# Python Tutorial

*發F 2.7.18*

**Guido van Rossum**
**and the Python development team**

**5 月 20, 2020**

# Contents

Python 是一種易學、功能F大的程式語言。它有高效能的高階資料結構，也有簡單但有效的方法去實現物件導向程式設計。Python 優雅的語法和動態型F，結合其直譯特性，使它成FF多領域和大多數平臺上，撰寫F本和快速開發應用程式的理想語言。

使用者可以自由且免費地從 Python 官網上 ([https://www.python.org/](https://www.python.org/)) 取得各大平台上用的 Python 直譯器和標准函式庫，下載其源碼或二進位形式執行檔，同時，也可以將其自由地散F。另外，Python 官網也提供了許多自由且免費的第三方 Python 模組、程式與工具、以及額外F明文件，有興趣的使用者，可在官網上找到相關的發行版本與連結網址。

使用 C 或 C++（或其他可被 C 呼叫的程式語言），可以很容易在 Python 直譯器F新增功能函式及資料型F。同時，對可讓使用者自F功能的應用程式來F，Python 也適合作F其擴充用界面語言 (extension language)。

這份教學將簡介 Python 語言與系統的基本概念及功能。除了F讀之外、實際用 Python 直譯器寫程式跑範例，將有助於學習。但如果只用讀的，也是可行的學習方式，因F所有範例的F容皆獨立且完整。

若想了解 Python 標准物件和模組的描述，請參F library-index。在 reference-index 中，您可以學到 Python 語言更正規的定義。想用 C 或 C++ 寫延伸套件 (extensions) 的讀者，請F讀 extending-index 和 c-api-index 。此外，市面上也能找到更深入的 Python 學習書。

這份教學中，我們不會介紹每一個功能，甚至，也不打算介紹完每一個常用功能。取而代之，我們的重心將放在介紹 Python 中最值得一提的那些功能，幫助您了解 Python 語言的特色與風格。讀完教學後，您將有能力F讀和撰寫 Python 模組與程式，也做好進一步學習 library-index 中各類型的 Python 函式庫模組的准備。

*Glossary* 頁面也值得細讀。

# 淺嘗滋味

如果你經常在電腦上工作，最終總能發現有些工作你會想要自動化。舉例來Ｆ，你會想在很多文字檔案Ｆ做相同的搜尋取代，或者是用個Ｆ雜的規則重新命名或整理一群照片。也有可能你想寫個自己的小資料庫，一個專門的 GUI 應用程式，或一個小Ｆ戲。

如果你是一個職業軟體開發者，你可能要操作數個 C/C++/Java 程式庫，Ｆ覺得平常寫程式碼、編譯、測試、再編譯的流程太慢；有可能你正Ｆ了一個程式庫撰寫一套測試集，但發現寫測試單調乏味；也有可能你正在開發一個能使用某一語言擴充的程式，但Ｆ不想要Ｆ了這程式特Ｆ設計一個全新的擴充語言。

在上述的例子中，Python 正是你合適的語言。

也許你可以Ｆ了某些任務而寫個 Unix shell Ｆ本或者 Windows 批次檔來處理，但 shell Ｆ本最適合於搬動檔案或更動文字Ｆ容，而不適於圖形應用程式或Ｆ戲。你可以Ｆ此寫個 C/C++/Java 程式，但僅僅是完成個草稿也需要很長的開發時間。相較而言，Python 更易於使用，Ｆ能在 Windows、Mac OSX、Unix 作業系統上執行，且能更快速地幫助你完成工作。

Python 即便易用也是個貨真價實的程式語言。它提供比 shell Ｆ本、批次檔更多樣的程式架構與更多的支援。另一方面，Python 提供比 C 更豐富的錯語檢查。相較於 C，Python 作Ｆ一個「非常高階的程式語言」，它Ｆ建了高階的資料型Ｆ如彈性的數列與字典。因Ｆ這些多用途的資料型Ｆ，Python 適用解Ｆ比 Awk（甚至是 Perl）能處理的更多問題上。至少在許多事情中，使用 Python 處理起來跟其他語言是同樣容易的。

Python 允許你把程式切割成許多模組 (module) Ｆ將他們重覆運用至其他 Python 程式中。Python 自帶了一個很大集合的標准模組，它們能做Ｆ你程式的基礎—或把它們當作一開始學寫 Python 程式的範例。有些模組提供了如檔案 I/O、系統呼叫、socket 的功能，甚至提供了 Tk 等圖形介面工具庫 (GUI toolkit) 的介面。

