the __dict__ attribute of that class will always be accessible, so a __slots__ definition in the subclass is meaningless.

- Without a __dict__ variable, instances cannot be assigned new variables not listed in the __slots__ definition. Attempts to assign to an unlisted variable name raises AttributeError. If dynamic assignment of new variables is desired, then add '__dict__' to the sequence of strings in the __slots__ declaration.

- Without a __weakref__ variable for each instance, classes defining __slots__ do not support weak references to its instances. If weak reference support is needed, then add '__weakref__' to the sequence of strings in the __slots__ declaration.

- __slots__ are implemented at the class level by creating descriptors (Implementing Descriptors) for each variable name. As a result, class attributes cannot be used to set default values for instance variables defined by __slots__; otherwise, the class attribute would overwrite the descriptor assignment.

- The action of a __slots__ declaration is limited to the class where it is defined. As a result, subclasses will have a __dict__ unless they also define __slots__ (which must only contain names of any additional slots).

- If a class defines a slot also defined in a base class, the instance variable defined by the base class slot is inaccessible (except by retrieving its descriptor directly from the base class). This renders the meaning of the program undefined. In the future, a check may be added to prevent this.

- Nonempty __slots__ does not work for classes derived from "variable-length" built-in types such as int, bytes and tuple.

- Any non-string iterable may be assigned to __slots__. Mappings may also be used; however, in the future, special meaning may be assigned to the values corresponding to each key.

- __class__ assignment works only if both classes have the same __slots__.

3.3.3 Customizing class creation

Whenever a class inherits from another class, __init_subclass__ is called on that class. This way, it is possible to write classes which change the behavior of subclasses. This is closely related to class decorators,

but where class decorators only affect the specific class they're applied to, __init_subclass__ solely applies to future subclasses of the class defining the method.

classmethod object.__init_subclass__(cls)

>   This method is called whenever the containing class is subclassed. cls is then the new subclass. If defined as a normal instance method, this method is implicitly converted to a class method.
>
>   Keyword arguments which are given to a new class are passed to the parent's class __init_subclass__. For compatibility with other classes using __init_subclass__, one should take out the needed keyword arguments and pass the others over to the base class, as in:

```python
class Philosopher:
    def __init_subclass__(cls, default_name, **kwargs):
        super().__init_subclass__(**kwargs)
        cls.default_name = default_name

class AustralianPhilosopher(Philosopher, default_name="Bruce"):
    pass
```

>   The default implementation object.__init_subclass__ does nothing, but raises an error if it is called with any arguments.
>
>   ---
>
>   Note: The metaclass hint metaclass is consumed by the rest of the type machinery, and is never passed to __init_subclass__ implementations. The actual metaclass (rather than the explicit hint) can be accessed as type(cls).
>
>   ---
>
>   New in version 3.6.

Metaclasses

By default, classes are constructed using type(). The class body is executed in a new namespace and the class name is bound locally to the result of type(name, bases, namespace).

The class creation process can be customized by passing the metaclass keyword argument in the class definition line, or by inheriting from an existing class that included such an argument. In the following example, both MyClass and MySubclass are instances of Meta:

```python
class Meta(type):
    pass

class MyClass(metaclass=Meta):
    pass

class MySubclass(MyClass):
    pass
```

Any other keyword arguments that are specified in the class definition are passed through to all metaclass operations described below.

When a class definition is executed, the following steps occur:

- the appropriate metaclass is determined
- the class namespace is prepared
- the class body is executed
- the class object is created

Determining the appropriate metaclass

The appropriate metaclass for a class definition is determined as follows:

- if no bases and no explicit metaclass are given, then type() is used

- if an explicit metaclass is given and it is not an instance of type(), then it is used directly as the metaclass

- if an instance of type() is given as the explicit metaclass, or bases are defined, then the most derived metaclass is used

The most derived metaclass is selected from the explicitly specified metaclass (if any) and the metaclasses (i.e. type(cls)) of all specified base classes. The most derived metaclass is one which is a subtype of all of these candidate metaclasses. If none of the candidate metaclasses meets that criterion, then the class definition will fail with TypeError.

Preparing the class namespace

Once the appropriate metaclass has been identified, then the class namespace is prepared. If the metaclass has a __prepare__ attribute, it is called as namespace = metaclass.__prepare__(name, bases, **kwds) (where the additional keyword arguments, if any, come from the class definition).

If the metaclass has no __prepare__ attribute, then the class namespace is initialised as an empty ordered mapping.

See also:

PEP 3115 - Metaclasses in Python 3000 Introduced the __prepare__ namespace hook

Executing the class body

The class body is executed (approximately) as exec(body, globals(), namespace). The key difference from a normal call to exec() is that lexical scoping allows the class body (including any methods) to reference names from the current and outer scopes when the class definition occurs inside a function.

However, even when the class definition occurs inside the function, methods defined inside the class still cannot see names defined at the class scope. Class variables must be accessed through the first parameter of instance or class methods, or through the implicit lexically scoped __class__ reference described in the next section.

Creating the class object

Once the class namespace has been populated by executing the class body, the class object is created by calling metaclass(name, bases, namespace, **kwds) (the additional keywords passed here are the same as those passed to __prepare__).

This class object is the one that will be referenced by the zero-argument form of super(). __class__ is an implicit closure reference created by the compiler if any methods in a class body refer to either __class__ or super. This allows the zero argument form of super() to correctly identify the class being defined based on lexical scoping, while the class or instance that was used to make the current call is identified based on the first argument passed to the method.

CPython implementation detail: In CPython 3.6 and later, the __class__ cell is passed to the metaclass as a __classcell__ entry in the class namespace. If present, this must be propagated up to the type.__new__ call in order for the class to be initialised correctly. Failing to do so will result in a DeprecationWarning in Python 3.6, and a RuntimeWarning in the future.

When using the default metaclass type, or any metaclass that ultimately calls type.__new__, the following additional customisation steps are invoked after creating the class object:

- first, type.__new__ collects all of the descriptors in the class namespace that define a __set_name__() method;

- second, all of these __set_name__ methods are called with the class being defined and the assigned name of that particular descriptor; and

- finally, the __init_subclass__() hook is called on the immediate parent of the new class in its method resolution order.

After the class object is created, it is passed to the class decorators included in the class definition (if any) and the resulting object is bound in the local namespace as the defined class.

When a new class is created by type.__new__, the object provided as the namespace parameter is copied to a new ordered mapping and the original object is discarded. The new copy is wrapped in a read-only proxy, which becomes the __dict__ attribute of the class object.

See also:

PEP 3135 - New super Describes the implicit __class__ closure reference

Metaclass example

The potential uses for metaclasses are boundless. Some ideas that have been explored include enum, logging, interface checking, automatic delegation, automatic property creation, proxies, frameworks, and automatic resource locking/synchronization.

Here is an example of a metaclass that uses an collections.OrderedDict to remember the order that class variables are defined:

```python
class OrderedClass(type):

    @classmethod
    def __prepare__(metacls, name, bases, **kwds):
        return collections.OrderedDict()

    def __new__(cls, name, bases, namespace, **kwds):
        result = type.__new__(cls, name, bases, dict(namespace))
        result.members = tuple(namespace)
        return result

class A(metaclass=OrderedClass):
    def one(self): pass
    def two(self): pass
    def three(self): pass
    def four(self): pass

>>> A.members
('__module__', 'one', 'two', 'three', 'four')
```

When the class definition for A gets executed, the process begins with calling the metaclass's __prepare__() method which returns an empty collections.OrderedDict. That mapping records the methods and attributes of A as they are defined within the body of the class statement. Once those definitions are executed, the ordered dictionary is fully populated and the metaclass's __new__() method gets invoked. That method builds the new type and it saves the ordered dictionary keys in an attribute called members.

3.3.4 Customizing instance and subclass checks

The following methods are used to override the default behavior of the isinstance() and issubclass() built-in functions.

In particular, the metaclass abc.ABCMeta implements these methods in order to allow the addition of Abstract Base Classes (ABCs) as "virtual base classes" to any class or type (including built-in types), including other ABCs.

class.__instancecheck__(self, instance)
> Return true if instance should be considered a (direct or indirect) instance of class. If defined, called to implement isinstance(instance, class).

class.__subclasscheck__(self, subclass)
> Return true if subclass should be considered a (direct or indirect) subclass of class. If defined, called to implement issubclass(subclass, class).

Note that these methods are looked up on the type (metaclass) of a class. They cannot be defined as class methods in the actual class. This is consistent with the lookup of special methods that are called on instances, only in this case the instance is itself a class.

See also:

PEP 3119 - Introducing Abstract Base Classes Includes the specification for customizing isinstance() and issubclass() behavior through __instancecheck__() and __subclasscheck__(), with motivation for this functionality in the context of adding Abstract Base Classes (see the abc module) to the language.

3.3.5 Emulating callable objects

object.__call__(self[, args...])
> Called when the instance is "called" as a function; if this method is defined, x(arg1, arg2, ...) is a shorthand for x.__call__(arg1, arg2, ...).

3.3.6 Emulating container types

The following methods can be defined to implement container objects. Containers usually are sequences (such as lists or tuples) or mappings (like dictionaries), but can represent other containers as well. The first set of methods is used either to emulate a sequence or to emulate a mapping; the difference is that for a sequence, the allowable keys should be the integers k for which $0 <= k < N$ where N is the length of the sequence, or slice objects, which define a range of items. It is also recommended that mappings provide the methods keys(), values(), items(), get(), clear(), setdefault(), pop(), popitem(), copy(), and update() behaving similar to those for Python's standard dictionary objects. The collections module provides a MutableMapping abstract base class to help create those methods from a base set of __getitem__(), __setitem__(), __delitem__(), and keys(). Mutable sequences should provide methods append(), count(), index(), extend(), insert(), pop(), remove(), reverse() and sort(), like Python standard list objects. Finally, sequence types should implement addition (meaning concatenation) and multiplication (meaning repetition) by defining the methods __add__(), __radd__(), __iadd__(), __mul__(), __rmul__() and __imul__() described below; they should not define other numerical operators. It is recommended that both mappings and sequences implement the __contains__() method to allow efficient use of the in operator; for mappings, in should search the mapping's keys; for sequences, it should search through the values. It is further recommended that both mappings and sequences implement the __iter__() method to allow efficient iteration through the container; for mappings, __iter__() should be the same as keys(); for sequences, it should iterate through the values.

object.__len__(self)
>   Called to implement the built-in function len(). Should return the length of the object, an integer >=
>   0. Also, an object that doesn't define a __bool__() method and whose __len__() method returns
>   zero is considered to be false in a Boolean context.
>
>   CPython implementation detail: In CPython, the length is required to be at most sys.maxsize. If the
>   length is larger than sys.maxsize some features (such as len()) may raise OverflowError. To prevent
>   raising OverflowError by truth value testing, an object must define a __bool__() method.

object.__length_hint__(self)
>   Called to implement operator.length_hint(). Should return an estimated length for the object (which
>   may be greater or less than the actual length). The length must be an integer >= 0. This method is
>   purely an optimization and is never required for correctness.
>
>   New in version 3.4.

Note: Slicing is done exclusively with the following three methods. A call like

```
a[1:2] = b
```

is translated to

```
a[slice(1, 2, None)] = b
```

and so forth. Missing slice items are always filled in with None.

---

object.__getitem__(self, key)
>   Called to implement evaluation of self[key]. For sequence types, the accepted keys should be integers
>   and slice objects. Note that the special interpretation of negative indexes (if the class wishes to emulate
>   a sequence type) is up to the __getitem__() method. If key is of an inappropriate type, TypeError
>   may be raised; if of a value outside the set of indexes for the sequence (after any special interpretation
>   of negative values), IndexError should be raised. For mapping types, if key is missing (not in the
>   container), KeyError should be raised.
>
>   ---
>   Note: for loops expect that an IndexError will be raised for illegal indexes to allow proper detection
>   of the end of the sequence.
>   ---

object.__missing__(self, key)
>   Called by dict.__getitem__() to implement self[key] for dict subclasses when key is not in the dic-
>   tionary.

object.__setitem__(self, key, value)
>   Called to implement assignment to self[key]. Same note as for __getitem__(). This should only be
>   implemented for mappings if the objects support changes to the values for keys, or if new keys can be
>   added, or for sequences if elements can be replaced. The same exceptions should be raised for improper
>   key values as for the __getitem__() method.

object.__delitem__(self, key)
>   Called to implement deletion of self[key]. Same note as for __getitem__(). This should only be
>   implemented for mappings if the objects support removal of keys, or for sequences if elements can be
>   removed from the sequence. The same exceptions should be raised for improper key values as for the
>   __getitem__() method.

object.__iter__(self)
>   This method is called when an iterator is required for a container. This method should return a new

---

iterator object that can iterate over all the objects in the container. For mappings, it should iterate over the keys of the container.

Iterator objects also need to implement this method; they are required to return themselves. For more information on iterator objects, see typeiter.

object.__reversed__(self)
   Called (if present) by the reversed() built-in to implement reverse iteration. It should return a new iterator object that iterates over all the objects in the container in reverse order.

   If the __reversed__() method is not provided, the reversed() built-in will fall back to using the sequence protocol (__len__() and __getitem__()). Objects that support the sequence protocol should only provide __reversed__() if they can provide an implementation that is more efficient than the one provided by reversed().

The membership test operators (in and not in) are normally implemented as an iteration through a sequence. However, container objects can supply the following special method with a more efficient implementation, which also does not require the object be a sequence.

object.__contains__(self, item)
   Called to implement membership test operators. Should return true if item is in self, false otherwise. For mapping objects, this should consider the keys of the mapping rather than the values or the key-item pairs.

   For objects that don't define __contains__(), the membership test first tries iteration via __iter__(), then the old sequence iteration protocol via __getitem__(), see this section in the language reference.

3.3.7 Emulating numeric types

The following methods can be defined to emulate numeric objects. Methods corresponding to operations that are not supported by the particular kind of number implemented (e.g., bitwise operations for non-integral numbers) should be left undefined.

object.__add__(self, other)
object.__sub__(self, other)
object.__mul__(self, other)
object.__matmul__(self, other)
object.__truediv__(self, other)
object.__floordiv__(self, other)
object.__mod__(self, other)
object.__divmod__(self, other)
object.__pow__(self, other[, modulo])
object.__lshift__(self, other)
object.__rshift__(self, other)
object.__and__(self, other)
object.__xor__(self, other)
object.__or__(self, other)
   These methods are called to implement the binary arithmetic operations (+, -, *, @, /, //, %, divmod(), pow(), **, <<, >>, &, ^, |). For instance, to evaluate the expression x + y, where x is an instance of a class that has an __add__() method, x.__add__(y) is called. The __divmod__() method should be the equivalent to using __floordiv__() and __mod__(); it should not be related to __truediv__(). Note that __pow__() should be defined to accept an optional third argument if the ternary version of the built-in pow() function is to be supported.

   If one of those methods does not support the operation with the supplied arguments, it should return NotImplemented.

object.__radd__(self, other)
object.__rsub__(self, other)
object.__rmul__(self, other)
object.__rmatmul__(self, other)
object.__rtruediv__(self, other)
object.__rfloordiv__(self, other)
object.__rmod__(self, other)
object.__rdivmod__(self, other)
object.__rpow__(self, other)
object.__rlshift__(self, other)
object.__rrshift__(self, other)
object.__rand__(self, other)
object.__rxor__(self, other)
object.__ror__(self, other)

>These methods are called to implement the binary arithmetic operations (+, -, *, @, /, //, %, divmod(), pow(), **, <<, >>, &, ^, |) with reflected (swapped) operands. These functions are only called if the left operand does not support the corresponding operation[3] and the operands are of different types.[4] For instance, to evaluate the expression x - y, where y is an instance of a class that has an __rsub__() method, y.__rsub__(x) is called if x.__sub__(y) returns NotImplemented.
>
>Note that ternary pow() will not try calling __rpow__() (the coercion rules would become too complicated).

Note: If the right operand's type is a subclass of the left operand's type and that subclass provides the reflected method for the operation, this method will be called before the left operand's non-reflected method. This behavior allows subclasses to override their ancestors' operations.

---

object.__iadd__(self, other)
object.__isub__(self, other)
object.__imul__(self, other)
object.__imatmul__(self, other)
object.__itruediv__(self, other)
object.__ifloordiv__(self, other)
object.__imod__(self, other)
object.__ipow__(self, other[, modulo])
object.__ilshift__(self, other)
object.__irshift__(self, other)
object.__iand__(self, other)
object.__ixor__(self, other)
object.__ior__(self, other)

>These methods are called to implement the augmented arithmetic assignments (+=, -=, *=, @=, /=, //=, %=, **=, <<=, >>=, &=, ^=, |=). These methods should attempt to do the operation in-place (modifying self) and return the result (which could be, but does not have to be, self). If a specific method is not defined, the augmented assignment falls back to the normal methods. For instance, if x is an instance of a class with an __iadd__() method, x += y is equivalent to x = x.__iadd__(y). Otherwise, x.__add__(y) and y.__radd__(x) are considered, as with the evaluation of x + y. In certain situations, augmented assignment can result in unexpected errors (see faq-augmented-assignment-tuple-error), but this behavior is in fact part of the data model.

---

[3] "Does not support" here means that the class has no such method, or the method returns NotImplemented. Do not set the method to None if you want to force fallback to the right operand's reflected method—that will instead have the opposite effect of explicitly blocking such fallback.

[4] For operands of the same type, it is assumed that if the non-reflected method (such as __add__()) fails the operation is not supported, which is why the reflected method is not called.

object.__neg__(self)
object.__pos__(self)
object.__abs__(self)
object.__invert__(self)
    Called to implement the unary arithmetic operations (-, +, abs() and ~).

object.__complex__(self)
object.__int__(self)
object.__float__(self)
object.__round__(self[, n])
    Called to implement the built-in functions complex(), int(), float() and round(). Should return a value
    of the appropriate type.

object.__index__(self)
    Called to implement operator.index(), and whenever Python needs to losslessly convert the numeric
    object to an integer object (such as in slicing, or in the built-in bin(), hex() and oct() functions).
    Presence of this method indicates that the numeric object is an integer type. Must return an integer.

    Note: In order to have a coherent integer type class, when __index__() is defined __int__() should
    also be defined, and both should return the same value.

3.3.8 With Statement Context Managers

A context manager is an object that defines the runtime context to be established when executing a with
statement. The context manager handles the entry into, and the exit from, the desired runtime context
for the execution of the block of code. Context managers are normally invoked using the with statement
(described in section The with statement), but can also be used by directly invoking their methods.

Typical uses of context managers include saving and restoring various kinds of global state, locking and
unlocking resources, closing opened files, etc.

For more information on context managers, see typecontextmanager.

object.__enter__(self)
    Enter the runtime context related to this object. The with statement will bind this method's return
    value to the target(s) specified in the as clause of the statement, if any.

object.__exit__(self, exc_type, exc_value, traceback)
    Exit the runtime context related to this object. The parameters describe the exception that caused
    the context to be exited. If the context was exited without an exception, all three arguments will be
    None.

    If an exception is supplied, and the method wishes to suppress the exception (i.e., prevent it from being
    propagated), it should return a true value. Otherwise, the exception will be processed normally upon
    exit from this method.

    Note that __exit__() methods should not reraise the passed-in exception; this is the caller's respon-
    sibility.

See also:

PEP 343 - The "with" statement The specification, background, and examples for the Python with state-
    ment.

3.3.9 Special method lookup

For custom classes, implicit invocations of special methods are only guaranted to work correctly if defined on an object's type, not in the object's instance dictionary. That behaviour is the reason why the following code raises an exception:

```
>>> class C:
...     pass
...
>>> c = C()
>>> c.__len__ = lambda: 5
>>> len(c)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'C' has no len()
```

The rationale behind this behaviour lies with a number of special methods such as __hash__() and __repr__() that are implemented by all objects, including type objects. If the implicit lookup of these methods used the conventional lookup process, they would fail when invoked on the type object itself:

```
>>> 1 .__hash__() == hash(1)
True
>>> int.__hash__() == hash(int)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor '__hash__' of 'int' object needs an argument
```

Incorrectly attempting to invoke an unbound method of a class in this way is sometimes referred to as 'metaclass confusion', and is avoided by bypassing the instance when looking up special methods:

```
>>> type(1).__hash__(1) == hash(1)
True
>>> type(int).__hash__(int) == hash(int)
True
```

In addition to bypassing any instance attributes in the interest of correctness, implicit special method lookup generally also bypasses the __getattribute__() method even of the object's metaclass:

```
>>> class Meta(type):
...     def __getattribute__(*args):
...         print("Metaclass getattribute invoked")
...         return type.__getattribute__(*args)
...
>>> class C(object, metaclass=Meta):
...     def __len__(self):
...         return 10
...     def __getattribute__(*args):
...         print("Class getattribute invoked")
...         return object.__getattribute__(*args)
...
>>> c = C()
>>> c.__len__()                 # Explicit lookup via instance
Class getattribute invoked
10
>>> type(c).__len__(c)          # Explicit lookup via type
Metaclass getattribute invoked
10
```

```
>>> len(c)                    # Implicit lookup
10
```

Bypassing the __getattribute__() machinery in this fashion provides significant scope for speed optimisations within the interpreter, at the cost of some flexibility in the handling of special methods (the special method must be set on the class object itself in order to be consistently invoked by the interpreter).