Python 是個直譯式語言，因Ｆ不需要編譯與連結，能Ｆ你在開發過程中省下可觀的時間。它的直譯器能互動地使用，因此能很方便地實驗每個語言的功能、寫些用完即Ｆ的程式、幫助測試一些從細部開始開發的函式。它也是個好用的計算機。

Python 讓程式寫得精簡Ｆ易讀。用 Python 實作的程式長度往往遠比用 C、C++、Java 實作的短。這有以下幾個原因：

- Python 高階的資料型Ｆ能在一陳述句 (statement) 中表達很Ｆ雜的操作；

- 陳述句的段落以縮排Ｆ區格而非括號；

- 不需要宣告變數和引數；

Python 是可擴充的：如果你會寫 C 程式，那⊡要加個新的⊡建函式或模組到直譯器中是很容易的。無論是⊡了用最快速的執行速度完成一些關鍵的操作，或是讓 Python 連結到一些僅以二進元形式 (binary form) 釋出的程式庫（例如特定供應商的繪圖程式庫）。如果你想更多這樣的結合，你其實也可以把 Python 直譯器連結到用 C 寫的應用程式，⊡在該應用程式中使用 Python 寫擴充或者作⊡下達指令的語言。

順帶一提，這個語言是以 BBC 的戲劇《Monty Python' s Flying Circus》命名，與爬蟲類完全⊡有關⊡。在⊡明文件中引用他們的喜劇不但⊡問題，這甚至是個被鼓勵的行⊡！

如果你現在已經躍躍欲試，你會想了解 Python 更多細節，而學習語言的最好方式就是直接使用它。接下來這個教學就將帶領你，一邊⊡讀，一邊將所學用在 Python 直譯器中玩耍。

在下個章節中，將會解⊡如何使用該直譯器。這也許只是個普通的資訊，但你必須試著操作接下來呈現的範例。

接下來的教學⊡，將會透過許多範例介紹 Python 語言與其系統的諸多特色。一開始是簡單的表示句 (expression)、陳述句 (statement) 和資料型⊡ (data type)；接著是函式 (function) 與模組 (module)；最後會接觸一些較進階的主題如例外狀⊡ (exception) 與使用者自定義類⊡ (class)。

使用 Python 直譯器

## 2.1 $\mathbb{F}$動直譯器

The Python interpreter is usually installed as /usr/local/bin/python on those machines where it is available; putting /usr/local/bin in your Unix shell's search path makes it possible to start it by typing the command

```
python
```

to the shell. Since the choice of the directory where the interpreter lives is an installation option, other places are possible; check with your local Python guru or system administrator. (E.g., /usr/local/python is a popular alternative location.)

On Windows machines, the Python installation is usually placed in C:\Python27, though you can change this when you're running the installer. To add this directory to your path, you can type the following command into the command prompt in a DOS box:

```
set path=%path%;C:\python27
```

在主提示符輸入一個 end-of-file 字元（在 Unix 上$\mathbb{F}$ Control-D；在 Windows 上$\mathbb{F}$ Control-Z）會使得直譯器以零退出狀$\mathbb{F}$ (zero exit status) 離開。如果上述的做法$\mathbb{F}$有效，也可以輸入指令 quit() 離開直譯器。

The interpreter's line-editing features usually aren't very sophisticated. On Unix, whoever installed the interpreter may have enabled support for the GNU readline library, which adds more elaborate interactive editing and history features. Perhaps the quickest check to see whether command line editing is supported is typing Control-P to the first Python prompt you get. If it beeps, you have command line editing; see Appendix *Interactive Input Editing and History Substitution* for an introduction to the keys. If nothing appears to happen, or if ^P is echoed, command line editing isn't available; you'll only be able to use backspace to remove characters from the current line.

這個直譯器使用起來像是 Unix shell：如果它被呼叫時連結至一個 tty 裝置，它會互動式地讀取$\mathbb{F}$執行指令；如果被呼叫時給定檔名$\mathbb{F}$引數或者使用 stdin 傳入檔案$\mathbb{F}$容，它會將這個檔案視$\mathbb{F}\mathbb{F}$本來$\mathbb{F}$讀。

另一個起動直譯器的方式$\mathbb{F}$ python -c command [arg] ...，它會執行在 *command* $\mathbb{F}$的指令（們），行$\mathbb{F}$如同 shell 的 -c 選項。因$\mathbb{F}$ Python 的指令包含空白等 shell 用到的特殊字元，通常建議用單引號把 *command* 包起來。

有些 Python 模組使用上如腳本般一樣方便。透過 `python -m module [arg] ...` 可以執行 *module* 模組的原始碼，就如同直接傳入那個模組的完整路徑一樣的行為。

當要執行一個腳本檔時，有時候會希望在腳本結束時進入互動模式。此時可在執行腳本的指令加入 `-i`。

All command-line options are described in using-on-general.

### 2.1.1 傳遞引數

當直譯器收到腳本的名稱和額外的引數後，他們會轉換成由字串所組成的 list（串列）並指派給 `sys` 模組的 `argv` 變數。你可以執行 `import sys` 取得這個串列。這個串列的長度至少為一；當沒有給任何腳本名稱和引數時，`sys.argv[0]` 為空字串。當腳本名為 `'-'`（指標準輸入）時，`sys.argv[0]` 為 `'-'`。當使用 `-c command` 時，`sys.argv[0]` 為 `'-c'`。當使用 `-m module` 時，`sys.argv[0]` 為該模組存在的完整路徑。其餘非 `-c command` 或 `-m module` 的選項不會被 Python 直譯器吸收掉，而是留在 `sys.argv` 變數中給後續的 command 或 module 使用。

### 2.1.2 互動模式

When commands are read from a tty, the interpreter is said to be in *interactive mode*. In this mode it prompts for the next command with the *primary prompt*, usually three greater-than signs (>>>); for continuation lines it prompts with the *secondary prompt*, by default three dots (...). The interpreter prints a welcome message stating its version number and a copyright notice before printing the first prompt:

```
python
Python 2.7 (#1, Feb 28 2010, 00:02:06)
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

接續多行的情況出現在需要多行才能建立完整指令時。舉例來說，像是 `if` 陳述：

```
>>> the_world_is_flat = 1
>>> if the_world_is_flat:
...     print "Be careful not to fall off!"
...
Be careful not to fall off!
```

更多有關互動模式的使用，請見互動模式。

## 2.2 直譯器與它的環境

### 2.2.1 原始碼的字元編碼 (encoding)

By default, Python source files are treated as encoded in ASCII. To declare an encoding other than the default one, a special comment line should be added as the *first* line of the file. The syntax is as follows:

```
# -*- coding: encoding -*-
```

where *encoding* is one of the valid `codecs` supported by Python.

For example, to declare that Windows-1252 encoding is to be used, the first line of your source code file should be:

```
# -*- coding: cp1252 -*-
```

One exception to the *first line* rule is when the source code starts with a *UNIX「shebang」line*. In this case, the encoding declaration should be added as the second line of the file. For example:

```
#!/usr/bin/env python
# -*- coding: cp1252 -*-
```

一個非正式的 Python 簡介

在下面的例子中，輸入與輸出的區囝在於有無提示符（prompt，»> 和…）：如果要重做範例，你必須在提示符出現的時候，輸入提示符後方的所有囝容；那些非提示符開始的文字行是直譯器的輸出。注意到在範例中，若出現單行只有次提示符時，代表該行你必須直接囝行；這被使用在多行指令結束輸入時。

在本手囝中的許多範例中，即便他們囝互動式地輸入，仍然包含囝解。Python 中的囝解 (comments) 由 hash 字元 # 開始一直到該行結束。囝解可以從該行之首、空白後、或程式碼之後開始，但不會出現在字串之中。hash 字元在字串之中時仍視囝一 hash 字元。因囝囝解只是用來囝明程式而不會被 Python 解讀，在練習範例時不一定要輸入。

一些範例如下：

```
# this is the first comment
spam = 1  # and this is the second comment
          # ... and now a third!
text = "# This is not a comment because it's inside quotes."
```

## 3.1 把 Python 當作計算機使用

讓我們來試試一些簡單的 Python 指令。囝動直譯器囝等待第一個主提示符 >>> 出現。（應該不會等太久）

### 3.1.1 數字 (Number)

直譯器如同一台簡單的計算機：你可以輸入一個 expression（運算式），它會寫出該式的值。Expression 的語法很使用：運算子 +、-、* 和 / 的行囝如同大多數的程式語言（例如：Pascal 或 C）；括號 () 可以用來分群。例如：