3.4 Coroutines

3.4.1 Awaitable Objects

An awaitable object generally implements an __await__() method. Coroutine objects returned from async def functions are awaitable.

Note: The generator iterator objects returned from generators decorated with types.coroutine() or asyncio. coroutine() are also awaitable, but they do not implement __await__().

---

object.__await__(self)
    Must return an iterator. Should be used to implement awaitable objects. For instance, asyncio.Future implements this method to be compatible with the await expression.

New in version 3.5.

See also:

PEP 492 for additional information about awaitable objects.

3.4.2 Coroutine Objects

Coroutine objects are awaitable objects. A coroutine's execution can be controlled by calling __await__() and iterating over the result. When the coroutine has finished executing and returns, the iterator raises StopIteration, and the exception's value attribute holds the return value. If the coroutine raises an exception, it is propagated by the iterator. Coroutines should not directly raise unhandled StopIteration exceptions.

Coroutines also have the methods listed below, which are analogous to those of generators (see Generator-iterator methods). However, unlike generators, coroutines do not directly support iteration.

Changed in version 3.5.2: It is a RuntimeError to await on a coroutine more than once.

coroutine.send(value)
    Starts or resumes execution of the coroutine. If value is None, this is equivalent to advancing the iterator returned by __await__(). If value is not None, this method delegates to the send() method of the iterator that caused the coroutine to suspend. The result (return value, StopIteration, or other exception) is the same as when iterating over the __await__() return value, described above.

coroutine.throw(type[, value[, traceback]])
    Raises the specified exception in the coroutine. This method delegates to the throw() method of the iterator that caused the coroutine to suspend, if it has such a method. Otherwise, the exception is raised at the suspension point. The result (return value, StopIteration, or other exception) is the same as when iterating over the __await__() return value, described above. If the exception is not caught in the coroutine, it propagates back to the caller.

---

coroutine.close()

> Causes the coroutine to clean itself up and exit. If the coroutine is suspended, this method first delegates to the close() method of the iterator that caused the coroutine to suspend, if it has such a method. Then it raises GeneratorExit at the suspension point, causing the coroutine to immediately clean itself up. Finally, the coroutine is marked as having finished executing, even if it was never started.

> Coroutine objects are automatically closed using the above process when they are about to be destroyed.

3.4.3 Asynchronous Iterators

An asynchronous iterable is able to call asynchronous code in its __aiter__ implementation, and an asynchronous iterator can call asynchronous code in its __anext__ method.

Asynchronous iterators can be used in an async for statement.

object.__aiter__(self)

> Must return an asynchronous iterator object.

object.__anext__(self)

> Must return an awaitable resulting in a next value of the iterator. Should raise a StopAsyncIteration error when the iteration is over.

An example of an asynchronous iterable object:

```python
class Reader:
    async def readline(self):
        ...

    def __aiter__(self):
        return self

    async def __anext__(self):
        val = await self.readline()
        if val == b'':
            raise StopAsyncIteration
        return val
```

New in version 3.5.

Note: Changed in version 3.5.2: Starting with CPython 3.5.2, __aiter__ can directly return asynchronous iterators. Returning an awaitable object will result in a PendingDeprecationWarning.

The recommended way of writing backwards compatible code in CPython 3.5.x is to continue returning awaitables from __aiter__. If you want to avoid the PendingDeprecationWarning and keep the code backwards compatible, the following decorator can be used:

```python
import functools
import sys

if sys.version_info < (3, 5, 2):
    def aiter_compat(func):
        @functools.wraps(func)
        async def wrapper(self):
            return func(self)
        return wrapper
else:
```

```
def aiter_compat(func):
    return func
```

Example:

```
class AsyncIterator:

    @aiter_compat
    def __aiter__(self):
        return self

    async def __anext__(self):
        ...
```

Starting with CPython 3.6, the PendingDeprecationWarning will be replaced with the DeprecationWarning. In CPython 3.7, returning an awaitable from __aiter__ will result in a RuntimeError.

3.4.4 Asynchronous Context Managers

An asynchronous context manager is a context manager that is able to suspend execution in its __aenter__ and __aexit__ methods.

Asynchronous context managers can be used in an async with statement.

object.__aenter__(self)
    This method is semantically similar to the __enter__(), with only difference that it must return an awaitable.

object.__aexit__(self, exc_type, exc_value, traceback)
    This method is semantically similar to the __exit__(), with only difference that it must return an awaitable.

An example of an asynchronous context manager class:

```
class AsyncContextManager:
    async def __aenter__(self):
        await log('entering context')

    async def __aexit__(self, exc_type, exc, tb):
        await log('exiting context')
```

New in version 3.5.

EXECUTION MODEL

4.1 Structure of a program

A Python program is constructed from code blocks. A block is a piece of Python program text that is executed as a unit. The following are blocks: a module, a function body, and a class definition. Each command typed interactively is a block. A script file (a file given as standard input to the interpreter or specified as a command line argument to the interpreter) is a code block. A script command (a command specified on the interpreter command line with the '-c' option) is a code block. The string argument passed to the built-in functions eval() and exec() is a code block.

A code block is executed in an execution frame. A frame contains some administrative information (used for debugging) and determines where and how execution continues after the code block's execution has completed.

4.2 Naming and binding

4.2.1 Binding of names

Names refer to objects. Names are introduced by name binding operations.

The following constructs bind names: formal parameters to functions, import statements, class and function definitions (these bind the class or function name in the defining block), and targets that are identifiers if occurring in an assignment, for loop header, or after as in a with statement or except clause. The import statement of the form from ... import * binds all names defined in the imported module, except those beginning with an underscore. This form may only be used at the module level.

A target occurring in a del statement is also considered bound for this purpose (though the actual semantics are to unbind the name).

Each assignment or import statement occurs within a block defined by a class or function definition or at the module level (the top-level code block).

If a name is bound in a block, it is a local variable of that block, unless declared as nonlocal or global. If a name is bound at the module level, it is a global variable. (The variables of the module code block are local and global.) If a variable is used in a code block but not defined there, it is a free variable.

Each occurrence of a name in the program text refers to the binding of that name established by the following name resolution rules.

4.2.2 Resolution of names

A scope defines the visibility of a name within a block. If a local variable is defined in a block, its scope includes that block. If the definition occurs in a function block, the scope extends to any blocks contained within the defining one, unless a contained block introduces a different binding for the name.

When a name is used in a code block, it is resolved using the nearest enclosing scope. The set of all such scopes visible to a code block is called the block's environment.

When a name is not found at all, a NameError exception is raised. If the current scope is a function scope, and the name refers to a local variable that has not yet been bound to a value at the point where the name is used, an UnboundLocalError exception is raised. UnboundLocalError is a subclass of NameError.

If a name binding operation occurs anywhere within a code block, all uses of the name within the block are treated as references to the current block. This can lead to errors when a name is used within a block before it is bound. This rule is subtle. Python lacks declarations and allows name binding operations to occur anywhere within a code block. The local variables of a code block can be determined by scanning the entire text of the block for name binding operations.

If the global statement occurs within a block, all uses of the name specified in the statement refer to the binding of that name in the top-level namespace. Names are resolved in the top-level namespace by searching the global namespace, i.e. the namespace of the module containing the code block, and the builtins namespace, the namespace of the module builtins. The global namespace is searched first. If the name is not found there, the builtins namespace is searched. The global statement must precede all uses of the name.

The global statement has the same scope as a name binding operation in the same block. If the nearest enclosing scope for a free variable contains a global statement, the free variable is treated as a global.

The nonlocal statement causes corresponding names to refer to previously bound variables in the nearest enclosing function scope. SyntaxError is raised at compile time if the given name does not exist in any enclosing function scope.

The namespace for a module is automatically created the first time a module is imported. The main module for a script is always called __main__.

Class definition blocks and arguments to exec() and eval() are special in the context of name resolution. A class definition is an executable statement that may use and define names. These references follow the normal rules for name resolution with an exception that unbound local variables are looked up in the global namespace. The namespace of the class definition becomes the attribute dictionary of the class. The scope of names defined in a class block is limited to the class block; it does not extend to the code blocks of methods – this includes comprehensions and generator expressions since they are implemented using a function scope. This means that the following will fail:

```python
class A:
    a = 42
    b = list(a + i for i in range(10))
```

4.2.3 Builtins and restricted execution

CPython implementation detail: Users should not touch __builtins__; it is strictly an implementation detail. Users wanting to override values in the builtins namespace should import the builtins module and modify its attributes appropriately.

The builtins namespace associated with the execution of a code block is actually found by looking up the name __builtins__ in its global namespace; this should be a dictionary or a module (in the latter case the module's dictionary is used). By default, when in the __main__ module, __builtins__ is the built-in

module builtins; when in any other module, __builtins__ is an alias for the dictionary of the builtins module itself.

4.2.4 Interaction with dynamic features

Name resolution of free variables occurs at runtime, not at compile time. This means that the following code will print 42:

```
i = 10
def f():
    print(i)
i = 42
f()
```

The eval() and exec() functions do not have access to the full environment for resolving names. Names may be resolved in the local and global namespaces of the caller. Free variables are not resolved in the nearest enclosing namespace, but in the global namespace.[1] The exec() and eval() functions have optional arguments to override the global and local namespace. If only one namespace is specified, it is used for both.

4.3 Exceptions

Exceptions are a means of breaking out of the normal flow of control of a code block in order to handle errors or other exceptional conditions. An exception is raised at the point where the error is detected; it may be handled by the surrounding code block or by any code block that directly or indirectly invoked the code block where the error occurred.

The Python interpreter raises an exception when it detects a run-time error (such as division by zero). A Python program can also explicitly raise an exception with the raise statement. Exception handlers are specified with the try ... except statement. The finally clause of such a statement can be used to specify cleanup code which does not handle the exception, but is executed whether an exception occurred or not in the preceding code.

Python uses the "termination" model of error handling: an exception handler can find out what happened and continue execution at an outer level, but it cannot repair the cause of the error and retry the failing operation (except by re-entering the offending piece of code from the top).

When an exception is not handled at all, the interpreter terminates execution of the program, or returns to its interactive main loop. In either case, it prints a stack backtrace, except when the exception is SystemExit.

Exceptions are identified by class instances. The except clause is selected depending on the class of the instance: it must reference the class of the instance or a base class thereof. The instance can be received by the handler and can carry additional information about the exceptional condition.

Note: Exception messages are not part of the Python API. Their contents may change from one version of Python to the next without warning and should not be relied on by code which will run under multiple versions of the interpreter.

See also the description of the try statement in section The try statement and raise statement in section The raise statement.

---

[1] This limitation occurs because the code that is executed by these operations is not available at the time the module is compiled.

THE IMPORT SYSTEM

Python code in one module gains access to the code in another module by the process of importing it. The import statement is the most common way of invoking the import machinery, but it is not the only way. Functions such as importlib.import_module() and built-in __import__() can also be used to invoke the import machinery.

The import statement combines two operations; it searches for the named module, then it binds the results of that search to a name in the local scope. The search operation of the import statement is defined as a call to the __import__() function, with the appropriate arguments. The return value of __import__() is used to perform the name binding operation of the import statement. See the import statement for the exact details of that name binding operation.

A direct call to __import__() performs only the module search and, if found, the module creation operation. While certain side-effects may occur, such as the importing of parent packages, and the updating of various caches (including sys.modules), only the import statement performs a name binding operation.

When calling __import__() as part of an import statement, the standard builtin __import__() is called. Other mechanisms for invoking the import system (such as importlib.import_module()) may choose to subvert __import__() and use its own solution to implement import semantics.

When a module is first imported, Python searches for the module and if found, it creates a module object[1], initializing it. If the named module cannot be found, a ModuleNotFoundError is raised. Python implements various strategies to search for the named module when the import machinery is invoked. These strategies can be modified and extended by using various hooks described in the sections below.

Changed in version 3.3: The import system has been updated to fully implement the second phase of PEP 302. There is no longer any implicit import machinery - the full import system is exposed through sys.meta_path. In addition, native namespace package support has been implemented (see PEP 420).

5.1 importlib

The importlib module provides a rich API for interacting with the import system. For example importlib.import_module() provides a recommended, simpler API than built-in __import__() for invoking the import machinery. Refer to the importlib library documentation for additional detail.

5.2 Packages

Python has only one type of module object, and all modules are of this type, regardless of whether the module is implemented in Python, C, or something else. To help organize modules and provide a naming hierarchy, Python has a concept of packages.

---

[1] See types.ModuleType.

You can think of packages as the directories on a file system and modules as files within directories, but don't take this analogy too literally since packages and modules need not originate from the file system. For the purposes of this documentation, we'll use this convenient analogy of directories and files. Like file system directories, packages are organized hierarchically, and packages may themselves contain subpackages, as well as regular modules.

It's important to keep in mind that all packages are modules, but not all modules are packages. Or put another way, packages are just a special kind of module. Specifically, any module that contains a __path__ attribute is considered a package.

All modules have a name. Subpackage names are separated from their parent package name by dots, akin to Python's standard attribute access syntax. Thus you might have a module called sys and a package called email, which in turn has a subpackage called email.mime and a module within that subpackage called email.mime.text.

5.2.1 Regular packages

Python defines two types of packages, regular packages and namespace packages. Regular packages are traditional packages as they existed in Python 3.2 and earlier. A regular package is typically implemented as a directory containing an __init__.py file. When a regular package is imported, this __init__.py file is implicitly executed, and the objects it defines are bound to names in the package's namespace. The __init__.py file can contain the same Python code that any other module can contain, and Python will add some additional attributes to the module when it is imported.

For example, the following file system layout defines a top level parent package with three subpackages:

```
parent/
    __init__.py
    one/
        __init__.py
    two/
        __init__.py
    three/
        __init__.py
```

Importing parent.one will implicitly execute parent/__init__.py and parent/one/__init__.py. Subsequent imports of parent.two or parent.three will execute parent/two/__init__.py and parent/three/__init__.py respectively.

5.2.2 Namespace packages

A namespace package is a composite of various portions, where each portion contributes a subpackage to the parent package. Portions may reside in different locations on the file system. Portions may also be found in zip files, on the network, or anywhere else that Python searches during import. Namespace packages may or may not correspond directly to objects on the file system; they may be virtual modules that have no concrete representation.

Namespace packages do not use an ordinary list for their __path__ attribute. They instead use a custom iterable type which will automatically perform a new search for package portions on the next import attempt within that package if the path of their parent package (or sys.path for a top level package) changes.

With namespace packages, there is no parent/__init__.py file. In fact, there may be multiple parent directories found during import search, where each one is provided by a different portion. Thus parent/one may not be physically located next to parent/two. In this case, Python will create a namespace package for the top-level parent package whenever it or one of its subpackages is imported.

See also PEP 420 for the namespace package specification.

5.3 Searching

To begin the search, Python needs the fully qualified name of the module (or package, but for the purposes of this discussion, the difference is immaterial) being imported. This name may come from various arguments to the import statement, or from the parameters to the importlib.import_module() or __import__() functions.

This name will be used in various phases of the import search, and it may be the dotted path to a submodule, e.g. foo.bar.baz. In this case, Python first tries to import foo, then foo.bar, and finally foo.bar.baz. If any of the intermediate imports fail, a ModuleNotFoundError is raised.

5.3.1 The module cache

The first place checked during import search is sys.modules. This mapping serves as a cache of all modules that have been previously imported, including the intermediate paths. So if foo.bar.baz was previously imported, sys.modules will contain entries for foo, foo.bar, and foo.bar.baz. Each key will have as its value the corresponding module object.

During import, the module name is looked up in sys.modules and if present, the associated value is the module satisfying the import, and the process completes. However, if the value is None, then a ModuleNotFoundError is raised. If the module name is missing, Python will continue searching for the module.

sys.modules is writable. Deleting a key may not destroy the associated module (as other modules may hold references to it), but it will invalidate the cache entry for the named module, causing Python to search anew for the named module upon its next import. The key can also be assigned to None, forcing the next import of the module to result in a ModuleNotFoundError.

Beware though, as if you keep a reference to the module object, invalidate its cache entry in sys.modules, and then re-import the named module, the two module objects will not be the same. By contrast, importlib. reload() will reuse the same module object, and simply reinitialise the module contents by rerunning the module's code.

5.3.2 Finders and loaders

If the named module is not found in sys.modules, then Python's import protocol is invoked to find and load the module. This protocol consists of two conceptual objects, finders and loaders. A finder's job is to determine whether it can find the named module using whatever strategy it knows about. Objects that implement both of these interfaces are referred to as importers - they return themselves when they find that they can load the requested module.

Python includes a number of default finders and importers. The first one knows how to locate built-in modules, and the second knows how to locate frozen modules. A third default finder searches an import path for modules. The import path is a list of locations that may name file system paths or zip files. It can also be extended to search for any locatable resource, such as those identified by URLs.

The import machinery is extensible, so new finders can be added to extend the range and scope of module searching.

Finders do not actually load modules. If they can find the named module, they return a module spec, an encapsulation of the module's import-related information, which the import machinery then uses when loading the module.

The following sections describe the protocol for finders and loaders in more detail, including how you can create and register new ones to extend the import machinery.

Changed in version 3.4: In previous versions of Python, finders returned loaders directly, whereas now they return module specs which contain loaders. Loaders are still used during import but have fewer responsibilities.

5.3.3 Import hooks

The import machinery is designed to be extensible; the primary mechanism for this are the import hooks. There are two types of import hooks: meta hooks and import path hooks.

Meta hooks are called at the start of import processing, before any other import processing has occurred, other than sys.modules cache look up. This allows meta hooks to override sys.path processing, frozen modules, or even built-in modules. Meta hooks are registered by adding new finder objects to sys.meta_path, as described below.

Import path hooks are called as part of sys.path (or package.__path__) processing, at the point where their associated path item is encountered. Import path hooks are registered by adding new callables to sys.path_hooks as described below.

5.3.4 The meta path

When the named module is not found in sys.modules, Python next searches sys.meta_path, which contains a list of meta path finder objects. These finders are queried in order to see if they know how to handle the named module. Meta path finders must implement a method called find_spec() which takes three arguments: a name, an import path, and (optionally) a target module. The meta path finder can use any strategy it wants to determine whether it can handle the named module or not.

If the meta path finder knows how to handle the named module, it returns a spec object. If it cannot handle the named module, it returns None. If sys.meta_path processing reaches the end of its list without returning a spec, then a ModuleNotFoundError is raised. Any other exceptions raised are simply propagated up, aborting the import process.

The find_spec() method of meta path finders is called with two or three arguments. The first is the fully qualified name of the module being imported, for example foo.bar.baz. The second argument is the path entries to use for the module search. For top-level modules, the second argument is None, but for submodules or subpackages, the second argument is the value of the parent package's __path__ attribute. If the appropriate __path__ attribute cannot be accessed, a ModuleNotFoundError is raised. The third argument is an existing module object that will be the target of loading later. The import system passes in a target module only during reload.

The meta path may be traversed multiple times for a single import request. For example, assuming none of the modules involved has already been cached, importing foo.bar.baz will first perform a top level import, calling mpf.find_spec("foo", None, None) on each meta path finder (mpf). After foo has been imported, foo.bar will be imported by traversing the meta path a second time, calling mpf.find_spec("foo.bar", foo.__path__, None). Once foo.bar has been imported, the final traversal will call mpf.find_spec("foo.bar.baz", foo.bar.__path__, None).

Some meta path finders only support top level imports. These importers will always return None when anything other than None is passed as the second argument.

Python's default sys.meta_path has three meta path finders, one that knows how to import built-in modules, one that knows how to import frozen modules, and one that knows how to import modules from an import path (i.e. the path based finder).

Changed in version 3.4: The find_spec() method of meta path finders replaced find_module(), which is now deprecated. While it will continue to work without change, the import machinery will try it only if the finder does not implement find_spec().

5.4 Loading

If and when a module spec is found, the import machinery will use it (and the loader it contains) when loading the module. Here is an approximation of what happens during the loading portion of import:

```python
module = None
if spec.loader is not None and hasattr(spec.loader, 'create_module'):
    # It is assumed 'exec_module' will also be defined on the loader.
    module = spec.loader.create_module(spec)
if module is None:
    module = ModuleType(spec.name)
# The import-related module attributes get set here:
_init_module_attrs(spec, module)

if spec.loader is None:
    if spec.submodule_search_locations is not None:
        # namespace package
        sys.modules[spec.name] = module
    else:
        # unsupported
        raise ImportError
elif not hasattr(spec.loader, 'exec_module'):
    module = spec.loader.load_module(spec.name)
    # Set __loader__ and __package__ if missing.
else:
    sys.modules[spec.name] = module
    try:
        spec.loader.exec_module(module)
    except BaseException:
        try:
            del sys.modules[spec.name]
        except KeyError:
            pass
        raise
return sys.modules[spec.name]
```

Note the following details:

- If there is an existing module object with the given name in sys.modules, import will have already returned it.

- The module will exist in sys.modules before the loader executes the module code. This is crucial because the module code may (directly or indirectly) import itself; adding it to sys.modules beforehand prevents unbounded recursion in the worst case and multiple loading in the best.

- If loading fails, the failing module – and only the failing module – gets removed from sys.modules. Any module already in the sys.modules cache, and any module that was successfully loaded as a side-effect, must remain in the cache. This contrasts with reloading where even the failing module is left in sys.modules.

- After the module is created but before execution, the import machinery sets the import-related module attributes ("_init_module_attrs" in the pseudo-code example above), as summarized in a later section.

- Module execution is the key moment of loading in which the module's namespace gets populated. Execution is entirely delegated to the loader, which gets to decide what gets populated and how.

- The module created during loading and passed to exec_module() may not be the one returned at the end of import[2].

Changed in version 3.4: The import system has taken over the boilerplate responsibilities of loaders. These were previously performed by the importlib.abc.Loader.load_module() method.

5.4.1 Loaders

Module loaders provide the critical function of loading: module execution. The import machinery calls the importlib.abc.Loader.exec_module() method with a single argument, the module object to execute. Any value returned from exec_module() is ignored.

Loaders must satisfy the following requirements:

- If the module is a Python module (as opposed to a built-in module or a dynamically loaded extension), the loader should execute the module's code in the module's global name space (module.__dict__).

- If the loader cannot execute the module, it should raise an ImportError, although any other exception raised during exec_module() will be propagated.

In many cases, the finder and loader can be the same object; in such cases the find_spec() method would just return a spec with the loader set to self.

Module loaders may opt in to creating the module object during loading by implementing a create_module() method. It takes one argument, the module spec, and returns the new module object to use during loading. create_module() does not need to set any attributes on the module object. If the method returns None, the import machinery will create the new module itself.

New in version 3.4: The create_module() method of loaders.

Changed in version 3.4: The load_module() method was replaced by exec_module() and the import machinery assumed all the boilerplate responsibilities of loading.

For compatibility with existing loaders, the import machinery will use the load_module() method of loaders if it exists and the loader does not also implement exec_module(). However, load_module() has been deprecated and loaders should implement exec_module() instead.

The load_module() method must implement all the boilerplate loading functionality described above in addition to executing the module. All the same constraints apply, with some additional clarification:

- If there is an existing module object with the given name in sys.modules, the loader must use that existing module. (Otherwise, importlib.reload() will not work correctly.) If the named module does not exist in sys.modules, the loader must create a new module object and add it to sys.modules.

- The module must exist in sys.modules before the loader executes the module code, to prevent unbounded recursion or multiple loading.

- If loading fails, the loader must remove any modules it has inserted into sys.modules, but it must remove only the failing module(s), and only if the loader itself has loaded the module(s) explicitly.

Changed in version 3.5: A DeprecationWarning is raised when exec_module() is defined but create_module() is not.

Changed in version 3.6: An ImportError is raised when exec_module() is defined but create_module() is not.

---

[2] The importlib implementation avoids using the return value directly. Instead, it gets the module object by looking the module name up in sys.modules. The indirect effect of this is that an imported module may replace itself in sys.modules. This is implementation-specific behavior that is not guaranteed to work in other Python implementations.

5.4.2 Submodules

When a submodule is loaded using any mechanism (e.g. importlib APIs, the import or import-from statements, or built-in __import__()) a binding is placed in the parent module's namespace to the submodule object. For example, if package spam has a submodule foo, after importing spam.foo, spam will have an attribute foo which is bound to the submodule. Let's say you have the following directory structure:

```
spam/
    __init__.py
    foo.py
    bar.py
```

and spam/__init__.py has the following lines in it:

```
from .foo import Foo
from .bar import Bar
```

then executing the following puts a name binding to foo and bar in the spam module:

```
>>> import spam
>>> spam.foo
<module 'spam.foo' from '/tmp/imports/spam/foo.py'>
>>> spam.bar
<module 'spam.bar' from '/tmp/imports/spam/bar.py'>
```

Given Python's familiar name binding rules this might seem surprising, but it's actually a fundamental feature of the import system. The invariant holding is that if you have sys.modules['spam'] and sys.modules['spam.foo'] (as you would after the above import), the latter must appear as the foo attribute of the former.

5.4.3 Module spec

The import machinery uses a variety of information about each module during import, especially before loading. Most of the information is common to all modules. The purpose of a module's spec is to encapsulate this import-related information on a per-module basis.

Using a spec during import allows state to be transferred between import system components, e.g. between the finder that creates the module spec and the loader that executes it. Most importantly, it allows the import machinery to perform the boilerplate operations of loading, whereas without a module spec the loader had that responsibility.

See ModuleSpec for more specifics on what information a module's spec may hold.

New in version 3.4.

5.4.4 Import-related module attributes

The import machinery fills in these attributes on each module object during loading, based on the module's spec, before the loader executes the module.

__name__
> The __name__ attribute must be set to the fully-qualified name of the module. This name is used to uniquely identify the module in the import system.

__loader__
> The __loader__ attribute must be set to the loader object that the import machinery used when

loading the module. This is mostly for introspection, but can be used for additional loader-specific functionality, for example getting data associated with a loader.

__package__

The module's __package__ attribute must be set. Its value must be a string, but it can be the same value as its __name__. When the module is a package, its __package__ value should be set to its __name__. When the module is not a package, __package__ should be set to the empty string for top-level modules, or for submodules, to the parent package's name. See PEP 366 for further details.

This attribute is used instead of __name__ to calculate explicit relative imports for main modules, as defined in PEP 366. It is expected to have the same value as __spec__.parent.

Changed in version 3.6: The value of __package__ is expected to be the same as __spec__.parent.

__spec__

The __spec__ attribute must be set to the module spec that was used when importing the module. Setting __spec__ appropriately applies equally to modules initialized during interpreter startup. The one exception is __main__, where __spec__ is set to None in some cases.

When __package__ is not defined, __spec__.parent is used as a fallback.

New in version 3.4.

Changed in version 3.6: __spec__.parent is used as a fallback when __package__ is not defined.

__path__

If the module is a package (either regular or namespace), the module object's __path__ attribute must be set. The value must be iterable, but may be empty if __path__ has no further significance. If __path__ is not empty, it must produce strings when iterated over. More details on the semantics of __path__ are given below.

Non-package modules should not have a __path__ attribute.

__file__

__cached__

__file__ is optional. If set, this attribute's value must be a string. The import system may opt to leave __file__ unset if it has no semantic meaning (e.g. a module loaded from a database).

If __file__ is set, it may also be appropriate to set the __cached__ attribute which is the path to any compiled version of the code (e.g. byte-compiled file). The file does not need to exist to set this attribute; the path can simply point to where the compiled file would exist (see PEP 3147).

It is also appropriate to set __cached__ when __file__ is not set. However, that scenario is quite atypical. Ultimately, the loader is what makes use of __file__ and/or __cached__. So if a loader can load from a cached module but otherwise does not load from a file, that atypical scenario may be appropriate.

5.4.5 module.__path__

By definition, if a module has a __path__ attribute, it is a package, regardless of its value.

A package's __path__ attribute is used during imports of its subpackages. Within the import machinery, it functions much the same as sys.path, i.e. providing a list of locations to search for modules during import. However, __path__ is typically much more constrained than sys.path.

__path__ must be an iterable of strings, but it may be empty. The same rules used for sys.path also apply to a package's __path__, and sys.path_hooks (described below) are consulted when traversing a package's __path__.

A package's __init__.py file may set or alter the package's __path__ attribute, and this was typically the way namespace packages were implemented prior to PEP 420. With the adoption of PEP 420, namespace packages no longer need to supply __init__.py files containing only __path__ manipulation code; the import machinery automatically sets __path__ correctly for the namespace package.

5.4.6 Module reprs

By default, all modules have a usable repr, however depending on the attributes set above, and in the module's spec, you can more explicitly control the repr of module objects.

If the module has a spec (__spec__), the import machinery will try to generate a repr from it. If that fails or there is no spec, the import system will craft a default repr using whatever information is available on the module. It will try to use the module.__name__, module.__file__, and module.__loader__ as input into the repr, with defaults for whatever information is missing.

Here are the exact rules used:

- If the module has a __spec__ attribute, the information in the spec is used to generate the repr. The "name", "loader", "origin", and "has_location" attributes are consulted.

- If the module has a __file__ attribute, this is used as part of the module's repr.

- If the module has no __file__ but does have a __loader__ that is not None, then the loader's repr is used as part of the module's repr.

- Otherwise, just use the module's __name__ in the repr.

Changed in version 3.4: Use of loader.module_repr() has been deprecated and the module spec is now used by the import machinery to generate a module repr.

For backward compatibility with Python 3.3, the module repr will be generated by calling the loader's module_repr() method, if defined, before trying either approach described above. However, the method is deprecated.

5.5 The Path Based Finder

As mentioned previously, Python comes with several default meta path finders. One of these, called the path based finder (PathFinder), searches an import path, which contains a list of path entries. Each path entry names a location to search for modules.

The path based finder itself doesn't know how to import anything. Instead, it traverses the individual path entries, associating each of them with a path entry finder that knows how to handle that particular kind of path.

The default set of path entry finders implement all the semantics for finding modules on the file system, handling special file types such as Python source code (.py files), Python byte code (.pyc files) and shared libraries (e.g. .so files). When supported by the zipimport module in the standard library, the default path entry finders also handle loading all of these file types (other than shared libraries) from zipfiles.

Path entries need not be limited to file system locations. They can refer to URLs, database queries, or any other location that can be specified as a string.

The path based finder provides additional hooks and protocols so that you can extend and customize the types of searchable path entries. For example, if you wanted to support path entries as network URLs, you could write a hook that implements HTTP semantics to find modules on the web. This hook (a callable) would return a path entry finder supporting the protocol described below, which was then used to get a loader for the module from the web.

A word of warning: this section and the previous both use the term finder, distinguishing between them by using the terms meta path finder and path entry finder. These two types of finders are very similar, support similar protocols, and function in similar ways during the import process, but it's important to keep in mind that they are subtly different. In particular, meta path finders operate at the beginning of the import process, as keyed off the sys.meta_path traversal.

By contrast, path entry finders are in a sense an implementation detail of the path based finder, and in fact, if the path based finder were to be removed from sys.meta_path, none of the path entry finder semantics would be invoked.

5.5.1 Path entry finders

The path based finder is responsible for finding and loading Python modules and packages whose location is specified with a string path entry. Most path entries name locations in the file system, but they need not be limited to this.

As a meta path finder, the path based finder implements the find_spec() protocol previously described, however it exposes additional hooks that can be used to customize how modules are found and loaded from the import path.

Three variables are used by the path based finder, sys.path, sys.path_hooks and sys.path_importer_cache. The __path__ attributes on package objects are also used. These provide additional ways that the import machinery can be customized.

sys.path contains a list of strings providing search locations for modules and packages. It is initialized from the PYTHONPATH environment variable and various other installation- and implementation-specific defaults. Entries in sys.path can name directories on the file system, zip files, and potentially other "locations" (see the site module) that should be searched for modules, such as URLs, or database queries. Only strings and bytes should be present on sys.path; all other data types are ignored. The encoding of bytes entries is determined by the individual path entry finders.

The path based finder is a meta path finder, so the import machinery begins the import path search by calling the path based finder's find_spec() method as described previously. When the path argument to find_spec() is given, it will be a list of string paths to traverse - typically a package's __path__ attribute for an import within that package. If the path argument is None, this indicates a top level import and sys.path is used.

The path based finder iterates over every entry in the search path, and for each of these, looks for an appropriate path entry finder (PathEntryFinder) for the path entry. Because this can be an expensive operation (e.g. there may be stat() call overheads for this search), the path based finder maintains a cache mapping path entries to path entry finders. This cache is maintained in sys.path_importer_cache (despite the name, this cache actually stores finder objects rather than being limited to importer objects). In this way, the expensive search for a particular path entry location's path entry finder need only be done once. User code is free to remove cache entries from sys.path_importer_cache forcing the path based finder to perform the path entry search again[3].

If the path entry is not present in the cache, the path based finder iterates over every callable in sys.path_hooks. Each of the path entry hooks in this list is called with a single argument, the path entry to be searched. This callable may either return a path entry finder that can handle the path entry, or it may raise ImportError. An ImportError is used by the path based finder to signal that the hook cannot find a path entry finder for that path entry. The exception is ignored and import path iteration continues. The hook should expect either a string or bytes object; the encoding of bytes objects is up to the hook (e.g. it may be a file system encoding, UTF-8, or something else), and if the hook cannot decode the argument, it should raise ImportError.

---

[3] In legacy code, it is possible to find instances of imp.NullImporter in the sys.path_importer_cache. It is recommended that code be changed to use None instead. See portingpythoncode for more details.

If sys.path_hooks iteration ends with no path entry finder being returned, then the path based finder's find_spec() method will store None in sys.path_importer_cache (to indicate that there is no finder for this path entry) and return None, indicating that this meta path finder could not find the module.

If a path entry finder is returned by one of the path entry hook callables on sys.path_hooks, then the following protocol is used to ask the finder for a module spec, which is then used when loading the module.

The current working directory – denoted by an empty string – is handled slightly differently from other entries on sys.path. First, if the current working directory is found to not exist, no value is stored in sys.path_importer_cache. Second, the value for the current working directory is looked up fresh for each module lookup. Third, the path used for sys.path_importer_cache and returned by importlib.machinery. PathFinder.find_spec() will be the actual current working directory and not the empty string.

5.5.2 Path entry finder protocol

In order to support imports of modules and initialized packages and also to contribute portions to namespace packages, path entry finders must implement the find_spec() method.

find_spec() takes two argument, the fully qualified name of the module being imported, and the (optional) target module. find_spec() returns a fully populated spec for the module. This spec will always have "loader" set (with one exception).

To indicate to the import machinery that the spec represents a namespace portion. the path entry finder sets "loader" on the spec to None and "submodule_search_locations" to a list containing the portion.

Changed in version 3.4: find_spec() replaced find_loader() and find_module(), both of which are now deprecated, but will be used if find_spec() is not defined.

Older path entry finders may implement one of these two deprecated methods instead of find_spec(). The methods are still respected for the sake of backward compatibility. However, if find_spec() is implemented on the path entry finder, the legacy methods are ignored.

find_loader() takes one argument, the fully qualified name of the module being imported. find_loader() returns a 2-tuple where the first item is the loader and the second item is a namespace portion. When the first item (i.e. the loader) is None, this means that while the path entry finder does not have a loader for the named module, it knows that the path entry contributes to a namespace portion for the named module. This will almost always be the case where Python is asked to import a namespace package that has no physical presence on the file system. When a path entry finder returns None for the loader, the second item of the 2-tuple return value must be a sequence, although it can be empty.

If find_loader() returns a non-None loader value, the portion is ignored and the loader is returned from the path based finder, terminating the search through the path entries.

For backwards compatibility with other implementations of the import protocol, many path entry finders also support the same, traditional find_module() method that meta path finders support. However path entry finder find_module() methods are never called with a path argument (they are expected to record the appropriate path information from the initial call to the path hook).

The find_module() method on path entry finders is deprecated, as it does not allow the path entry finder to contribute portions to namespace packages. If both find_loader() and find_module() exist on a path entry finder, the import system will always call find_loader() in preference to find_module().

5.6 Replacing the standard import system

The most reliable mechanism for replacing the entire import system is to delete the default contents of sys.meta_path, replacing them entirely with a custom meta path hook.

If it is acceptable to only alter the behaviour of import statements without affecting other APIs that access the import system, then replacing the builtin __import__() function may be sufficient. This technique may also be employed at the module level to only alter the behaviour of import statements within that module.

To selectively prevent import of some modules from a hook early on the meta path (rather than disabling the standard import system entirely), it is sufficient to raise ModuleNotFoundError directly from find_spec() instead of returning None. The latter indicates that the meta path search should continue, while raising an exception terminates it immediately.

5.7 Special considerations for __main__

The __main__ module is a special case relative to Python's import system. As noted elsewhere, the __main__ module is directly initialized at interpreter startup, much like sys and builtins. However, unlike those two, it doesn't strictly qualify as a built-in module. This is because the manner in which __main__ is initialized depends on the flags and other options with which the interpreter is invoked.

5.7.1 __main__.__spec__

Depending on how __main__ is initialized, __main__.__spec__ gets set appropriately or to None.

When Python is started with the -m option, __spec__ is set to the module spec of the corresponding module or package. __spec__ is also populated when the __main__ module is loaded as part of executing a directory, zipfile or other sys.path entry.

In the remaining cases __main__.__spec__ is set to None, as the code used to populate the __main__ does not correspond directly with an importable module:

- interactive prompt
- -c switch
- running from stdin
- running directly from a source or bytecode file

Note that __main__.__spec__ is always None in the last case, even if the file could technically be imported directly as a module instead. Use the -m switch if valid module metadata is desired in __main__.

Note also that even when __main__ corresponds with an importable module and __main__.__spec__ is set accordingly, they're still considered distinct modules. This is due to the fact that blocks guarded by if __name__ == "__main__": checks only execute when the module is used to populate the __main__ namespace, and not during normal import.

5.8 Open issues

XXX It would be really nice to have a diagram.

XXX * (import_machinery.rst) how about a section devoted just to the attributes of modules and packages, perhaps expanding upon or supplanting the related entries in the data model reference page?

XXX runpy, pkgutil, et al in the library manual should all get "See Also" links at the top pointing to the new import system section.

XXX Add more explanation regarding the different ways in which __main__ is initialized?

XXX Add more info on _ _main_ _ quirks/pitfalls (i.e. copy from PEP 395).

5.9 References

The import machinery has evolved considerably since Python's early days. The original specification for packages is still available to read, although some details have changed since the writing of that document.

The original specification for sys.meta_path was PEP 302, with subsequent extension in PEP 420.

PEP 420 introduced namespace packages for Python 3.3. PEP 420 also introduced the find_loader() protocol as an alternative to find_module().

PEP 366 describes the addition of the _ _package_ _ attribute for explicit relative imports in main modules.

PEP 328 introduced absolute and explicit relative imports and initially proposed _ _name_ _ for semantics PEP 366 would eventually specify for _ _package_ _.

PEP 338 defines executing modules as scripts.

PEP 451 adds the encapsulation of per-module import state in spec objects. It also off-loads most of the boilerplate responsibilities of loaders back onto the import machinery. These changes allow the deprecation of several APIs in the import system and also addition of new methods to finders and loaders.

EXPRESSIONS

This chapter explains the meaning of the elements of expressions in Python.

Syntax Notes: In this and the following chapters, extended BNF notation will be used to describe syntax, not lexical analysis. When (one alternative of) a syntax rule has the form

  name   ::=   othername

and no semantics are given, the semantics of this form of name are the same as for othername.

6.1 Arithmetic conversions

When a description of an arithmetic operator below uses the phrase "the numeric arguments are converted to a common type," this means that the operator implementation for built-in types works as follows:

- If either argument is a complex number, the other is converted to complex;

- otherwise, if either argument is a floating point number, the other is converted to floating point;

- otherwise, both must be integers and no conversion is necessary.

Some additional rules apply for certain operators (e.g., a string as a left argument to the '%' operator). Extensions must define their own conversion behavior.

6.2 Atoms

Atoms are the most basic elements of expressions. The simplest atoms are identifiers or literals. Forms enclosed in parentheses, brackets or braces are also categorized syntactically as atoms. The syntax for atoms is:

```
atom        ::=    identifier | literal | enclosure
enclosure   ::=    parenth_form | list_display | dict_display | set_display
                   | generator_expression | yield_atom
```

6.2.1 Identifiers (Names)

An identifier occurring as an atom is a name. See section Identifiers and keywords for lexical definition and section Naming and binding for documentation of naming and binding.

When the name is bound to an object, evaluation of the atom yields that object. When a name is not bound, an attempt to evaluate it raises a NameError exception.

Private name mangling: When an identifier that textually occurs in a class definition begins with two or more underscore characters and does not end in two or more underscores, it is considered a private name of that class. Private names are transformed to a longer form before code is generated for them. The transformation inserts the class name, with leading underscores removed and a single underscore inserted, in front of the name. For example, the identifier __spam occurring in a class named Ham will be transformed to _Ham__spam. This transformation is independent of the syntactical context in which the identifier is used. If the transformed name is extremely long (longer than 255 characters), implementation defined truncation may happen. If the class name consists only of underscores, no transformation is done.

6.2.2 Literals

Python supports string and bytes literals and various numeric literals:

> literal   ::=   stringliteral | bytesliteral
> | integer | floatnumber | imagnumber

Evaluation of a literal yields an object of the given type (string, bytes, integer, floating point number, complex number) with the given value. The value may be approximated in the case of floating point and imaginary (complex) literals. See section Literals for details.

All literals correspond to immutable data types, and hence the object's identity is less important than its value. Multiple evaluations of literals with the same value (either the same occurrence in the program text or a different occurrence) may obtain the same object or a different object with the same value.

6.2.3 Parenthesized forms

A parenthesized form is an optional expression list enclosed in parentheses:

> parenth_form   ::=   "(" [starred_expression] ")"

A parenthesized expression list yields whatever that expression list yields: if the list contains at least one comma, it yields a tuple; otherwise, it yields the single expression that makes up the expression list.