```
>>> 2 + 2
4
>>> 50 - 5*6
20
```

```
>>> (50 - 5.0*6) / 4
5.0
>>> 8 / 5.0
1.6
```

整數數字（即 2、4、20）⊡ int 型態，數字有小數點部份的（即 5.0、1.6）⊡ float 型態。我們將在之後的教學中看到更多數字相關的型態。

The return type of a division (/) operation depends on its operands. If both operands are of type int, *floor division* is performed and an int is returned. If either operand is a float, classic division is performed and a float is returned. The // operator is also provided for doing floor division no matter what the operands are. The remainder can be calculated with the % operator:

```
>>> 17 / 3  # int / int -> int
5
>>> 17 / 3.0  # int / float -> float
5.666666666666667
>>> 17 // 3.0  # explicit floor division discards the fractional part
5.0
>>> 17 % 3  # the % operator returns the remainder of the division
2
>>> 5 * 3 + 2  # result * divisor + remainder
17
```

在 Python 中，計算⊡次 (powers) 可以使用 ** 運算子[1]：

```
>>> 5 ** 2  # 5 squared
25
>>> 2 ** 7  # 2 to the power of 7
128
```

等於符號 (=) 可以用於⊡變數賦值。賦值完之後，在下個指示符前⊡不會顯示任何結果：

```
>>> width = 20
>>> height = 5 * 9
>>> width * height
900
```

如果一個變數未被「定義 (defined)」（即變數未被賦值），試著使用它時會出現一個錯誤：

```
>>> n  # try to access an undefined variable
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'n' is not defined
```

浮點數的運算有完善的支援，運算子 (operator) 遇上混合的運算元 (operand) 時會把整數的運算元轉⊡⊡浮點數：

```
>>> 3 * 3.75 / 1.5
7.5
>>> 7.0 / 2
3.5
```

在互動式模式中，最後一個印出的運算式的結果會被指派至變數 _ 中。這表示當你把 Python 當作桌上計算機使用者，要接續計算變得容易許多：

---

[1] 因⊡ ** 擁有較 - 高的優先次序，-3**2 會被解釋⊡ -(3**2) ⊡得到 -9。如果要避免這樣的優先順序以得到 9，你可以使用 (-3)**2。

---

```
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

這個變數應該被使用者視⿱只能讀取。不應該明確地⿱它賦值─你可以創一個獨立但名稱相同的本地變數來覆蓋掉預設變數和它的神奇行⿱。

除了 `int` 和 `float`，Python 還支援了其他的數字型態，包含 `Decimal` 和 `Fraction`。Python 亦⿱建支援⿱數 (complex numbers)，⿱使用 `j` 和 `J` 後綴來指定⿱數的部份 (即 `3+5j`)。

### 3.1.2 字串 (String)

除了數字之外，Python 也可以操作字串，而表達字串有數種方式。它們可以用包含在單引號 (`'...'`) 或雙引號 (`"..."`) 之中，兩者會得到相同的結果[2]。使用 `\` 跳⿱出現於字串中的引號：

```
>>> 'spam eggs'  # single quotes
'spam eggs'
>>> 'doesn\'t'  # use \' to escape the single quote...
"doesn't"
>>> "doesn't"  # ...or use double quotes instead
"doesn't"
>>> '"Yes," they said.'
'"Yes," they said.'
>>> "\"Yes,\" they said."
'"Yes," they said.'
>>> '"Isn\'t," they said.'
'"Isn\'t," they said.'
```

In the interactive interpreter, the output string is enclosed in quotes and special characters are escaped with backslashes. While this might sometimes look different from the input (the enclosing quotes could change), the two strings are equivalent. The string is enclosed in double quotes if the string contains a single quote and no double quotes, otherwise it is enclosed in single quotes. The `print` statement produces a more readable output, by omitting the enclosing quotes and by printing escaped and special characters:

```
>>> '"Isn\'t," they said.'
'"Isn\'t," they said.'
>>> print '"Isn\'t," they said.'
"Isn't," they said.
>>> s = 'First line.\nSecond line.'  # \n means newline
>>> s  # without print, \n is included in the output
'First line.\nSecond line.'
>>> print s  # with print, \n produces a new line
First line.
Second line.
```

如果你不希望字元前出現 `\` 就被當成特殊字元時，可以改使用 *raw string*，在第一個包圍引號前加上 `r`：

---

[2] 不像其他語言，特殊符號如 `\n` 在單 (`'...'`) 和雙 (`"..."`) 括號中有相同的意思。兩種刮號的唯一差⿱，在於使用單刮號時，不需要跳⿱ (escape) `"` (但需要跳⿱ `\'`)，反之亦同。

```
>>> print 'C:\some\name'  # here \n means newline!
C:\some
ame
>>> print r'C:\some\name'  # note the r before the quote
C:\some\name
```