An empty pair of parentheses yields an empty tuple object. Since tuples are immutable, the rules for literals apply (i.e., two occurrences of the empty tuple may or may not yield the same object).

Note that tuples are not formed by the parentheses, but rather by use of the comma operator. The exception is the empty tuple, for which parentheses are required — allowing unparenthesized "nothing" in expressions would cause ambiguities and allow common typos to pass uncaught.

6.2.4 Displays for lists, sets and dictionaries

For constructing a list, a set or a dictionary Python provides special syntax called "displays", each of them in two flavors:

- either the container contents are listed explicitly, or
- they are computed via a set of looping and filtering instructions, called a comprehension.

Common syntax elements for comprehensions are:

comprehension	::=	expression comp_for
comp_for	::=	[ASYNC] "for" target_list "in" or_test [comp_iter]
comp_iter	::=	comp_for | comp_if
comp_if	::=	"if" expression_nocond [comp_iter]

The comprehension consists of a single expression followed by at least one for clause and zero or more for or if clauses. In this case, the elements of the new container are those that would be produced by considering each of the for or if clauses a block, nesting from left to right, and evaluating the expression to produce an element each time the innermost block is reached.

Note that the comprehension is executed in a separate scope, so names assigned to in the target list don't "leak" into the enclosing scope.

Since Python 3.6, in an async def function, an async for clause may be used to iterate over a asynchronous iterator. A comprehension in an async def function may consist of either a for or async for clause following the leading expression, may contain additional for or async for clauses, and may also use await expressions. If a comprehension contains either async for clauses or await expressions it is called an asynchronous comprehension. An asynchronous comprehension may suspend the execution of the coroutine function in which it appears. See also PEP 530.

6.2.5 List displays

A list display is a possibly empty series of expressions enclosed in square brackets:

| list_display | ::= | "[" [starred_list \| comprehension] "]" |

A list display yields a new list object, the contents being specified by either a list of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and placed into the list object in that order. When a comprehension is supplied, the list is constructed from the elements resulting from the comprehension.

6.2.6 Set displays

A set display is denoted by curly braces and distinguishable from dictionary displays by the lack of colons separating keys and values:

| set_display | ::= | "{" (starred_list \| comprehension) "}" |

A set display yields a new mutable set object, the contents being specified by either a sequence of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and added to the set object. When a comprehension is supplied, the set is constructed from the elements resulting from the comprehension.

An empty set cannot be constructed with {}; this literal constructs an empty dictionary.

6.2.7 Dictionary displays

A dictionary display is a possibly empty series of key/datum pairs enclosed in curly braces:

dict_display	::=	"{" [key_datum_list | dict_comprehension] "}"
key_datum_list	::=	key_datum ("," key_datum)* [","]
key_datum	::=	expression ":" expression | "**" or_expr
dict_comprehension	::=	expression ":" expression comp_for

A dictionary display yields a new dictionary object.

If a comma-separated sequence of key/datum pairs is given, they are evaluated from left to right to define the entries of the dictionary: each key object is used as a key into the dictionary to store the corresponding datum. This means that you can specify the same key multiple times in the key/datum list, and the final dictionary's value for that key will be the last one given.

A double asterisk ** denotes dictionary unpacking. Its operand must be a mapping. Each mapping item is added to the new dictionary. Later values replace values already set by earlier key/datum pairs and earlier dictionary unpackings.

New in version 3.5: Unpacking into dictionary displays, originally proposed by PEP 448.

A dict comprehension, in contrast to list and set comprehensions, needs two expressions separated with a colon followed by the usual "for" and "if" clauses. When the comprehension is run, the resulting key and value elements are inserted in the new dictionary in the order they are produced.

Restrictions on the types of the key values are listed earlier in section The standard type hierarchy. (To summarize, the key type should be hashable, which excludes all mutable objects.) Clashes between duplicate keys are not detected; the last datum (textually rightmost in the display) stored for a given key value prevails.

6.2.8 Generator expressions

A generator expression is a compact generator notation in parentheses:

generator_expression	::=	"(" expression comp_for ")"

A generator expression yields a new generator object. Its syntax is the same as for comprehensions, except that it is enclosed in parentheses instead of brackets or curly braces.

Variables used in the generator expression are evaluated lazily when the __next__() method is called for the generator object (in the same fashion as normal generators). However, the leftmost for clause is immediately evaluated, so that an error produced by it can be seen before any other possible error in the code that handles the generator expression. Subsequent for clauses cannot be evaluated immediately since they may depend on the previous for loop. For example: (x*y for x in range(10) for y in bar(x)).

The parentheses can be omitted on calls with only one argument. See section Calls for details.

Since Python 3.6, if the generator appears in an async def function, then async for clauses and await expressions are permitted as with an asynchronous comprehension. If a generator expression contains either async for clauses or await expressions it is called an asynchronous generator expression. An asynchronous generator expression yields a new asynchronous generator object, which is an asynchronous iterator (see Asynchronous Iterators).

6.2.9 Yield expressions

yield_atom	::=	"(" yield_expression ")"
yield_expression	::=	"yield" [expression_list | "from" expression]

The yield expression is used when defining a generator function or an asynchronous generator function and thus can only be used in the body of a function definition. Using a yield expression in a function's body causes that function to be a generator, and using it in an async def function's body causes that coroutine function to be an asynchronous generator. For example:

```
def gen():  # defines a generator function
    yield 123

async def agen():  # defines an asynchronous generator function (PEP 525)
    yield 123
```

Generator functions are described below, while asynchronous generator functions are described separately in section Asynchronous generator functions.

When a generator function is called, it returns an iterator known as a generator. That generator then controls the execution of the generator function. The execution starts when one of the generator's methods is called. At that time, the execution proceeds to the first yield expression, where it is suspended again, returning the value of expression_list to the generator's caller. By suspended, we mean that all local state is retained, including the current bindings of local variables, the instruction pointer, the internal evaluation stack, and the state of any exception handling. When the execution is resumed by calling one of the generator's methods, the function can proceed exactly as if the yield expression were just another external call. The value of the yield expression after resuming depends on the method which resumed the execution. If __next__() is used (typically via either a for or the next() builtin) then the result is None. Otherwise, if send() is used, then the result will be the value passed in to that method.

All of this makes generator functions quite similar to coroutines; they yield multiple times, they have more than one entry point and their execution can be suspended. The only difference is that a generator function cannot control where the execution should continue after it yields; the control is always transferred to the generator's caller.

Yield expressions are allowed anywhere in a try construct. If the generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), the generator-iterator's close() method will be called, allowing any pending finally clauses to execute.

When yield from <expr> is used, it treats the supplied expression as a subiterator. All values produced by that subiterator are passed directly to the caller of the current generator's methods. Any values passed in with send() and any exceptions passed in with throw() are passed to the underlying iterator if it has the appropriate methods. If this is not the case, then send() will raise AttributeError or TypeError, while throw() will just raise the passed in exception immediately.

When the underlying iterator is complete, the value attribute of the raised StopIteration instance becomes the value of the yield expression. It can be either set explicitly when raising StopIteration, or automatically when the sub-iterator is a generator (by returning a value from the sub-generator).

Changed in version 3.3: Added yield from <expr> to delegate control flow to a subiterator.

The parentheses may be omitted when the yield expression is the sole expression on the right hand side of an assignment statement.

See also:

PEP 255 - Simple Generators The proposal for adding generators and the yield statement to Python.

PEP 342 - Coroutines via Enhanced Generators The proposal to enhance the API and syntax of generators, making them usable as simple coroutines.

PEP 380 - Syntax for Delegating to a Subgenerator The proposal to introduce the yield_from syntax, making delegation to sub-generators easy.

Generator-iterator methods

This subsection describes the methods of a generator iterator. They can be used to control the execution of a generator function.

Note that calling any of the generator methods below when the generator is already executing raises a ValueError exception.

generator.__next__()

Starts the execution of a generator function or resumes it at the last executed yield expression. When a generator function is resumed with a __next__() method, the current yield expression always evaluates to None. The execution then continues to the next yield expression, where the generator is suspended again, and the value of the expression_list is returned to __next__()'s caller. If the generator exits without yielding another value, a StopIteration exception is raised.

This method is normally called implicitly, e.g. by a for loop, or by the built-in next() function.

generator.send(value)

Resumes the execution and "sends" a value into the generator function. The value argument becomes the result of the current yield expression. The send() method returns the next value yielded by the generator, or raises StopIteration if the generator exits without yielding another value. When send() is called to start the generator, it must be called with None as the argument, because there is no yield expression that could receive the value.

generator.throw(type[, value[, traceback]])

Raises an exception of type type at the point where the generator was paused, and returns the next value yielded by the generator function. If the generator exits without yielding another value, a StopIteration exception is raised. If the generator function does not catch the passed-in exception, or raises a different exception, then that exception propagates to the caller.

generator.close()

Raises a GeneratorExit at the point where the generator function was paused. If the generator function then exits gracefully, is already closed, or raises GeneratorExit (by not catching the exception), close returns to its caller. If the generator yields a value, a RuntimeError is raised. If the generator raises any other exception, it is propagated to the caller. close() does nothing if the generator has already exited due to an exception or normal exit.

Examples

Here is a simple example that demonstrates the behavior of generators and generator functions:

```
>>> def echo(value=None):
...     print("Execution starts when 'next()' is called for the first time.")
...     try:
...         while True:
...             try:
...                 value = (yield value)
...             except Exception as e:
...                 value = e
...     finally:
...         print("Don't forget to clean up when 'close()' is called.")
...
>>> generator = echo(1)
>>> print(next(generator))
Execution starts when 'next()' is called for the first time.
1
>>> print(next(generator))
```

```
None
>>> print(generator.send(2))
2
>>> generator.throw(TypeError, "spam")
TypeError('spam',)
>>> generator.close()
Don't forget to clean up when 'close()' is called.
```

For examples using yield from, see pep-380 in "What's New in Python."

Asynchronous generator functions

The presence of a yield expression in a function or method defined using async def further defines the function as a asynchronous generator function.

When an asynchronous generator function is called, it returns an asynchronous iterator known as an asynchronous generator object. That object then controls the execution of the generator function. An asynchronous generator object is typically used in an async for statement in a coroutine function analogously to how a generator object would be used in a for statement.

Calling one of the asynchronous generator's methods returns an awaitable object, and the execution starts when this object is awaited on. At that time, the execution proceeds to the first yield expression, where it is suspended again, returning the value of expression_list to the awaiting coroutine. As with a generator, suspension means that all local state is retained, including the current bindings of local variables, the instruction pointer, the internal evaluation stack, and the state of any exception handling. When the execution is resumed by awaiting on the next object returned by the asynchronous generator's methods, the function can proceed exactly as if the yield expression were just another external call. The value of the yield expression after resuming depends on the method which resumed the execution. If __anext__() is used then the result is None. Otherwise, if asend() is used, then the result will be the value passed in to that method.

In an asynchronous generator function, yield expressions are allowed anywhere in a try construct. However, if an asynchronous generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), then a yield expression within a try construct could result in a failure to execute pending finally clauses. In this case, it is the responsibility of the event loop or scheduler running the asynchronous generator to call the asynchronous generator-iterator's aclose() method and run the resulting coroutine object, thus allowing any pending finally clauses to execute.

To take care of finalization, an event loop should define a finalizer function which takes an asynchronous generator-iterator and presumably calls aclose() and executes the coroutine. This finalizer may be registered by calling sys.set_asyncgen_hooks(). When first iterated over, an asynchronous generator-iterator will store the registered finalizer to be called upon finalization. For a reference example of a finalizer method see the implementation of asyncio.Loop.shutdown_asyncgens in Lib/asyncio/base_events.py.

The expression yield from <expr> is a syntax error when used in an asynchronous generator function.

Asynchronous generator-iterator methods

This subsection describes the methods of an asynchronous generator iterator, which are used to control the execution of a generator function.

coroutine agen.__anext__()

Returns an awaitable which when run starts to execute the asynchronous generator or resumes it at the last executed yield expression. When an asynchronous generator function is resumed with a __anext__() method, the current yield expression always evaluates to None in the returned awaitable, which when run will continue to the next yield expression. The value of the expression_list of

the yield expression is the value of the StopIteration exception raised by the completing coroutine. If the asynchronous generator exits without yielding another value, the awaitable instead raises an StopAsyncIteration exception, signalling that the asynchronous iteration has completed.

This method is normally called implicitly by a async for loop.

coroutine agen.asend(value)

Returns an awaitable which when run resumes the execution of the asynchronous generator. As with the send() method for a generator, this "sends" a value into the asynchronous generator function, and the value argument becomes the result of the current yield expression. The awaitable returned by the asend() method will return the next value yielded by the generator as the value of the raised StopIteration, or raises StopAsyncIteration if the asynchronous generator exits without yielding another value. When asend() is called to start the asynchronous generator, it must be called with None as the argument, because there is no yield expression that could receive the value.

coroutine agen.athrow(type[, value[, traceback]])

Returns an awaitable that raises an exception of type type at the point where the asynchronous generator was paused, and returns the next value yielded by the generator function as the value of the raised StopIteration exception. If the asynchronous generator exits without yielding another value, an StopAsyncIteration exception is raised by the awaitable. If the generator function does not catch the passed-in exception, or raises a different exception, then when the awaitable is run that exception propagates to the caller of the awaitable.

coroutine agen.aclose()

Returns an awaitable that when run will throw a GeneratorExit into the asynchronous generator function at the point where it was paused. If the asynchronous generator function then exits gracefully, is already closed, or raises GeneratorExit (by not catching the exception), then the returned awaitable will raise a StopIteration exception. Any further awaitables returned by subsequent calls to the asynchronous generator will raise a StopAsyncIteration exception. If the asynchronous generator yields a value, a RuntimeError is raised by the awaitable. If the asynchronous generator raises any other exception, it is propagated to the caller of the awaitable. If the asynchronous generator has already exited due to an exception or normal exit, then further calls to aclose() will return an awaitable that does nothing.

6.3 Primaries

Primaries represent the most tightly bound operations of the language. Their syntax is:

 primary   ::=   atom | attributeref | subscription | slicing | call

6.3.1 Attribute references

An attribute reference is a primary followed by a period and a name:

 attributeref   ::=   primary "." identifier

The primary must evaluate to an object of a type that supports attribute references, which most objects do. This object is then asked to produce the attribute whose name is the identifier. This production can be customized by overriding the __getattr__() method. If this attribute is not available, the exception AttributeError is raised. Otherwise, the type and value of the object produced is determined by the object. Multiple evaluations of the same attribute reference may yield different objects.

6.3.2 Subscriptions

A subscription selects an item of a sequence (string, tuple or list) or mapping (dictionary) object:

subscription   ::=   primary "[" expression_list "]"

The primary must evaluate to an object that supports subscription (lists or dictionaries for example). User-defined objects can support subscription by defining a __getitem__() method.

For built-in objects, there are two types of objects that support subscription:

If the primary is a mapping, the expression list must evaluate to an object whose value is one of the keys of the mapping, and the subscription selects the value in the mapping that corresponds to that key. (The expression list is a tuple except if it has exactly one item.)

If the primary is a sequence, the expression (list) must evaluate to an integer or a slice (as discussed in the following section).

The formal syntax makes no special provision for negative indices in sequences; however, built-in sequences all provide a __getitem__() method that interprets negative indices by adding the length of the sequence to the index (so that x[-1] selects the last item of x). The resulting value must be a nonnegative integer less than the number of items in the sequence, and the subscription selects the item whose index is that value (counting from zero). Since the support for negative indices and slicing occurs in the object's __getitem__() method, subclasses overriding this method will need to explicitly add that support.

A string's items are characters. A character is not a separate data type but a string of exactly one character.

6.3.3 Slicings

A slicing selects a range of items in a sequence object (e.g., a string, tuple or list). Slicings may be used as expressions or as targets in assignment or del statements. The syntax for a slicing:

slicing   ::=   primary "[" slice_list "]"
slice_list   ::=   slice_item ("," slice_item)* [","]
slice_item   ::=   expression | proper_slice
proper_slice   ::=   [lower_bound] ":" [upper_bound] [":" [stride]]
lower_bound   ::=   expression
upper_bound   ::=   expression
stride   ::=   expression

There is ambiguity in the formal syntax here: anything that looks like an expression list also looks like a slice list, so any subscription can be interpreted as a slicing. Rather than further complicating the syntax, this is disambiguated by defining that in this case the interpretation as a subscription takes priority over the interpretation as a slicing (this is the case if the slice list contains no proper slice).

The semantics for a slicing are as follows. The primary is indexed (using the same __getitem__() method as normal subscription) with a key that is constructed from the slice list, as follows. If the slice list contains at least one comma, the key is a tuple containing the conversion of the slice items; otherwise, the conversion of the lone slice item is the key. The conversion of a slice item that is an expression is that expression. The conversion of a proper slice is a slice object (see section The standard type hierarchy) whose start, stop and step attributes are the values of the expressions given as lower bound, upper bound and stride, respectively, substituting None for missing expressions.

6.3.4 Calls

A call calls a callable object (e.g., a function) with a possibly empty series of arguments:

call	::=	primary "(" [argument_list [","] | comprehension] ")"
argument_list	::=	positional_arguments ["," starred_and_keywords]
		["," keywords_arguments]
		| starred_and_keywords ["," keywords_arguments]
		| keywords_arguments
positional_arguments	::=	["*"] expression ("," ["*"] expression)*
starred_and_keywords	::=	("*" expression | keyword_item)
		("," "*" expression | "," keyword_item)*
keywords_arguments	::=	(keyword_item | "**" expression)
		("," keyword_item | "," "**" expression)*
keyword_item	::=	identifier "=" expression

An optional trailing comma may be present after the positional and keyword arguments but does not affect the semantics.

The primary must evaluate to a callable object (user-defined functions, built-in functions, methods of built-in objects, class objects, methods of class instances, and all objects having a __call__() method are callable). All argument expressions are evaluated before the call is attempted. Please refer to section Function definitions for the syntax of formal parameter lists.

If keyword arguments are present, they are first converted to positional arguments, as follows. First, a list of unfilled slots is created for the formal parameters. If there are N positional arguments, they are placed in the first N slots. Next, for each keyword argument, the identifier is used to determine the corresponding slot (if the identifier is the same as the first formal parameter name, the first slot is used, and so on). If the slot is already filled, a TypeError exception is raised. Otherwise, the value of the argument is placed in the slot, filling it (even if the expression is None, it fills the slot). When all arguments have been processed, the slots that are still unfilled are filled with the corresponding default value from the function definition. (Default values are calculated, once, when the function is defined; thus, a mutable object such as a list or dictionary used as default value will be shared by all calls that don't specify an argument value for the corresponding slot; this should usually be avoided.) If there are any unfilled slots for which no default value is specified, a TypeError exception is raised. Otherwise, the list of filled slots is used as the argument list for the call.

CPython implementation detail: An implementation may provide built-in functions whose positional parameters do not have names, even if they are 'named' for the purpose of documentation, and which therefore cannot be supplied by keyword. In CPython, this is the case for functions implemented in C that use PyArg_ParseTuple() to parse their arguments.

If there are more positional arguments than there are formal parameter slots, a TypeError exception is raised, unless a formal parameter using the syntax *identifier is present; in this case, that formal parameter receives a tuple containing the excess positional arguments (or an empty tuple if there were no excess positional arguments).

If any keyword argument does not correspond to a formal parameter name, a TypeError exception is raised, unless a formal parameter using the syntax **identifier is present; in this case, that formal parameter receives a dictionary containing the excess keyword arguments (using the keywords as keys and the argument values as corresponding values), or a (new) empty dictionary if there were no excess keyword arguments.

If the syntax *expression appears in the function call, expression must evaluate to an iterable. Elements from these iterables are treated as if they were additional positional arguments. For the call f(x1, x2, *y, x3, x4), if y evaluates to a sequence y1, ..., yM, this is equivalent to a call with M+4 positional arguments x1, x2, y1, ..., yM, x3, x4.

A consequence of this is that although the *expression syntax may appear after explicit keyword arguments, it is processed before the keyword arguments (and any **expression arguments – see below). So:

```
>>> def f(a, b):
...     print(a, b)
...
>>> f(b=1, *(2,))
2 1
>>> f(a=1, *(2,))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: f() got multiple values for keyword argument 'a'
>>> f(1, *(2,))
1 2
```

It is unusual for both keyword arguments and the *expression syntax to be used in the same call, so in practice this confusion does not arise.

If the syntax **expression appears in the function call, expression must evaluate to a mapping, the contents of which are treated as additional keyword arguments. If a keyword is already present (as an explicit keyword argument, or from another unpacking), a TypeError exception is raised.

Formal parameters using the syntax *identifier or **identifier cannot be used as positional argument slots or as keyword argument names.

Changed in version 3.5: Function calls accept any number of * and ** unpackings, positional arguments may follow iterable unpackings (*), and keyword arguments may follow dictionary unpackings (**). Originally proposed by PEP 448.

A call always returns some value, possibly None, unless it raises an exception. How this value is computed depends on the type of the callable object.

If it is—

a user-defined function: The code block for the function is executed, passing it the argument list. The first thing the code block will do is bind the formal parameters to the arguments; this is described in section Function definitions. When the code block executes a return statement, this specifies the return value of the function call.

a built-in function or method: The result is up to the interpreter; see built-in-funcs for the descriptions of built-in functions and methods.

a class object: A new instance of that class is returned.

a class instance method: The corresponding user-defined function is called, with an argument list that is one longer than the argument list of the call: the instance becomes the first argument.

a class instance: The class must define a __call__() method; the effect is then the same as if that method was called.

6.4 Await expression

Suspend the execution of coroutine on an awaitable object. Can only be used inside a coroutine function.

```
await_expr   ::=   "await" primary
```

New in version 3.5.

6.5 The power operator

The power operator binds more tightly than unary operators on its left; it binds less tightly than unary operators on its right. The syntax is:

> power   ::=   (await_expr | primary) ["**" u_expr]

Thus, in an unparenthesized sequence of power and unary operators, the operators are evaluated from right to left (this does not constrain the evaluation order for the operands): -1**2 results in -1.

The power operator has the same semantics as the built-in pow() function, when called with two arguments: it yields its left argument raised to the power of its right argument. The numeric arguments are first converted to a common type, and the result is of that type.

For int operands, the result has the same type as the operands unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, 10**2 returns 100, but 10**-2 returns 0.01.

Raising 0.0 to a negative power results in a ZeroDivisionError. Raising a negative number to a fractional power results in a complex number. (In earlier versions it raised a ValueError.)

6.6 Unary arithmetic and bitwise operations

All unary arithmetic and bitwise operations have the same priority:

> u_expr   ::=   power | "-" u_expr | "+" u_expr | "~" u_expr

The unary - (minus) operator yields the negation of its numeric argument.

The unary + (plus) operator yields its numeric argument unchanged.

The unary ~ (invert) operator yields the bitwise inversion of its integer argument. The bitwise inversion of x is defined as -(x+1). It only applies to integral numbers.

In all three cases, if the argument does not have the proper type, a TypeError exception is raised.

6.7 Binary arithmetic operations

The binary arithmetic operations have the conventional priority levels. Note that some of these operations also apply to certain non-numeric types. Apart from the power operator, there are only two levels, one for multiplicative operators and one for additive operators:

> m_expr   ::=   u_expr | m_expr "*" u_expr | m_expr "@" m_expr |
>   m_expr "//" u_expr| m_expr "/" u_expr |
>   m_expr "%" u_expr
> a_expr   ::=   m_expr | a_expr "+" m_expr | a_expr "-" m_expr

The * (multiplication) operator yields the product of its arguments. The arguments must either both be numbers, or one argument must be an integer and the other must be a sequence. In the former case, the numbers are converted to a common type and then multiplied together. In the latter case, sequence repetition

is performed; a negative repetition factor yields an empty sequence.

The @ (at) operator is intended to be used for matrix multiplication. No builtin Python types implement this operator.

New in version 3.5.

The / (division) and // (floor division) operators yield the quotient of their arguments. The numeric arguments are first converted to a common type. Division of integers yields a float, while floor division of integers results in an integer; the result is that of mathematical division with the 'floor' function applied to the result. Division by zero raises the ZeroDivisionError exception.

The % (modulo) operator yields the remainder from the division of the first argument by the second. The numeric arguments are first converted to a common type. A zero right argument raises the ZeroDivisionError exception. The arguments may be floating point numbers, e.g., 3.14%0.7 equals 0.34 (since 3.14 equals 4*0.7 + 0.34.) The modulo operator always yields a result with the same sign as its second operand (or zero); the absolute value of the result is strictly smaller than the absolute value of the second operand[1].

The floor division and modulo operators are connected by the following identity: x == (x//y)*y + (x%y). Floor division and modulo are also connected with the built-in function divmod(): divmod(x, y) == (x//y, x%y).[2]

In addition to performing the modulo operation on numbers, the % operator is also overloaded by string objects to perform old-style string formatting (also known as interpolation). The syntax for string formatting is described in the Python Library Reference, section old-string-formatting.

The floor division operator, the modulo operator, and the divmod() function are not defined for complex numbers. Instead, convert to a floating point number using the abs() function if appropriate.

The + (addition) operator yields the sum of its arguments. The arguments must either both be numbers or both be sequences of the same type. In the former case, the numbers are converted to a common type and then added together. In the latter case, the sequences are concatenated.

The - (subtraction) operator yields the difference of its arguments. The numeric arguments are first converted to a common type.

6.8 Shifting operations

The shifting operations have lower priority than the arithmetic operations:

  shift_expr   ::=   a_expr | shift_expr ("<<" | ">>") a_expr

These operators accept integers as arguments. They shift the first argument to the left or right by the number of bits given by the second argument.

A right shift by n bits is defined as floor division by pow(2,n). A left shift by n bits is defined as multiplication with pow(2,n).

Note: In the current implementation, the right-hand operand is required to be at most sys.maxsize. If the

---

[1] While abs(x%y) < abs(y) is true mathematically, for floats it may not be true numerically due to roundoff. For example, and assuming a platform on which a Python float is an IEEE 754 double-precision number, in order that -1e-100 % 1e100 have the same sign as 1e100, the computed result is -1e-100 + 1e100, which is numerically exactly equal to 1e100. The function math.fmod() returns a result whose sign matches the sign of the first argument instead, and so returns -1e-100 in this case. Which approach is more appropriate depends on the application.

[2] If x is very close to an exact integer multiple of y, it's possible for x//y to be one larger than (x-x%y)//y due to rounding. In such cases, Python returns the latter result, in order to preserve that divmod(x,y)[0] * y + x % y be very close to x.

---

right-hand operand is larger than sys.maxsize an OverflowError exception is raised.

6.9 Binary bitwise operations

Each of the three bitwise operations has a different priority level:

and_expr	::=	shift_expr	and_expr "&" shift_expr
xor_expr	::=	and_expr	xor_expr "^" and_expr
or_expr	::=	xor_expr	or_expr "|" xor_expr

The & operator yields the bitwise AND of its arguments, which must be integers.

The ^ operator yields the bitwise XOR (exclusive OR) of its arguments, which must be integers.

The | operator yields the bitwise (inclusive) OR of its arguments, which must be integers.

6.10 Comparisons

Unlike C, all comparison operations in Python have the same priority, which is lower than that of any arithmetic, shifting or bitwise operation. Also unlike C, expressions like a < b < c have the interpretation that is conventional in mathematics:

comparison	::=	or_expr (comp_operator or_expr)*
comp_operator	::=	"<"	">"	"=="	">="	"<="	"!="
		| "is" ["not"] | ["not"] "in"

Comparisons yield boolean values: True or False.

Comparisons can be chained arbitrarily, e.g., x < y <= z is equivalent to x < y and y <= z, except that y is evaluated only once (but in both cases z is not evaluated at all when x < y is found to be false).

Formally, if a, b, c, ..., y, z are expressions and op1, op2, ..., opN are comparison operators, then a op1 b op2 c ... y opN z is equivalent to a op1 b and b op2 c and ... y opN z, except that each expression is evaluated at most once.

Note that a op1 b op2 c doesn't imply any kind of comparison between a and c, so that, e.g., x < y > z is perfectly legal (though perhaps not pretty).

6.10.1 Value comparisons

The operators <, >, ==, >=, <=, and != compare the values of two objects. The objects do not need to have the same type.

Chapter Objects, values and types states that objects have a value (in addition to type and identity). The value of an object is a rather abstract notion in Python: For example, there is no canonical access method for an object's value. Also, there is no requirement that the value of an object should be constructed in a particular way, e.g. comprised of all its data attributes. Comparison operators implement a particular notion of what the value of an object is. One can think of them as defining the value of an object indirectly, by means of their comparison implementation.

Because all types are (direct or indirect) subtypes of object, they inherit the default comparison behavior from object. Types can customize their comparison behavior by implementing rich comparison methods like `__lt__()`, described in Basic customization.

The default behavior for equality comparison (== and !=) is based on the identity of the objects. Hence, equality comparison of instances with the same identity results in equality, and equality comparison of instances with different identities results in inequality. A motivation for this default behavior is the desire that all objects should be reflexive (i.e. x is y implies x == y).

A default order comparison ($<$, $>$, $<=$, and $>=$) is not provided; an attempt raises TypeError. A motivation for this default behavior is the lack of a similar invariant as for equality.

The behavior of the default equality comparison, that instances with different identities are always unequal, may be in contrast to what types will need that have a sensible definition of object value and value-based equality. Such types will need to customize their comparison behavior, and in fact, a number of built-in types have done that.

The following list describes the comparison behavior of the most important built-in types.

- Numbers of built-in numeric types (typesnumeric) and of the standard library types fractions.Fraction and decimal.Decimal can be compared within and across their types, with the restriction that complex numbers do not support order comparison. Within the limits of the types involved, they compare mathematically (algorithmically) correct without loss of precision.

  The not-a-number values float('NaN') and Decimal('NaN') are special. They are identical to themselves (x is x is true) but are not equal to themselves (x == x is false). Additionally, comparing any number to a not-a-number value will return False. For example, both $3 <$ float('NaN') and float('NaN') < 3 will return False.

- Binary sequences (instances of bytes or bytearray) can be compared within and across their types. They compare lexicographically using the numeric values of their elements.

- Strings (instances of str) compare lexicographically using the numerical Unicode code points (the result of the built-in function ord()) of their characters.[3]

  Strings and binary sequences cannot be directly compared.

- Sequences (instances of tuple, list, or range) can be compared only within each of their types, with the restriction that ranges do not support order comparison. Equality comparison across these types results in inequality, and ordering comparison across these types raises TypeError.

  Sequences compare lexicographically using comparison of corresponding elements, whereby reflexivity of the elements is enforced.

  In enforcing reflexivity of elements, the comparison of collections assumes that for a collection element x, x == x is always true. Based on that assumption, element identity is compared first, and element comparison is performed only for distinct elements. This approach yields the same result as a strict element comparison would, if the compared elements are reflexive. For non-reflexive elements, the result is different than for strict element comparison, and may be surprising: The non-reflexive not-a-number values for example result in the following comparison behavior when used in a list:

---

[3] The Unicode standard distinguishes between code points (e.g. U+0041) and abstract characters (e.g. "LATIN CAPITAL LETTER A"). While most abstract characters in Unicode are only represented using one code point, there is a number of abstract characters that can in addition be represented using a sequence of more than one code point. For example, the abstract character "LATIN CAPITAL LETTER C WITH CEDILLA" can be represented as a single precomposed character at code position U+00C7, or as a sequence of a base character at code position U+0043 (LATIN CAPITAL LETTER C), followed by a combining character at code position U+0327 (COMBINING CEDILLA).

The comparison operators on strings compare at the level of Unicode code points. This may be counter-intuitive to humans. For example, `"\u00C7" == "\u0043\u0327"` is False, even though both strings represent the same abstract character "LATIN CAPITAL LETTER C WITH CEDILLA".

To compare strings at the level of abstract characters (that is, in a way intuitive to humans), use unicodedata.normalize().

```
>>> nan = float('NaN')
>>> nan is nan
True
>>> nan == nan
False                    <-- the defined non-reflexive behavior of NaN
>>> [nan] == [nan]
True                     <-- list enforces reflexivity and tests identity first
```

Lexicographical comparison between built-in collections works as follows:

– For two collections to compare equal, they must be of the same type, have the same length, and each pair of corresponding elements must compare equal (for example, [1,2] == (1,2) is false because the type is not the same).

– Collections that support order comparison are ordered the same as their first unequal elements (for example, [1,2,x] <= [1,2,y] has the same value as x <= y). If a corresponding element does not exist, the shorter collection is ordered first (for example, [1,2] < [1,2,3] is true).

• Mappings (instances of dict) compare equal if and only if they have equal (key, value) pairs. Equality comparison of the keys and values enforces reflexivity.

Order comparisons (<, >, <=, and >=) raise TypeError.

• Sets (instances of set or frozenset) can be compared within and across their types.

They define order comparison operators to mean subset and superset tests. Those relations do not define total orderings (for example, the two sets {1,2} and {2,3} are not equal, nor subsets of one another, nor supersets of one another). Accordingly, sets are not appropriate arguments for functions which depend on total ordering (for example, min(), max(), and sorted() produce undefined results given a list of sets as inputs).

Comparison of sets enforces reflexivity of its elements.

• Most other built-in types have no comparison methods implemented, so they inherit the default comparison behavior.

User-defined classes that customize their comparison behavior should follow some consistency rules, if possible:

• Equality comparison should be reflexive. In other words, identical objects should compare equal:

x is y implies x == y

• Comparison should be symmetric. In other words, the following expressions should have the same result:

x == y and y == x

x != y and y != x

x < y and y > x

x <= y and y >= x

• Comparison should be transitive. The following (non-exhaustive) examples illustrate that:

x > y and y > z implies x > z

x < y and y <= z implies x < z

• Inverse comparison should result in the boolean negation. In other words, the following expressions should have the same result:

x == y and not x != y

x < y and not x >= y (for total ordering)

x > y and not x <= y (for total ordering)

The last two expressions apply to totally ordered collections (e.g. to sequences, but not to sets or mappings). See also the total_ordering() decorator.

- The hash() result should be consistent with equality. Objects that are equal should either have the same hash value, or be marked as unhashable.

Python does not enforce these consistency rules. In fact, the not-a-number values are an example for not following these rules.

6.10.2 Membership test operations

The operators in and not in test for membership. x in s evaluates to True if x is a member of s, and False otherwise. x not in s returns the negation of x in s. All built-in sequences and set types support this as well as dictionary, for which in tests whether the dictionary has a given key. For container types such as list, tuple, set, frozenset, dict, or collections.deque, the expression x in y is equivalent to any(x is e or x == e for e in y).

For the string and bytes types, x in y is True if and only if x is a substring of y. An equivalent test is y.find(x) != -1. Empty strings are always considered to be a substring of any other string, so "" in "abc" will return True.

For user-defined classes which define the __contains__() method, x in y returns True if y.__contains__(x) returns a true value, and False otherwise.

For user-defined classes which do not define __contains__() but do define __iter__(), x in y is True if some value z with x == z is produced while iterating over y. If an exception is raised during the iteration, it is as if in raised that exception.

Lastly, the old-style iteration protocol is tried: if a class defines __getitem__(), x in y is True if and only if there is a non-negative integer index i such that x == y[i], and all lower integer indices do not raise IndexError exception. (If any other exception is raised, it is as if in raised that exception).

The operator not in is defined to have the inverse true value of in.

6.10.3 Identity comparisons

The operators is and is not test for object identity: x is y is true if and only if x and y are the same object. Object identity is determined using the id() function. x is not y yields the inverse truth value.[4]

6.11 Boolean operations

or_test	::=	and_test | or_test "or" and_test
and_test	::=	not_test | and_test "and" not_test
not_test	::=	comparison | "not" not_test

In the context of Boolean operations, and also when expressions are used by control flow statements, the

---

[4] Due to automatic garbage-collection, free lists, and the dynamic nature of descriptors, you may notice seemingly unusual behaviour in certain uses of the is operator, like those involving comparisons between instance methods, or constants. Check their documentation for more info.

following values are interpreted as false: False, None, numeric zero of all types, and empty strings and containers (including strings, tuples, lists, dictionaries, sets and frozensets). All other values are interpreted as true. User-defined objects can customize their truth value by providing a __bool__() method.

The operator not yields True if its argument is false, False otherwise.

The expression x and y first evaluates x; if x is false, its value is returned; otherwise, y is evaluated and the resulting value is returned.

The expression x or y first evaluates x; if x is true, its value is returned; otherwise, y is evaluated and the resulting value is returned.

(Note that neither and nor or restrict the value and type they return to False and True, but rather return the last evaluated argument. This is sometimes useful, e.g., if s is a string that should be replaced by a default value if it is empty, the expression s or 'foo' yields the desired value. Because not has to create a new value, it returns a boolean value regardless of the type of its argument (for example, not 'foo' produces False rather than ''.)

6.12 Conditional expressions

conditional_expression	::=	or_test ["if" or_test "else" expression]
expression	::=	conditional_expression | lambda_expr
expression_nocond	::=	or_test | lambda_expr_nocond

Conditional expressions (sometimes called a "ternary operator") have the lowest priority of all Python operations.

The expression x if C else y first evaluates the condition, C rather than x. If C is true, x is evaluated and its value is returned; otherwise, y is evaluated and its value is returned.

See PEP 308 for more details about conditional expressions.

6.13 Lambdas

| lambda_expr | ::= | "lambda" [parameter_list]: expression |
| lambda_expr_nocond | ::= | "lambda" [parameter_list]: expression_nocond |

Lambda expressions (sometimes called lambda forms) are used to create anonymous functions. The expression lambda arguments: expression yields a function object. The unnamed object behaves like a function object defined with:

```
def <lambda>(arguments):
    return expression
```

See section Function definitions for the syntax of parameter lists. Note that functions created with lambda expressions cannot contain statements or annotations.

6.14 Expression lists

| expression_list | ::= | expression ("," expression)* [","] |

starred_list	::=	starred_item ("," starred_item)* [","]
starred_expression	::=	expression | (starred_item ",")* [starred_item]
starred_item	::=	expression | "*" or_expr

Except when part of a list or set display, an expression list containing at least one comma yields a tuple. The length of the tuple is the number of expressions in the list. The expressions are evaluated from left to right.

An asterisk * denotes iterable unpacking. Its operand must be an iterable. The iterable is expanded into a sequence of items, which are included in the new tuple, list, or set, at the site of the unpacking.

New in version 3.5: Iterable unpacking in expression lists, originally proposed by PEP 448.

The trailing comma is required only to create a single tuple (a.k.a. a singleton); it is optional in all other cases. A single expression without a trailing comma doesn't create a tuple, but rather yields the value of that expression. (To create an empty tuple, use an empty pair of parentheses: ().)

6.15 Evaluation order

Python evaluates expressions from left to right. Notice that while evaluating an assignment, the right-hand side is evaluated before the left-hand side.

In the following lines, expressions will be evaluated in the arithmetic order of their suffixes:

```
expr1, expr2, expr3, expr4
(expr1, expr2, expr3, expr4)
{expr1: expr2, expr3: expr4}
expr1 + expr2 * (expr3 - expr4)
expr1(expr2, expr3, *expr4, **expr5)
expr3, expr4 = expr1, expr2
```

6.16 Operator precedence

The following table summarizes the operator precedence in Python, from lowest precedence (least binding) to highest precedence (most binding). Operators in the same box have the same precedence. Unless the syntax is explicitly given, operators are binary. Operators in the same box group left to right (except for exponentiation, which groups from right to left).

Note that comparisons, membership tests, and identity tests, all have the same precedence and have a left-to-right chaining feature as described in the Comparisons section.

Operator	Description
lambda	Lambda expression
if – else	Conditional expression
or	Boolean OR
and	Boolean AND
not x	Boolean NOT
in, not in, is, is not, <, <=, >, >=, !=, ==	Comparisons, including membership tests and identity tests
|	Bitwise OR
^	Bitwise XOR
&	Bitwise AND
<<, >>	Shifts
+, -	Addition and subtraction
*, @, /, //, %	Multiplication, matrix multiplication division, remainder[5]
+x, -x, ~x	Positive, negative, bitwise NOT
**	Exponentiation[6]
await x	Await expression
x[index], x[index:index], x(arguments...), x.attribute	Subscription, slicing, call, attribute reference
(expressions...), [expressions...], {key: value...}, {expressions...}	Binding or tuple display, list display, dictionary display, set display

---

[5] The % operator is also used for string formatting; the same precedence applies.
[6] The power operator ** binds less tightly than an arithmetic or bitwise unary operator on its right, that is, 2**-1 is 0.5.

SIMPLE STATEMENTS

A simple statement is comprised within a single logical line. Several simple statements may occur on a single line separated by semicolons. The syntax for simple statements is:

simple_stmt	::=	expression_stmt
		| assert_stmt
		| assignment_stmt
		| augmented_assignment_stmt
		| annotated_assignment_stmt
		| pass_stmt
		| del_stmt
		| return_stmt
		| yield_stmt
		| raise_stmt
		| break_stmt
		| continue_stmt
		| import_stmt
		| global_stmt
		| nonlocal_stmt

7.1 Expression statements

Expression statements are used (mostly interactively) to compute and write a value, or (usually) to call a procedure (a function that returns no meaningful result; in Python, procedures return the value None). Other uses of expression statements are allowed and occasionally useful. The syntax for an expression statement is:

expression_stmt	::=	starred_expression

An expression statement evaluates the expression list (which may be a single expression).

In interactive mode, if the value is not None, it is converted to a string using the built-in repr() function and the resulting string is written to standard output on a line by itself (except if the result is None, so that procedure calls do not cause any output.)