字串值可以跨越數行。其中一方式是使用三個重覆引號：`"""..."""` 或 `'''...'''`。此時⬚行會被自動加入字串值中，但也可以在⬚行前加入 \ 來取消這個行⬚。在以下的例子中：

```
print """\
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
"""
```

會⬚生以下的輸出（注意第一個⬚行⬚⬚有被包含進字串值中）：

```
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
```

字串可以使用 + 運算子連接 (concatenate)，⬚用 * 重覆該字串的⬚容：

```
>>> # 3 times 'un', followed by 'ium'
>>> 3 * 'un' + 'ium'
'unununium'
```

兩個以上相鄰的字串值（*string literal*，即被引號包圍的字串）會被自動連接起來：

```
>>> 'Py' 'thon'
'Python'
```

當你想要分段一個非常長的字串時，兩相鄰字串值自動連接的特性十分有用：

```
>>> text = ('Put several strings within parentheses '
...         'to have them joined together.')
>>> text
'Put several strings within parentheses to have them joined together.'
```

但這特性只限於兩相鄰的字串值間，而非兩相鄰變數或表達式：

```
>>> prefix = 'Py'
>>> prefix 'thon'  # can't concatenate a variable and a string literal
  ...
SyntaxError: invalid syntax
>>> ('un' * 3) 'ium'
  ...
SyntaxError: invalid syntax
```

如果要連接變數們或一個變數與一個字串值，使用 +：

```
>>> prefix + 'thon'
'Python'
```

字串可以被「索引 *indexed*」（下標，即 subscripted），第一個字元的索引值⬚ 0。⬚有獨立表示字元的型⬚；一個字元就是一個大小⬚ 1 的字串：

```
>>> word = 'Python'
>>> word[0]  # character in position 0
'P'
>>> word[5]  # character in position 5
'n'
```

索引值可以是負的，此時改成從右開始計數：

```
>>> word[-1]  # last character
'n'
>>> word[-2]  # second-last character
'o'
>>> word[-6]
'P'
```

注意到因⊞ -0 等同於 0，負的索引值由 -1 開始。

In addition to indexing, *slicing* is also supported. While indexing is used to obtain individual characters, *slicing* allows you to obtain a substring:

```
>>> word[0:2]  # characters from position 0 (included) to 2 (excluded)
'Py'
>>> word[2:5]  # characters from position 2 (included) to 5 (excluded)
'tho'
```

注意到起點永遠被包含，而結尾永遠不被包含。這確保了 s[:i] + s[i:] 永遠等於 s：

```
>>> word[:2] + word[2:]
'Python'
>>> word[:4] + word[4:]
'Python'
```

切片索引 (slice indices) 有很常用的預設值，省略起點索引值時預設⊞ 0，而省略第二個索引值時預設整個字串被包含在 slice 中：

```
>>> word[:2]  # character from the beginning to position 2 (excluded)
'Py'
>>> word[4:]  # characters from position 4 (included) to the end
'on'
>>> word[-2:]  # characters from the second-last (included) to the end
'on'
```

這⊞有個簡單記住 slice 是如何運作的方式。想像 slice 的索引值指著字元們之間，其中第一個字元的左側邊緣由 0 計數。則 $n$ 個字元的字串中最後一個字元的右側邊緣會有索引值 $n$，例如：

```
 +---+---+---+---+---+---+
 | P | y | t | h | o | n |
 +---+---+---+---+---+---+
 0   1   2   3   4   5   6
-6  -5  -4  -3  -2  -1
```

第一行數字給定字串索引值⊞ 0…6 的位置；第二行則標示了負索引值的位置。由 $i$ 至 $j$ 的 slice 包含了標示 $i$ 和 $j$ 邊緣間的所有字元。

對非負數的索引值而言，一個 slice 的長度等於其索引值之差，如果索引值落在字串邊界⊞。例如，word[1:3] 的長度是 2。

嘗試使用一個過大的索引值會造成錯誤：

```
>>> word[42]  # the word only has 6 characters
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
```