7.2 Assignment statements

Assignment statements are used to (re)bind names to values and to modify attributes or items of mutable objects:

```
assignment_stmt    ::=   (target_list "=")+ (starred_expression | yield_expression)
target_list        ::=   target ("," target)* [","]
target             ::=   identifier
                         | "(" [target_list] ")"
                         | "[" [target_list] "]"
                         | attributeref
                         | subscription
                         | slicing
                         | "*" target
```

(See section Primaries for the syntax definitions for attributeref, subscription, and slicing.)

An assignment statement evaluates the expression list (remember that this can be a single expression or a comma-separated list, the latter yielding a tuple) and assigns the single resulting object to each of the target lists, from left to right.

Assignment is defined recursively depending on the form of the target (list). When a target is part of a mutable object (an attribute reference, subscription or slicing), the mutable object must ultimately perform the assignment and decide about its validity, and may raise an exception if the assignment is unacceptable. The rules observed by various types and the exceptions raised are given with the definition of the object types (see section The standard type hierarchy).

Assignment of an object to a target list, optionally enclosed in parentheses or square brackets, is recursively defined as follows.

- If the target list is empty: The object must also be an empty iterable.

- If the target list is a single target in parentheses: The object is assigned to that target.

- If the target list is a comma-separated list of targets, or a single target in square brackets: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.

  - If the target list contains one target prefixed with an asterisk, called a "starred" target: The object must be an iterable with at least as many items as there are targets in the target list, minus one. The first items of the iterable are assigned, from left to right, to the targets before the starred target. The final items of the iterable are assigned to the targets after the starred target. A list of the remaining items in the iterable is then assigned to the starred target (the list can be empty).

  - Else: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.

Assignment of an object to a single target is recursively defined as follows.

- If the target is an identifier (name):

  - If the name does not occur in a global or nonlocal statement in the current code block: the name is bound to the object in the current local namespace.

  - Otherwise: the name is bound to the object in the global namespace or the outer namespace determined by nonlocal, respectively.

The name is rebound if it was already bound. This may cause the reference count for the object previously bound to the name to reach zero, causing the object to be deallocated and its destructor (if it has one) to be called.

- If the target is an attribute reference: The primary expression in the reference is evaluated. It should yield an object with assignable attributes; if this is not the case, TypeError is raised. That object is then asked to assign the assigned object to the given attribute; if it cannot perform the assignment, it raises an exception (usually but not necessarily AttributeError). Note: If the object is a class instance and the attribute reference occurs on both sides of the assignment operator, the RHS expression, a.x can access either an instance attribute or (if no instance attribute exists) a class attribute. The LHS target a.x is always set as an instance attribute, creating it if necessary. Thus, the two occurrences of a.x do not necessarily refer to the same attribute: if the RHS expression refers to a class attribute, the LHS creates a new instance attribute as the target of the assignment:

```
class Cls:
    x = 3             # class variable
inst = Cls()
inst.x = inst.x + 1   # writes inst.x as 4 leaving Cls.x as 3
```

This description does not necessarily apply to descriptor attributes, such as properties created with property().

- If the target is a subscription: The primary expression in the reference is evaluated. It should yield either a mutable sequence object (such as a list) or a mapping object (such as a dictionary). Next, the subscript expression is evaluated.

If the primary is a mutable sequence object (such as a list), the subscript must yield an integer. If it is negative, the sequence's length is added to it. The resulting value must be a nonnegative integer less than the sequence's length, and the sequence is asked to assign the assigned object to its item with that index. If the index is out of range, IndexError is raised (assignment to a subscripted sequence cannot add new items to a list).

If the primary is a mapping object (such as a dictionary), the subscript must have a type compatible with the mapping's key type, and the mapping is then asked to create a key/datum pair which maps the subscript to the assigned object. This can either replace an existing key/value pair with the same key value, or insert a new key/value pair (if no key with the same value existed).

For user-defined objects, the __setitem__() method is called with appropriate arguments.

- If the target is a slicing: The primary expression in the reference is evaluated. It should yield a mutable sequence object (such as a list). The assigned object should be a sequence object of the same type. Next, the lower and upper bound expressions are evaluated, insofar they are present; defaults are zero and the sequence's length. The bounds should evaluate to integers. If either bound is negative, the sequence's length is added to it. The resulting bounds are clipped to lie between zero and the sequence's length, inclusive. Finally, the sequence object is asked to replace the slice with the items of the assigned sequence. The length of the slice may be different from the length of the assigned sequence, thus changing the length of the target sequence, if the target sequence allows it.

CPython implementation detail: In the current implementation, the syntax for targets is taken to be the same as for expressions, and invalid syntax is rejected during the code generation phase, causing less detailed error messages.

Although the definition of assignment implies that overlaps between the left-hand side and the right-hand side are 'simultaneous' (for example a, b = b, a swaps two variables), overlaps within the collection of assigned-to variables occur left-to-right, sometimes resulting in confusion. For instance, the following program prints [0, 2]:

```
x = [0, 1]
i = 0
```

```
i, x[i] = 1, 2          # i is updated, then x[i] is updated
print(x)
```

See also:

PEP 3132 - Extended Iterable Unpacking The specification for the *target feature.

7.2.1 Augmented assignment statements

Augmented assignment is the combination, in a single statement, of a binary operation and an assignment statement:

augmented_assignment_stmt	::=	augtarget augop (expression_list | yield_expression)
augtarget	::=	identifier | attributeref | subscription | slicing
augop	::=	"+=" | "-=" | "*=" | "@=" | "/=" | "//=" | "%=" | "**="
		| ">>=" | "<<=" | "&=" | "^=" | "|="

(See section Primaries for the syntax definitions of the last three symbols.)

An augmented assignment evaluates the target (which, unlike normal assignment statements, cannot be an unpacking) and the expression list, performs the binary operation specific to the type of assignment on the two operands, and assigns the result to the original target. The target is only evaluated once.

An augmented assignment expression like x += 1 can be rewritten as x = x + 1 to achieve a similar, but not exactly equal effect. In the augmented version, x is only evaluated once. Also, when possible, the actual operation is performed in-place, meaning that rather than creating a new object and assigning that to the target, the old object is modified instead.

Unlike normal assignments, augmented assignments evaluate the left-hand side before evaluating the right-hand side. For example, a[i] += f(x) first looks-up a[i], then it evaluates f(x) and performs the addition, and lastly, it writes the result back to a[i].

With the exception of assigning to tuples and multiple targets in a single statement, the assignment done by augmented assignment statements is handled the same way as normal assignments. Similarly, with the exception of the possible in-place behavior, the binary operation performed by augmented assignment is the same as the normal binary operations.

For targets which are attribute references, the same caveat about class and instance attributes applies as for regular assignments.

7.2.2 Annotated assignment statements

Annotation assignment is the combination, in a single statement, of a variable or attribute annotation and an optional assignment statement:

annotated_assignment_stmt	::=	augtarget ":" expression ["=" expression]

The difference from normal Assignment statements is that only single target and only single right hand side value is allowed.

For simple names as assignment targets, if in class or module scope, the annotations are evaluated and stored in a special class or module attribute __annotations__ that is a dictionary mapping from variable names (mangled if private) to evaluated annotations. This attribute is writable and is automatically created at the

start of class or module body execution, if annotations are found statically.

For expressions as assignment targets, the annotations are evaluated if in class or module scope, but not stored.

If a name is annotated in a function scope, then this name is local for that scope. Annotations are never evaluated and stored in function scopes.

If the right hand side is present, an annotated assignment performs the actual assignment before evaluating annotations (where applicable). If the right hand side is not present for an expression target, then the interpreter evaluates the target except for the last __setitem__() or __setattr__() call.

See also:

PEP 526 - Variable and attribute annotation syntax PEP 484 - Type hints

7.3 The assert statement

Assert statements are a convenient way to insert debugging assertions into a program:

```
assert_stmt    ::=    "assert" expression ["," expression]
```

The simple form, assert expression, is equivalent to

```
if __debug__:
    if not expression: raise AssertionError
```

The extended form, assert expression1, expression2, is equivalent to

```
if __debug__:
    if not expression1: raise AssertionError(expression2)
```

These equivalences assume that __debug__ and AssertionError refer to the built-in variables with those names. In the current implementation, the built-in variable __debug__ is True under normal circumstances, False when optimization is requested (command line option -O). The current code generator emits no code for an assert statement when optimization is requested at compile time. Note that it is unnecessary to include the source code for the expression that failed in the error message; it will be displayed as part of the stack trace.

Assignments to __debug__ are illegal. The value for the built-in variable is determined when the interpreter starts.

7.4 The pass statement

```
pass_stmt    ::=    "pass"
```

pass is a null operation — when it is executed, nothing happens. It is useful as a placeholder when a statement is required syntactically, but no code needs to be executed, for example:

```
def f(arg): pass    # a function that does nothing (yet)

class C: pass       # a class with no methods (yet)
```

7.5 The del statement

del_stmt   ::=   "del" target_list

Deletion is recursively defined very similar to the way assignment is defined. Rather than spelling it out in full details, here are some hints.

Deletion of a target list recursively deletes each target, from left to right.

Deletion of a name removes the binding of that name from the local or global namespace, depending on whether the name occurs in a global statement in the same code block. If the name is unbound, a NameError exception will be raised.

Deletion of attribute references, subscriptions and slicings is passed to the primary object involved; deletion of a slicing is in general equivalent to assignment of an empty slice of the right type (but even this is determined by the sliced object).

Changed in version 3.2: Previously it was illegal to delete a name from the local namespace if it occurs as a free variable in a nested block.

7.6 The return statement

return_stmt   ::=   "return" [expression_list]

return may only occur syntactically nested in a function definition, not within a nested class definition.

If an expression list is present, it is evaluated, else None is substituted.

return leaves the current function call with the expression list (or None) as return value.

When return passes control out of a try statement with a finally clause, that finally clause is executed before really leaving the function.

In a generator function, the return statement indicates that the generator is done and will cause StopIteration to be raised. The returned value (if any) is used as an argument to construct StopIteration and becomes the StopIteration.value attribute.

In an asynchronous generator function, an empty return statement indicates that the asynchronous generator is done and will cause StopAsyncIteration to be raised. A non-empty return statement is a syntax error in an asynchronous generator function.

7.7 The yield statement

yield_stmt   ::=   yield_expression

A yield statement is semantically equivalent to a yield expression. The yield statement can be used to omit the parentheses that would otherwise be required in the equivalent yield expression statement. For example, the yield statements

```
yield <expr>
yield from <expr>
```

are equivalent to the yield expression statements

```
(yield <expr>)
(yield from <expr>)
```

Yield expressions and statements are only used when defining a generator function, and are only used in the body of the generator function. Using yield in a function definition is sufficient to cause that definition to create a generator function instead of a normal function.

For full details of yield semantics, refer to the Yield expressions section.

7.8 The raise statement

```
raise_stmt   ::=    "raise" [expression ["from" expression]]
```

If no expressions are present, raise re-raises the last exception that was active in the current scope. If no exception is active in the current scope, a RuntimeError exception is raised indicating that this is an error.

Otherwise, raise evaluates the first expression as the exception object. It must be either a subclass or an instance of BaseException. If it is a class, the exception instance will be obtained when needed by instantiating the class with no arguments.

The type of the exception is the exception instance's class, the value is the instance itself.

A traceback object is normally created automatically when an exception is raised and attached to it as the __traceback__ attribute, which is writable. You can create an exception and set your own traceback in one step using the with_traceback() exception method (which returns the same exception instance, with its traceback set to its argument), like so:

```
raise Exception("foo occurred").with_traceback(tracebackobj)
```

The from clause is used for exception chaining: if given, the second expression must be another exception class or instance, which will then be attached to the raised exception as the __cause__ attribute (which is writable). If the raised exception is not handled, both exceptions will be printed:

```
>>> try:
...     print(1 / 0)
... except Exception as exc:
...     raise RuntimeError("Something bad happened") from exc
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: division by zero

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

Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

A similar mechanism works implicitly if an exception is raised inside an exception handler or a finally clause: the previous exception is then attached as the new exception's __context__ attribute:

```
>>> try:
...     print(1 / 0)
... except:
...     raise RuntimeError("Something bad happened")
```

```
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: division by zero

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

Exception chaining can be explicitly suppressed by specifying None in the from clause:

```
>>> try:
...     print(1 / 0)
... except:
...     raise RuntimeError("Something bad happened") from None
...
Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

Additional information on exceptions can be found in section Exceptions, and information about handling exceptions is in section The try statement.

Changed in version 3.3: None is now permitted as Y in raise X from Y.

New in version 3.3: The __suppress_context__ attribute to suppress automatic display of the exception context.

7.9 The break statement

```
break_stmt   ::=   "break"
```

break may only occur syntactically nested in a for or while loop, but not nested in a function or class definition within that loop.

It terminates the nearest enclosing loop, skipping the optional else clause if the loop has one.

If a for loop is terminated by break, the loop control target keeps its current value.

When break passes control out of a try statement with a finally clause, that finally clause is executed before really leaving the loop.

7.10 The continue statement

```
continue_stmt   ::=   "continue"
```

continue may only occur syntactically nested in a for or while loop, but not nested in a function or class definition or finally clause within that loop. It continues with the next cycle of the nearest enclosing loop.

When continue passes control out of a try statement with a finally clause, that finally clause is executed before really starting the next loop cycle.

7.11 The import statement

import_stmt	::=	"import" module ["as" name] ("," module ["as" name])*
		| "from" relative_module "import" identifier ["as" name]
		("," identifier ["as" name])*
		| "from" relative_module "import" "(" identifier ["as" name]
		("," identifier ["as" name])* [","] ")"
		| "from" module "import" "*"
module	::=	(identifier ".")* identifier
relative_module	::=	"."* module | "."+
name	::=	identifier

The basic import statement (no from clause) is executed in two steps:

1. find a module, loading and initializing it if necessary

2. define a name or names in the local namespace for the scope where the import statement occurs.

When the statement contains multiple clauses (separated by commas) the two steps are carried out separately for each clause, just as though the clauses had been separated out into individual import statements.

The details of the first step, finding and loading modules are described in greater detail in the section on the import system, which also describes the various types of packages and modules that can be imported, as well as all the hooks that can be used to customize the import system. Note that failures in this step may indicate either that the module could not be located, or that an error occurred while initializing the module, which includes execution of the module's code.

If the requested module is retrieved successfully, it will be made available in the local namespace in one of three ways:

- If the module name is followed by as, then the name following as is bound directly to the imported module.

- If no other name is specified, and the module being imported is a top level module, the module's name is bound in the local namespace as a reference to the imported module

- If the module being imported is not a top level module, then the name of the top level package that contains the module is bound in the local namespace as a reference to the top level package. The imported module must be accessed using its full qualified name rather than directly

The from form uses a slightly more complex process:

1. find the module specified in the from clause, loading and initializing it if necessary;

2. for each of the identifiers specified in the import clauses:

   (a) check if the imported module has an attribute by that name

   (b) if not, attempt to import a submodule with that name and then check the imported module again for that attribute

   (c) if the attribute is not found, ImportError is raised.

   (d) otherwise, a reference to that value is stored in the local namespace, using the name in the as clause if it is present, otherwise using the attribute name

Examples:

```
import foo                 # foo imported and bound locally
import foo.bar.baz         # foo.bar.baz imported, foo bound locally
import foo.bar.baz as fbb  # foo.bar.baz imported and bound as fbb
```

```
from foo.bar import baz     # foo.bar.baz imported and bound as baz
from foo import attr        # foo imported and foo.attr bound as attr
```

If the list of identifiers is replaced by a star (`'*'`), all public names defined in the module are bound in the local namespace for the scope where the import statement occurs.

The public names defined by a module are determined by checking the module's namespace for a variable named `__all__`; if defined, it must be a sequence of strings which are names defined or imported by that module. The names given in `__all__` are all considered public and are required to exist. If `__all__` is not defined, the set of public names includes all names found in the module's namespace which do not begin with an underscore character (`'_'`). `__all__` should contain the entire public API. It is intended to avoid accidentally exporting items that are not part of the API (such as library modules which were imported and used within the module).

The wild card form of import — from module import * — is only allowed at the module level. Attempting to use it in class or function definitions will raise a SyntaxError.

When specifying what module to import you do not have to specify the absolute name of the module. When a module or package is contained within another package it is possible to make a relative import within the same top package without having to mention the package name. By using leading dots in the specified module or package after from you can specify how high to traverse up the current package hierarchy without specifying exact names. One leading dot means the current package where the module making the import exists. Two dots means up one package level. Three dots is up two levels, etc. So if you execute from . import mod from a module in the pkg package then you will end up importing pkg.mod. If you execute from ..subpkg2 import mod from within pkg.subpkg1 you will import pkg.subpkg2.mod. The specification for relative imports is contained within PEP 328.

importlib.import_module() is provided to support applications that determine dynamically the modules to be loaded.

7.11.1 Future statements

A future statement is a directive to the compiler that a particular module should be compiled using syntax or semantics that will be available in a specified future release of Python where the feature becomes standard.

The future statement is intended to ease migration to future versions of Python that introduce incompatible changes to the language. It allows use of the new features on a per-module basis before the release in which the feature becomes standard.

```
future_statement   ::=    "from" "__future__" "import" feature ["as" name]
                          ("," feature ["as" name])*
                          | "from" "__future__" "import" "(" feature ["as" name]
                          ("," feature ["as" name])* [","] ")"
feature            ::=    identifier
name               ::=    identifier
```

A future statement must appear near the top of the module. The only lines that can appear before a future statement are:

- the module docstring (if any),

- comments,

- blank lines, and

- other future statements.

The features recognized by Python 3.0 are absolute_import, division, generators, unicode_literals, print_function, nested_scopes and with_statement. They are all redundant because they are always enabled, and only kept for backwards compatibility.

A future statement is recognized and treated specially at compile time: Changes to the semantics of core constructs are often implemented by generating different code. It may even be the case that a new feature introduces new incompatible syntax (such as a new reserved word), in which case the compiler may need to parse the module differently. Such decisions cannot be pushed off until runtime.

For any given release, the compiler knows which feature names have been defined, and raises a compile-time error if a future statement contains a feature not known to it.

The direct runtime semantics are the same as for any import statement: there is a standard module __future__, described later, and it will be imported in the usual way at the time the future statement is executed.

The interesting runtime semantics depend on the specific feature enabled by the future statement.

Note that there is nothing special about the statement:

```
import __future__ [as name]
```

That is not a future statement; it's an ordinary import statement with no special semantics or syntax restrictions.

Code compiled by calls to the built-in functions exec() and compile() that occur in a module M containing a future statement will, by default, use the new syntax or semantics associated with the future statement. This can be controlled by optional arguments to compile() — see the documentation of that function for details.

A future statement typed at an interactive interpreter prompt will take effect for the rest of the interpreter session. If an interpreter is started with the -i option, is passed a script name to execute, and the script includes a future statement, it will be in effect in the interactive session started after the script is executed.

See also:

PEP 236 - Back to the __future__ The original proposal for the __future__ mechanism.

7.12 The global statement

```
global_stmt   ::=   "global" identifier ("," identifier)*
```

The global statement is a declaration which holds for the entire current code block. It means that the listed identifiers are to be interpreted as globals. It would be impossible to assign to a global variable without global, although free variables may refer to globals without being declared global.

Names listed in a global statement must not be used in the same code block textually preceding that global statement.

Names listed in a global statement must not be defined as formal parameters or in a for loop control target, class definition, function definition, import statement, or variable annotation.

CPython implementation detail: The current implementation does not enforce some of these restriction, but programs should not abuse this freedom, as future implementations may enforce them or silently change the meaning of the program.

Programmer's note: global is a directive to the parser. It applies only to code parsed at the same time as the global statement. In particular, a global statement contained in a string or code object supplied to the

built-in exec() function does not affect the code block containing the function call, and code contained in such a string is unaffected by global statements in the code containing the function call. The same applies to the eval() and compile() functions.

7.13 The nonlocal statement

nonlocal_stmt   ::=   "nonlocal" identifier ("," identifier)*

The nonlocal statement causes the listed identifiers to refer to previously bound variables in the nearest enclosing scope excluding globals. This is important because the default behavior for binding is to search the local namespace first. The statement allows encapsulated code to rebind variables outside of the local scope besides the global (module) scope.

Names listed in a nonlocal statement, unlike those listed in a global statement, must refer to pre-existing bindings in an enclosing scope (the scope in which a new binding should be created cannot be determined unambiguously).

Names listed in a nonlocal statement must not collide with pre-existing bindings in the local scope.

See also:

PEP 3104 - Access to Names in Outer Scopes The specification for the nonlocal statement.

COMPOUND STATEMENTS

Compound statements contain (groups of) other statements; they affect or control the execution of those other statements in some way. In general, compound statements span multiple lines, although in simple incarnations a whole compound statement may be contained in one line.

The if, while and for statements implement traditional control flow constructs. try specifies exception handlers and/or cleanup code for a group of statements, while the with statement allows the execution of initialization and finalization code around a block of code. Function and class definitions are also syntactically compound statements.

A compound statement consists of one or more 'clauses.' A clause consists of a header and a 'suite.' The clause headers of a particular compound statement are all at the same indentation level. Each clause header begins with a uniquely identifying keyword and ends with a colon. A suite is a group of statements controlled by a clause. A suite can be one or more semicolon-separated simple statements on the same line as the header, following the header's colon, or it can be one or more indented statements on subsequent lines. Only the latter form of a suite can contain nested compound statements; the following is illegal, mostly because it wouldn't be clear to which if clause a following else clause would belong:

```
if test1: if test2: print(x)
```

Also note that the semicolon binds tighter than the colon in this context, so that in the following example, either all or none of the print() calls are executed:

```
if x < y < z: print(x); print(y); print(z)
```

Summarizing:

compound_stmt	::=	if_stmt
		| while_stmt
		| for_stmt
		| try_stmt
		| with_stmt
		| funcdef
		| classdef
		| async_with_stmt
		| async_for_stmt
		| async_funcdef
suite	::=	stmt_list NEWLINE | NEWLINE INDENT statement+ DEDENT
statement	::=	stmt_list NEWLINE | compound_stmt
stmt_list	::=	simple_stmt (";" simple_stmt)* [";"]

Note that statements always end in a NEWLINE possibly followed by a DEDENT. Also note that optional

continuation clauses always begin with a keyword that cannot start a statement, thus there are no ambiguities (the 'dangling else' problem is solved in Python by requiring nested if statements to be indented).

The formatting of the grammar rules in the following sections places each clause on a separate line for clarity.

8.1 The if statement

The if statement is used for conditional execution:

```
if_stmt    ::=    "if" expression ":" suite
                  ( "elif" expression ":" suite )*
                  ["else" ":" suite]
```

It selects exactly one of the suites by evaluating the expressions one by one until one is found to be true (see section Boolean operations for the definition of true and false); then that suite is executed (and no other part of the if statement is executed or evaluated). If all expressions are false, the suite of the else clause, if present, is executed.

8.2 The while statement

The while statement is used for repeated execution as long as an expression is true:

```
while_stmt    ::=    "while" expression ":" suite
                     ["else" ":" suite]
```

This repeatedly tests the expression and, if it is true, executes the first suite; if the expression is false (which may be the first time it is tested) the suite of the else clause, if present, is executed and the loop terminates.

A break statement executed in the first suite terminates the loop without executing the else clause's suite. A continue statement executed in the first suite skips the rest of the suite and goes back to testing the expression.

8.3 The for statement

The for statement is used to iterate over the elements of a sequence (such as a string, tuple or list) or other iterable object:

```
for_stmt    ::=    "for" target_list "in" expression_list ":" suite
                   ["else" ":" suite]
```

The expression list is evaluated once; it should yield an iterable object. An iterator is created for the result of the expression_list. The suite is then executed once for each item provided by the iterator, in the order returned by the iterator. Each item in turn is assigned to the target list using the standard rules for assignments (see Assignment statements), and then the suite is executed. When the items are exhausted (which is immediately when the sequence is empty or an iterator raises a StopIteration exception), the suite in the else clause, if present, is executed, and the loop terminates.

A break statement executed in the first suite terminates the loop without executing the else clause's suite. A continue statement executed in the first suite skips the rest of the suite and continues with the next item, or with the else clause if there is no next item.

The for-loop makes assignments to the variables(s) in the target list. This overwrites all previous assignments to those variables including those made in the suite of the for-loop:

```python
for i in range(10):
    print(i)
    i = 5              # this will not affect the for-loop
                       # because i will be overwritten with the next
                       # index in the range
```

Names in the target list are not deleted when the loop is finished, but if the sequence is empty, they will not have been assigned to at all by the loop. Hint: the built-in function range() returns an iterator of integers suitable to emulate the effect of Pascal's for i := a to b do; e.g., list(range(3)) returns the list [0, 1, 2].

Note: There is a subtlety when the sequence is being modified by the loop (this can only occur for mutable sequences, i.e. lists). An internal counter is used to keep track of which item is used next, and this is incremented on each iteration. When this counter has reached the length of the sequence the loop terminates. This means that if the suite deletes the current (or a previous) item from the sequence, the next item will be skipped (since it gets the index of the current item which has already been treated). Likewise, if the suite inserts an item in the sequence before the current item, the current item will be treated again the next time through the loop. This can lead to nasty bugs that can be avoided by making a temporary copy using a slice of the whole sequence, e.g.,

```python
for x in a[:]:
    if x < 0: a.remove(x)
```

8.4 The try statement

The try statement specifies exception handlers and/or cleanup code for a group of statements:

```
try_stmt   ::=   try1_stmt | try2_stmt
try1_stmt  ::=   "try" ":" suite
                 ("except" [expression ["as" identifier]] ":" suite)+
                 ["else" ":" suite]
                 ["finally" ":" suite]
try2_stmt  ::=   "try" ":" suite
                 "finally" ":" suite
```

The except clause(s) specify one or more exception handlers. When no exception occurs in the try clause, no exception handler is executed. When an exception occurs in the try suite, a search for an exception handler is started. This search inspects the except clauses in turn until one is found that matches the exception. An expression-less except clause, if present, must be last; it matches any exception. For an except clause with an expression, that expression is evaluated, and the clause matches the exception if the resulting object is "compatible" with the exception. An object is compatible with an exception if it is the class or a base class of the exception object or a tuple containing an item compatible with the exception.

If no except clause matches the exception, the search for an exception handler continues in the surrounding

code and on the invocation stack.[1]

If the evaluation of an expression in the header of an except clause raises an exception, the original search for a handler is canceled and a search starts for the new exception in the surrounding code and on the call stack (it is treated as if the entire try statement raised the exception).

When a matching except clause is found, the exception is assigned to the target specified after the as keyword in that except clause, if present, and the except clause's suite is executed. All except clauses must have an executable block. When the end of this block is reached, execution continues normally after the entire try statement. (This means that if two nested handlers exist for the same exception, and the exception occurs in the try clause of the inner handler, the outer handler will not handle the exception.)

When an exception has been assigned using as target, it is cleared at the end of the except clause. This is as if

```
except E as N:
    foo
```

was translated to

```
except E as N:
    try:
        foo
    finally:
        del N
```

This means the exception must be assigned to a different name to be able to refer to it after the except clause. Exceptions are cleared because with the traceback attached to them, they form a reference cycle with the stack frame, keeping all locals in that frame alive until the next garbage collection occurs.

Before an except clause's suite is executed, details about the exception are stored in the sys module and can be accessed via sys.exc_info(). sys.exc_info() returns a 3-tuple consisting of the exception class, the exception instance and a traceback object (see section The standard type hierarchy) identifying the point in the program where the exception occurred. sys.exc_info() values are restored to their previous values (before the call) when returning from a function that handled an exception.

The optional else clause is executed if and when control flows off the end of the try clause.[2] Exceptions in the else clause are not handled by the preceding except clauses.

If finally is present, it specifies a 'cleanup' handler. The try clause is executed, including any except and else clauses. If an exception occurs in any of the clauses and is not handled, the exception is temporarily saved. The finally clause is executed. If there is a saved exception it is re-raised at the end of the finally clause. If the finally clause raises another exception, the saved exception is set as the context of the new exception. If the finally clause executes a return or break statement, the saved exception is discarded:

```
>>> def f():
...     try:
...         1/0
...     finally:
...         return 42
...
>>> f()
42
```

The exception information is not available to the program during execution of the finally clause.

---

[1] The exception is propagated to the invocation stack unless there is a finally clause which happens to raise another exception. That new exception causes the old one to be lost.

[2] Currently, control "flows off the end" except in the case of an exception or the execution of a return, continue, or break statement.

When a return, break or continue statement is executed in the try suite of a try. . . finally statement, the finally clause is also executed 'on the way out.' A continue statement is illegal in the finally clause. (The reason is a problem with the current implementation — this restriction may be lifted in the future).

The return value of a function is determined by the last return statement executed. Since the finally clause always executes, a return statement executed in the finally clause will always be the last one executed:

```
>>> def foo():
...     try:
...         return 'try'
...     finally:
...         return 'finally'
...
>>> foo()
'finally'
```

Additional information on exceptions can be found in section Exceptions, and information on using the raise statement to generate exceptions may be found in section The raise statement.

8.5 The with statement

The with statement is used to wrap the execution of a block with methods defined by a context manager (see section With Statement Context Managers). This allows common try. . . except. . . finally usage patterns to be encapsulated for convenient reuse.

| with_stmt | ::= | "with" with_item ("," with_item)* ":" suite |
| with_item | ::= | expression ["as" target] |

The execution of the with statement with one "item" proceeds as follows:

1. The context expression (the expression given in the with_item) is evaluated to obtain a context manager.

2. The context manager's __exit__() is loaded for later use.

3. The context manager's __enter__() method is invoked.

4. If a target was included in the with statement, the return value from __enter__() is assigned to it.

Note: The with statement guarantees that if the __enter__() method returns without an error, then __exit__() will always be called. Thus, if an error occurs during the assignment to the target list, it will be treated the same as an error occurring within the suite would be. See step 6 below.

---

5. The suite is executed.

6. The context manager's __exit__() method is invoked. If an exception caused the suite to be exited, its type, value, and traceback are passed as arguments to __exit__(). Otherwise, three None arguments are supplied.

   If the suite was exited due to an exception, and the return value from the __exit__() method was false, the exception is reraised. If the return value was true, the exception is suppressed, and execution continues with the statement following the with statement.

   If the suite was exited for any reason other than an exception, the return value from __exit__() is ignored, and execution proceeds at the normal location for the kind of exit that was taken.

With more than one item, the context managers are processed as if multiple with statements were nested:

```
with A() as a, B() as b:
    suite
```

is equivalent to

```
with A() as a:
    with B() as b:
        suite
```

Changed in version 3.1: Support for multiple context expressions.

See also:

PEP 343 - The "with" statement The specification, background, and examples for the Python with statement.

8.6 Function definitions

A function definition defines a user-defined function object (see section The standard type hierarchy):

funcdef	::=	[decorators] "def" funcname "(" [parameter_list] ")" ["->" expression] ":" suite
decorators	::=	decorator+
decorator	::=	"@" dotted_name ["(" [argument_list [","]] ")"] NEWLINE
dotted_name	::=	identifier ("." identifier)*
parameter_list	::=	defparameter ("," defparameter)* ["," [parameter_list_starargs]]
		| parameter_list_starargs
parameter_list_starargs	::=	"*" [parameter] ("," defparameter)* ["," ["**" parameter [","]]]
		| "**" parameter [","]
parameter	::=	identifier [":" expression]
defparameter	::=	parameter ["=" expression]
funcname	::=	identifier

A function definition is an executable statement. Its execution binds the function name in the current local namespace to a function object (a wrapper around the executable code for the function). This function object contains a reference to the current global namespace as the global namespace to be used when the function is called.

The function definition does not execute the function body; this gets executed only when the function is called.[3]

A function definition may be wrapped by one or more decorator expressions. Decorator expressions are evaluated when the function is defined, in the scope that contains the function definition. The result must be a callable, which is invoked with the function object as the only argument. The returned value is bound to the function name instead of the function object. Multiple decorators are applied in nested fashion. For example, the following code

```
@f1(arg)
@f2
def func(): pass
```

---

[3] A string literal appearing as the first statement in the function body is transformed into the function's __doc__ attribute and therefore the function's docstring.

---

is roughly equivalent to

```
def func(): pass
func = f1(arg)(f2(func))
```

except that the original function is not temporarily bound to the name func.

When one or more parameters have the form parameter = expression, the function is said to have "default parameter values." For a parameter with a default value, the corresponding argument may be omitted from a call, in which case the parameter's default value is substituted. If a parameter has a default value, all following parameters up until the "*" must also have a default value — this is a syntactic restriction that is not expressed by the grammar.

Default parameter values are evaluated from left to right when the function definition is executed. This means that the expression is evaluated once, when the function is defined, and that the same "pre-computed" value is used for each call. This is especially important to understand when a default parameter is a mutable object, such as a list or a dictionary: if the function modifies the object (e.g. by appending an item to a list), the default value is in effect modified. This is generally not what was intended. A way around this is to use None as the default, and explicitly test for it in the body of the function, e.g.:

```
def whats_on_the_telly(penguin=None):
    if penguin is None:
        penguin = []
    penguin.append("property of the zoo")
    return penguin
```

Function call semantics are described in more detail in section Calls. A function call always assigns values to all parameters mentioned in the parameter list, either from position arguments, from keyword arguments, or from default values. If the form "*identifier" is present, it is initialized to a tuple receiving any excess positional parameters, defaulting to the empty tuple. If the form "**identifier" is present, it is initialized to a new ordered mapping receiving any excess keyword arguments, defaulting to a new empty mapping of the same type. Parameters after "*" or "*identifier" are keyword-only parameters and may only be passed used keyword arguments.

Parameters may have annotations of the form ": expression" following the parameter name. Any parameter may have an annotation even those of the form *identifier or **identifier. Functions may have "return" annotation of the form "-> expression" after the parameter list. These annotations can be any valid Python expression and are evaluated when the function definition is executed. Annotations may be evaluated in a different order than they appear in the source code. The presence of annotations does not change the semantics of a function. The annotation values are available as values of a dictionary keyed by the parameters' names in the __annotations__ attribute of the function object.

It is also possible to create anonymous functions (functions not bound to a name), for immediate use in expressions. This uses lambda expressions, described in section Lambdas. Note that the lambda expression is merely a shorthand for a simplified function definition; a function defined in a "def" statement can be passed around or assigned to another name just like a function defined by a lambda expression. The "def" form is actually more powerful since it allows the execution of multiple statements and annotations.

Programmer's note: Functions are first-class objects. A "def" statement executed inside a function definition defines a local function that can be returned or passed around. Free variables used in the nested function can access the local variables of the function containing the def. See section Naming and binding for details.

See also:

PEP 3107 - Function Annotations The original specification for function annotations.

8.7 Class definitions

A class definition defines a class object (see section The standard type hierarchy):

```
classdef      ::=    [decorators] "class" classname [inheritance] ":" suite
inheritance   ::=    "(" [argument_list] ")"
classname     ::=    identifier
```

A class definition is an executable statement. The inheritance list usually gives a list of base classes (see Metaclasses for more advanced uses), so each item in the list should evaluate to a class object which allows subclassing. Classes without an inheritance list inherit, by default, from the base class object; hence,

```
class Foo:
    pass
```

is equivalent to

```
class Foo(object):
    pass
```

The class's suite is then executed in a new execution frame (see Naming and binding), using a newly created local namespace and the original global namespace. (Usually, the suite contains mostly function definitions.) When the class's suite finishes execution, its execution frame is discarded but its local namespace is saved.[4] A class object is then created using the inheritance list for the base classes and the saved local namespace for the attribute dictionary. The class name is bound to this class object in the original local namespace.

The order in which attributes are defined in the class body is preserved in the new class's __dict__. Note that this is reliable only right after the class is created and only for classes that were defined using the definition syntax.

Class creation can be customized heavily using metaclasses.

Classes can also be decorated: just like when decorating functions,

```
@f1(arg)
@f2
class Foo: pass
```

is roughly equivalent to

```
class Foo: pass
Foo = f1(arg)(f2(Foo))
```

The evaluation rules for the decorator expressions are the same as for function decorators. The result is then bound to the class name.

Programmer's note: Variables defined in the class definition are class attributes; they are shared by instances. Instance attributes can be set in a method with self.name = value. Both class and instance attributes are accessible through the notation "self.name", and an instance attribute hides a class attribute with the same name when accessed in this way. Class attributes can be used as defaults for instance attributes, but using mutable values there can lead to unexpected results. Descriptors can be used to create instance variables with different implementation details.

See also:

---

[4] A string literal appearing as the first statement in the class body is transformed into the namespace's __doc__ item and therefore the class's docstring.

PEP 3115 - Metaclasses in Python 3 PEP 3129 - Class Decorators

8.8 Coroutines

New in version 3.5.

8.8.1 Coroutine function definition

> async_funcdef   ::=   [decorators] "async" "def" funcname "(" [parameter_list] ")" ["->" expression] ":" suite

Execution of Python coroutines can be suspended and resumed at many points (see coroutine). In the body of a coroutine, any await and async identifiers become reserved keywords; await expressions, async for and async with can only be used in coroutine bodies.

Functions defined with async def syntax are always coroutine functions, even if they do not contain await or async keywords.

It is a SyntaxError to use yield from expressions in async def coroutines.

An example of a coroutine function:

```
async def func(param1, param2):
    do_stuff()
    await some_coroutine()
```

8.8.2 The async for statement

> async_for_stmt   ::=   "async" for_stmt

An asynchronous iterable is able to call asynchronous code in its iter implementation, and asynchronous iterator can call asynchronous code in its next method.

The async for statement allows convenient iteration over asynchronous iterators.

The following code:

```
async for TARGET in ITER:
    BLOCK
else:
    BLOCK2
```

Is semantically equivalent to:

```
iter = (ITER)
iter = type(iter).__aiter__(iter)
running = True
while running:
    try:
        TARGET = await type(iter).__anext__(iter)
    except StopAsyncIteration:
        running = False
    else:
        BLOCK
```

```
else:
    BLOCK2
```

See also `__aiter__()` and `__anext__()` for details.

It is a SyntaxError to use async for statement outside of an async def function.

8.8.3 The async with statement

```
async_with_stmt   ::=    "async" with_stmt
```

An asynchronous context manager is a context manager that is able to suspend execution in its enter and exit methods.

The following code:

```
async with EXPR as VAR:
    BLOCK
```

Is semantically equivalent to:

```
mgr = (EXPR)
aexit = type(mgr).__aexit__
aenter = type(mgr).__aenter__(mgr)
exc = True

VAR = await aenter
try:
    BLOCK
except:
    if not await aexit(mgr, *sys.exc_info()):
        raise
else:
    await aexit(mgr, None, None, None)
```

See also `__aenter__()` and `__aexit__()` for details.

It is a SyntaxError to use async with statement outside of an async def function.

See also:

PEP 492 - Coroutines with async and await syntax

TOP-LEVEL COMPONENTS

The Python interpreter can get its input from a number of sources: from a script passed to it as standard input or as program argument, typed in interactively, from a module source file, etc. This chapter gives the syntax used in these cases.

9.1 Complete Python programs

While a language specification need not prescribe how the language interpreter is invoked, it is useful to have a notion of a complete Python program. A complete Python program is executed in a minimally initialized environment: all built-in and standard modules are available, but none have been initialized, except for sys (various system services), builtins (built-in functions, exceptions and None) and _ _main_ _. The latter is used to provide the local and global namespace for execution of the complete program.

The syntax for a complete Python program is that for file input, described in the next section.

The interpreter may also be invoked in interactive mode; in this case, it does not read and execute a complete program but reads and executes one statement (possibly compound) at a time. The initial environment is identical to that of a complete program; each statement is executed in the namespace of _ _main_ _.

Under Unix, a complete program can be passed to the interpreter in three forms: with the -c string command line option, as a file passed as the first command line argument, or as standard input. If the file or standard input is a tty device, the interpreter enters interactive mode; otherwise, it executes the file as a complete program.

9.2 File input

All input read from non-interactive files has the same form:

file_input   ::=   (NEWLINE | statement)*

This syntax is used in the following situations:

- when parsing a complete Python program (from a file or from a string);
- when parsing a module;
- when parsing a string passed to the exec() function;

9.3 Interactive input

Input in interactive mode is parsed using the following grammar:

interactive_input   ::=   [stmt_list] NEWLINE | compound_stmt NEWLINE

Note that a (top-level) compound statement must be followed by a blank line in interactive mode; this is needed to help the parser detect the end of the input.

9.4 Expression input

eval() is used for expression input. It ignores leading whitespace. The string argument to eval() must have the following form:

eval_input   ::=   expression_list NEWLINE*

FULL GRAMMAR SPECIFICATION

This is the full Python grammar, as it is read by the parser generator and used to parse Python source files:

```
# Grammar for Python

# NOTE WELL: You should also follow all the steps listed at
# https://devguide.python.org/grammar/

# Start symbols for the grammar:
#       single_input is a single interactive statement;
#       file_input is a module or sequence of commands read from an input file;
#       eval_input is the input for the eval() functions.
# NB: compound_stmt in single_input is followed by extra NEWLINE!
single_input: NEWLINE | simple_stmt | compound_stmt NEWLINE
file_input: (NEWLINE | stmt)* ENDMARKER
eval_input: testlist NEWLINE* ENDMARKER

decorator: '@' dotted_name [ '(' [arglist] ')' ] NEWLINE
decorators: decorator+
decorated: decorators (classdef | funcdef | async_funcdef)

async_funcdef: ASYNC funcdef
funcdef: 'def' NAME parameters ['->' test] ':' suite

parameters: '(' [typedargslist] ')'
typedargslist: (tfpdef ['=' test] (',' tfpdef ['=' test])* [',' [
        '*' [tfpdef] (',' tfpdef ['=' test])* [',' ['**' tfpdef [',']]]
    | '**' tfpdef [',']]]
  | '*' [tfpdef] (',' tfpdef ['=' test])* [',' ['**' tfpdef [',']]]
  | '**' tfpdef [','])
tfpdef: NAME [':' test]
varargslist: (vfpdef ['=' test] (',' vfpdef ['=' test])* [',' [
        '*' [vfpdef] (',' vfpdef ['=' test])* [',' ['**' vfpdef [',']]]
    | '**' vfpdef [',']]]
  | '*' [vfpdef] (',' vfpdef ['=' test])* [',' ['**' vfpdef [',']]]
  | '**' vfpdef [',']
)
vfpdef: NAME

stmt: simple_stmt | compound_stmt
simple_stmt: small_stmt (';' small_stmt)* [';'] NEWLINE
small_stmt: (expr_stmt | del_stmt | pass_stmt | flow_stmt |
            import_stmt | global_stmt | nonlocal_stmt | assert_stmt)
expr_stmt: testlist_star_expr (annassign | augassign (yield_expr|testlist) |
                ('=' (yield_expr|testlist_star_expr))*)
annassign: ':' test ['=' test]
```

```
testlist_star_expr: (test|star_expr) (',' (test|star_expr))* [',']
augassign: ('+=' | '-=' | '*=' | '@=' | '/=' | '%=' | '&=' | '|=' | '^=' |
            '<<=' | '>>=' | '**=' | '//=')
# For normal and annotated assignments, additional restrictions enforced by the interpreter
del_stmt: 'del' exprlist
pass_stmt: 'pass'
flow_stmt: break_stmt | continue_stmt | return_stmt | raise_stmt | yield_stmt
break_stmt: 'break'
continue_stmt: 'continue'
return_stmt: 'return' [testlist]
yield_stmt: yield_expr
raise_stmt: 'raise' [test ['from' test]]
import_stmt: import_name | import_from
import_name: 'import' dotted_as_names
# note below: the ('.' | '...') is necessary because '...' is tokenized as ELLIPSIS
import_from: ('from' (('.' | '...')* dotted_name | ('.' | '...')+)
             'import' ('*' | '(' import_as_names ')' | import_as_names))
import_as_name: NAME ['as' NAME]
dotted_as_name: dotted_name ['as' NAME]
import_as_names: import_as_name (',' import_as_name)* [',']
dotted_as_names: dotted_as_name (',' dotted_as_name)*
dotted_name: NAME ('.' NAME)*
global_stmt: 'global' NAME (',' NAME)*
nonlocal_stmt: 'nonlocal' NAME (',' NAME)*
assert_stmt: 'assert' test [',' test]

compound_stmt: if_stmt | while_stmt | for_stmt | try_stmt | with_stmt | funcdef | classdef | decorated | async_
→stmt
async_stmt: ASYNC (funcdef | with_stmt | for_stmt)
if_stmt: 'if' test ':' suite ('elif' test ':' suite)* ['else' ':' suite]
while_stmt: 'while' test ':' suite ['else' ':' suite]
for_stmt: 'for' exprlist 'in' testlist ':' suite ['else' ':' suite]
try_stmt: ('try' ':' suite
          ((except_clause ':' suite)+
           ['else' ':' suite]
           ['finally' ':' suite] |
           'finally' ':' suite))
with_stmt: 'with' with_item (',' with_item)*  ':' suite
with_item: test ['as' expr]
# NB compile.c makes sure that the default except clause is last
except_clause: 'except' [test ['as' NAME]]
suite: simple_stmt | NEWLINE INDENT stmt+ DEDENT

test: or_test ['if' or_test 'else' test] | lambdef
test_nocond: or_test | lambdef_nocond
lambdef: 'lambda' [varargslist] ':' test
lambdef_nocond: 'lambda' [varargslist] ':' test_nocond
or_test: and_test ('or' and_test)*
and_test: not_test ('and' not_test)*
not_test: 'not' not_test | comparison
comparison: expr (comp_op expr)*
# <> isn't actually a valid comparison operator in Python. It's here for the
# sake of a __future__ import described in PEP 401 (which really works :-)
comp_op: '<'|'>'|'=='|'>='|'<='|'<>'|'!='|'in'|'not' 'in'|'is'|'is' 'not'
star_expr: '*' expr
expr: xor_expr ('|' xor_expr)*
xor_expr: and_expr ('^' and_expr)*
and_expr: shift_expr ('&' shift_expr)*
```

```
shift_expr: arith_expr (('<<'|'>>') arith_expr)*
arith_expr: term (('+'|'-') term)*
term: factor (('*'|'@'|'/'|'%'|'//') factor)*
factor: ('+'|'-'|'~') factor | power
power: atom_expr ['**' factor]
atom_expr: [AWAIT] atom trailer*
atom: ('(' [yield_expr|testlist_comp] ')' |
       '[' [testlist_comp] ']' |
       '{' [dictorsetmaker] '}' |
       NAME | NUMBER | STRING+ | '...' | 'None' | 'True' | 'False')
testlist_comp: (test|star_expr) ( comp_for | (',' (test|star_expr))* [','] )
trailer: '(' [arglist] ')' | '[' subscriptlist ']' | '.' NAME
subscriptlist: subscript (',' subscript)* [',']
subscript: test | [test] ':' [test] [sliceop]
sliceop: ':' [test]
exprlist: (expr|star_expr) (',' (expr|star_expr))* [',']
testlist: test (',' test)* [',']
dictorsetmaker: ( ((test ':' test | '**' expr)
                   (comp_for | (',' (test ':' test | '**' expr))* [','])) |
                  ((test | star_expr)
                   (comp_for | (',' (test | star_expr))* [','])) )

classdef: 'class' NAME ['(' [arglist] ')'] ':' suite

arglist: argument (',' argument)*  [',']

# The reason that keywords are test nodes instead of NAME is that using NAME
# results in an ambiguity. ast.c makes sure it's a NAME.
# "test '=' test" is really "keyword '=' test", but we have no such token.
# These need to be in a single rule to avoid grammar that is ambiguous
# to our LL(1) parser. Even though 'test' includes '*expr' in star_expr,
# we explicitly match '*' here, too, to give it proper precedence.
# Illegal combinations and orderings are blocked in ast.c:
# multiple (test comp_for) arguments are blocked; keyword unpackings
# that precede iterable unpackings are blocked; etc.
argument: ( test [comp_for] |
            test '=' test |
            '**' test |
            '*' test )

comp_iter: comp_for | comp_if
comp_for: [ASYNC] 'for' exprlist 'in' or_test [comp_iter]
comp_if: 'if' test_nocond [comp_iter]

# not used in grammar, but may appear in "node" passed from Parser to Compiler
encoding_decl: NAME

yield_expr: 'yield' [yield_arg]
yield_arg: 'from' test | testlist
```

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as lib2to3; a standalone entry point is provided as Tools/scripts/2to3. See 2to3-reference.

abstract base class Abstract base classes complement duck-typing by providing a way to define interfaces when other techniques like hasattr() would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by isinstance() and issubclass(); see the abc module documentation. Python comes with many built-in ABCs for data structures (in the collections.abc module), numbers (in the numbers module), streams (in the io module), import finders and loaders (in the importlib.abc module). You can create your own ABCs with the abc module.

argument A value passed to a function (or method) when calling the function. There are two kinds of argument:

- keyword argument: an argument preceded by an identifier (e.g. name=) in a function call or passed as a value in a dictionary preceded by **. For example, 3 and 5 are both keyword arguments in the following calls to complex():

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- positional argument: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an iterable preceded by *. For example, 3 and 5 are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the Calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the parameter glossary entry, the FAQ question on the difference between arguments and parameters, and PEP 362.

asynchronous context manager An object which controls the environment seen in an async with statement by defining __aenter__() and __aexit__() methods. Introduced by PEP 492.

asynchronous generator   A function which returns an asynchronous generator iterator. It looks like a coroutine function defined with async def except that it contains yield expressions for producing a series of values usable in an async for loop.

Usually refers to a asynchronous generator function, but may refer to an asynchronous generator iterator in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain await expressions as well as async for, and async with statements.

asynchronous generator iterator   An object created by a asynchronous generator function.

This is an asynchronous iterator which when called using the __anext__() method returns an awaitable object which will execute that the body of the asynchronous generator function until the next yield expression.

Each yield temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the asynchronous generator iterator effectively resumes with another awaitable returned by __anext__(), it picks-up where it left-off. See PEP 492 and PEP 525.

asynchronous iterable   An object, that can be used in an async for statement. Must return an asynchronous iterator from its __aiter__() method. Introduced by PEP 492.

asynchronous iterator   An object that implements __aiter__() and __anext__() methods. __anext__ must return an awaitable object. async for resolves awaitable returned from asynchronous iterator's __anext__() method until it raises StopAsyncIteration exception. Introduced by PEP 492.

attribute   A value associated with an object which is referenced by name using dotted expressions. For example, if an object o has an attribute a it would be referenced as o.a.

awaitable   An object that can be used in an await expression. Can be a coroutine or an object with an __await__() method. See also PEP 492.

BDFL   Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file   A file object able to read and write bytes-like objects. Examples of binary files are files opened in binary mode ('rb', 'wb' or 'rb+'), sys.stdin.buffer, sys.stdout.buffer, and instances of io.BytesIO and gzip.GzipFile.

See also:

A text file reads and writes str objects.

bytes-like object   An object that supports the bufferobjects and can export a C-contiguous buffer. This includes all bytes, bytearray, and array.array objects, as well as many common memoryview objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include bytearray and a memoryview of a bytearray. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include bytes and a memoryview of a bytes object.

bytecode   Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in .pyc files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a virtual machine that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, int(3.15) converts the floating point number to the integer 3, but in 3+4.5, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a TypeError. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., float(3)+4.5 rather than just 3+4.5.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of -1), often written i in mathematics or j in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a j suffix, e.g., 3+1j. To get access to complex equivalents of the math module, use cmath. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a with statement by defining __enter__() and __exit__() methods. See PEP 343.

contiguous A buffer is considered contiguous exactly if it is either C-contiguous or Fortran contiguous. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the async def statement. See also PEP 492.

coroutine function A function which returns a coroutine object. A coroutine function may be defined with the async def statement, and may contain await, async for, and async with keywords. These were introduced by PEP 492.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the @wrapper syntax. Common examples for decorators are classmethod() and staticmethod().

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)

@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods __get__(), __set__(), or __delete__(). When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally,

using a.b to get, set or delete an attribute looks up the object named b in the class dictionary for a, but if b is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see Implementing Descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with __hash__() and __eq__() methods. Called a hash in Perl.

dictionary view The objects returned from dict.keys(), dict.values(), and dict.items() are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use list(dictview). See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the __doc__ attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using type() or isinstance(). (Note, however, that duck-typing can be complemented with abstract base classes.) Instead, it typically employs hasattr() tests or EAFP programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many try and except statements. The technique contrasts with the LBYL style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also statements which cannot be used as expressions, such as if. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with 'f' or 'F' are commonly called "f-strings" which is short for formatted string literals. See also PEP 498.

file object An object exposing a file-oriented API (with methods such as read() or write()) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called file-like objects or streams.

There are actually three categories of file objects: raw binary files, buffered binary files and text files. Their interfaces are defined in the io module. The canonical way to create a file object is by using the open() function.

file-like object A synonym for file object.

finder An object that tries to find the loader for a module that is being imported.

Since Python 3.3, there are two types of finder: meta path finders for use with sys.meta_path, and path entry finders for use with sys.path_hooks.

See PEP 302, PEP 420 and PEP 451 for much more detail.

floor division   Mathematical division that rounds down to nearest integer. The floor division operator is //. For example, the expression 11 // 4 evaluates to 2 in contrast to the 2.75 returned by float true division. Note that (-11) // 4 is -3 because that is -2.75 rounded downward. See PEP 238.

function   A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also parameter, method, and the Function definitions section.

function annotation   An arbitrary metadata value associated with a function parameter or return value. Its syntax is explained in section Function definitions. Annotations may be accessed via the __annotations__ special attribute of a function object.

Python itself does not assign any particular meaning to function annotations. They are intended to be interpreted by third-party libraries or tools. See PEP 3107, which describes some of their potential uses.

__future__   A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the __future__ module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection   The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles.

generator   A function which returns a generator iterator. It looks like a normal function except that it contains yield expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the next() function.

Usually refers to a generator function, but may refer to a generator iterator in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator   An object created by a generator function.

Each yield temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the generator iterator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

generator expression   An expression that returns an iterator. It looks like a normal expression followed by a for expression defining a loop variable, range, and an optional if expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function   A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the single dispatch glossary entry, the functools.singledispatch() decorator, and PEP 443.

GIL   See global interpreter lock.

global interpreter lock   The mechanism used by the CPython interpreter to assure that only one thread executes Python bytecode at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as dict) implicitly safe against concurrent access.

Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hashable An object is hashable if it has a hash value which never changes during its lifetime (it needs a __hash__() method), and can be compared to other objects (it needs an __eq__() method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their id().

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or path entries) that are searched by the path based finder for modules to import. During import, this list of locations usually comes from sys.path, but for subpackages it may also come from the parent package's __path__ attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a finder and loader object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch python with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember help(x)).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also interactive.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the garbage collector. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the __main__ module or the script being run has finished executing.

iterable   An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as list, str, and tuple) and some non-sequence types like dict, file objects, and objects of any classes you define with an __iter__() or __getitem__() method. Iterables can be used in a for loop and in many other places where a sequence is needed (zip(), map(), . . .). When an iterable object is passed as an argument to the built-in function iter(), it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call iter() or deal with iterator objects yourself. The for statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also iterator, sequence, and generator.

iterator   An object representing a stream of data. Repeated calls to the iterator's __next__() method (or passing it to the built-in function next()) return successive items in the stream. When no more data are available a StopIteration exception is raised instead. At this point, the iterator object is exhausted and any further calls to its __next__() method just raise StopIteration again. Iterators are required to have an __iter__() method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a list) produces a fresh new iterator each time you pass it to the iter() function or use it in a for loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function   A key function or collation function is a callable that returns a value used for sorting or ordering. For example, locale.strxfrm() is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include min(), max(), sorted(), list.sort(), heapq.merge(), heapq.nsmallest(), heapq.nlargest(), and itertools.groupby().

There are several ways to create a key function. For example. the str.lower() method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a lambda expression such as lambda r: (r[0], r[2]). Also, the operator module provides three key function constructors: attrgetter(), itemgetter(), and methodcaller(). See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument   See argument.

lambda   An anonymous inline function consisting of a single expression which is evaluated when the function is called. The syntax to create a lambda function is lambda [arguments]: expression

LBYL   Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the EAFP approach and is characterized by the presence of many if statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, if key in mapping: return mapping[key] can fail if another thread removes key from mapping after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list   A built-in Python sequence. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are O(1).

list comprehension   A compact way to process all or part of the elements in a sequence and return a list with the results. result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0] generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The if clause is optional. If omitted, all elements in range(256) are processed.

loader   An object that loads a module. It must define a method named load_module(). A loader is typically returned by a finder. See PEP 302 for details and importlib.abc.Loader for an abstract base class.

mapping   A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping abstract base classes. Examples include dict, collections.defaultdict, collections.OrderedDict and collections.Counter.

meta path finder   A finder returned by a search of sys.meta_path. Meta path finders are related to, but different from path entry finders.

   See importlib.abc.MetaPathFinder for the methods that meta path finders implement.

metaclass   The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

   More information can be found in Metaclasses.

method   A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first argument (which is usually called self). See function and nested scope.

method resolution order   Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module   An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of importing.

   See also package.

module spec   A namespace containing the import-related information used to load a module. An instance of importlib.machinery.ModuleSpec.

MRO   See method resolution order.

mutable   Mutable objects can change their value but keep their id(). See also immutable.

named tuple   Any tuple-like class whose indexable elements are also accessible using named attributes (for example, time.localtime() returns a tuple-like object where the year is accessible either with an index such as t[0] or with a named attribute like t.tm_year).

   A named tuple can be a built-in type such as time.struct_time, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function collections.namedtuple(). The latter approach automatically provides extra features such as a self-documenting representation like Employee(name='jones', title='programmer').

namespace   The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions builtins.open and os.open() are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing random.seed() or itertools.islice() makes it clear that those functions are implemented by the random and itertools modules, respectively.

namespace package   A PEP 420 package which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a regular package because they have no __init__.py file.

See also module.

nested scope   The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The nonlocal allows writing to outer scopes.

new-style class   Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like __slots__, descriptors, properties, __getattribute__(), class methods, and static methods.

object   Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any new-style class.

package   A Python module which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an __path__ attribute.

See also regular package and namespace package.

parameter   A named entity in a function (or method) definition that specifies an argument (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- positional-or-keyword: specifies an argument that can be passed either positionally or as a keyword argument. This is the default kind of parameter, for example foo and bar in the following:

```
def func(foo, bar=None): ...
```

- positional-only: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. abs()).

- keyword-only: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare * in the parameter list of the function definition before them, for example kw_only1 and kw_only2 in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- var-positional: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with *, for example args in the following:

```
def func(*args, **kwargs): ...
```

- var-keyword: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with **, for example kwargs in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the argument glossary entry, the FAQ question on the difference between arguments and parameters, the inspect.Parameter class, the Function definitions section, and PEP 362.

path entry   A single location on the import path which the path based finder consults to find modules for importing.

path entry finder   A finder returned by a callable on sys.path_hooks (i.e. a path entry hook) which knows how to locate modules given a path entry.

See importlib.abc.PathEntryFinder for the methods that path entry finders implement.

path entry hook A callable on the sys.path_hook list which returns a path entry finder if it knows how to find modules on a specific path entry.

path based finder One of the default meta path finders which searches an import path for modules.

path-like object An object representing a file system path. A path-like object is either a str or bytes object representing a path, or an object implementing the os.PathLike protocol. An object that supports the os.PathLike protocol can be converted to a str or bytes file system path by calling the os.fspath() function; os.fsdecode() and os.fsencode() can be used to guarantee a str or bytes result instead, respectively. Introduced by PEP 519.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in PEP 420.

positional argument See argument.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See PEP 411 for more details.

provisional package See provisional API.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a for statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in PEP 3155. For top-level functions and classes, the qualified name is the same as the object's name:

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

```
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the fully qualified name means the entire dotted path to the module, including any parent packages, e.g. email.mime.text:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the CPython implementation. The sys module defines a getrefcount() function that programmers can call to return the reference count for a particular object.

regular package A traditional package, such as a directory containing an __init__.py file.

See also namespace package.

__slots__ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An iterable which supports efficient element access using integer indices via the __getitem__() special method and defines a __len__() method that returns the length of the sequence. Some built-in sequence types are list, str, tuple, and bytes. Note that dict also supports __getitem__() and __len__(), but is considered a mapping rather than a sequence because the lookups use arbitrary immutable keys rather than integers.

The collections.abc.Sequence abstract base class defines a much richer interface that goes beyond just __getitem__() and __len__(), adding count(), index(), __contains__(), and __reversed__(). Types that implement this expanded interface can be registered explicitly using register().

single dispatch A form of generic function dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a sequence. A slice is created using the subscript notation, [] with colons between numbers when several are given, such as in variable_name[1:3:5]. The bracket (subscript) notation uses slice objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in Special method names.

statement A statement is part of a suite (a "block" of code). A statement is either an expression or one of several constructs with a keyword, such as if, while or for.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to named tuple in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like _make() or _asdict(). Examples of struct sequences include sys.float_info and the return value of os.stat().

text encoding A codec which encodes Unicode strings to bytes.

text file A file object able to read and write str objects. Often, a text file actually accesses a byte-oriented datastream and handles the text encoding automatically. Examples of text files are files opened in text mode ('r' or 'w'), sys.stdin, sys.stdout, and instances of io.StringIO.

See also:

A binary file reads and write bytes objects.

triple-quoted string   A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type   The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its __class__ attribute or can be retrieved with type(obj).

universal newlines   A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention '\n', the Windows convention '\r\n', and the old Macintosh convention '\r'. See PEP 278 and PEP 3116, as well as bytes.splitlines() for an additional use.

variable annotation   A type metadata value associated with a module global variable or a class attribute. Its syntax is explained in section Annotated assignment statements. Annotations are stored in the __annotations__ special attribute of a class or module object and can be accessed using typing. get_type_hints().

Python itself does not assign any particular meaning to variable annotations. They are intended to be interpreted by third-party libraries or type checking tools. See PEP 526, PEP 484 which describe some of their potential uses.

virtual environment   A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also venv.

virtual machine   A computer defined entirely in software. Python's virtual machine executes the bytecode emitted by the bytecode compiler.

Zen of Python   Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "import this" at the interactive prompt.

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;

- the Docutils project for creating reStructuredText and the Docutils suite;

- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

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The _random module includes code based on a download from http://www.math.sci.hiroshima-u.ac.jp/
~m-mat/MT/MT2002/emt19937ar.html. The following are the verbatim comments from the original code:

A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
email: m-mat @ math.sci.hiroshima-u.ac.jp (remove space)

C.3.2 Sockets

The socket module uses the functions, getaddrinfo(), and getnameinfo(), which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
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- Arguments more compliant with Python standard
```

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C.3.11 SipHash24

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
```

C.3.12 strtod and dtoa

The file Python/dtoa.c, which supplies C functions dtoa and strtod for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from http://www.netlib.org/fp/. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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C.3.18 libmpdec

The _decimal Module is built using an included copy of the libmpdec library unless the build is configured
--with-system-libmpdec:

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