然而，超出範圍的索引值在 slice 中會被妥善的處理：

```
>>> word[4:42]
'on'
>>> word[42:]
''
```

Python 字串無法被改變—它們是*immutable*。因此，嘗試對字串中某個索引位置賦值會⬚生錯誤：

```
>>> word[0] = 'J'
  ...
TypeError: 'str' object does not support item assignment
>>> word[2:] = 'py'
  ...
TypeError: 'str' object does not support item assignment
```

如果你需要一個不一樣的字串，你必須建立一個新的：

```
>>> 'J' + word[1:]
'Jython'
>>> word[:2] + 'py'
'Pypy'
```

⬚建的函式 `len()` 回傳一個字串的長度：

```
>>> s = 'supercalifragilisticexpialidocious'
>>> len(s)
34
```

**也參考:**

**typesseq**  Strings, and the Unicode strings described in the next section, are examples of *sequence types*, and support the common operations supported by such types.

**string-methods**  Both strings and Unicode strings support a large number of methods for basic transformations and searching.

**formatstrings**  關於透過 `str.format()` 字串格式化 (string formatting) 的資訊。

**string-formatting**  The old formatting operations invoked when strings and Unicode strings are the left operand of the `%` operator are described in more detail here.

## 3.1.3 Unicode Strings

Starting with Python 2.0 a new data type for storing text data is available to the programmer: the Unicode object. It can be used to store and manipulate Unicode data (see http://www.unicode.org/) and integrates well with the existing string objects, providing auto-conversions where necessary.

Unicode has the advantage of providing one ordinal for every character in every script used in modern and ancient texts. Previously, there were only 256 possible ordinals for script characters. Texts were typically bound to a code page which mapped the ordinals to script characters. This lead to very much confusion especially with respect to internationalization (usually written as `i18n` —`'i'` + 18 characters + `'n'`) of software. Unicode solves these problems by defining one code page for all scripts.

Creating Unicode strings in Python is just as simple as creating normal strings:

```
>>> u'Hello World !'
u'Hello World !'
```

The small `'u'` in front of the quote indicates that a Unicode string is supposed to be created. If you want to include special characters in the string, you can do so by using the Python *Unicode-Escape* encoding. The following example shows how:

```
>>> u'Hello\u0020World !'
u'Hello World !'
```

The escape sequence `\u0020` indicates to insert the Unicode character with the ordinal value 0x0020 (the space character) at the given position.

Other characters are interpreted by using their respective ordinal values directly as Unicode ordinals. If you have literal strings in the standard Latin-1 encoding that is used in many Western countries, you will find it convenient that the lower 256 characters of Unicode are the same as the 256 characters of Latin-1.

For experts, there is also a raw mode just like the one for normal strings. You have to prefix the opening quote with 『ur』 to have Python use the *Raw-Unicode-Escape* encoding. It will only apply the above `\uXXXX` conversion if there is an uneven number of backslashes in front of the small 『u』.

```
>>> ur'Hello\u0020World !'
u'Hello World !'
>>> ur'Hello\\u0020World !'
u'Hello\\\\u0020World !'
```

The raw mode is most useful when you have to enter lots of backslashes, as can be necessary in regular expressions.

Apart from these standard encodings, Python provides a whole set of other ways of creating Unicode strings on the basis of a known encoding.

The built-in function `unicode()` provides access to all registered Unicode codecs (COders and DECoders). Some of the more well known encodings which these codecs can convert are *Latin-1*, *ASCII*, *UTF-8*, and *UTF-16*. The latter two are variable-length encodings that store each Unicode character in one or more bytes. The default encoding is normally set to ASCII, which passes through characters in the range 0 to 127 and rejects any other characters with an error. When a Unicode string is printed, written to a file, or converted with `str()`, conversion takes place using this default encoding.

```
>>> u"abc"
u'abc'
>>> str(u"abc")
'abc'
>>> u"äöü"
u'\xe4\xf6\xfc'
>>> str(u"äöü")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
UnicodeEncodeError: 'ascii' codec can't encode characters in position 0-2: ordinal
→not in range(128)
```

To convert a Unicode string into an 8-bit string using a specific encoding, Unicode objects provide an `encode()` method that takes one argument, the name of the encoding. Lowercase names for encodings are preferred.

```
>>> u"äöü".encode('utf-8')
'\xc3\xa4\xc3\xb6\xc3\xbc'
```

If you have data in a specific encoding and want to produce a corresponding Unicode string from it, you can use the `unicode()` function with the encoding name as the second argument.

```
>>> unicode('\xc3\xa4\xc3\xb6\xc3\xbc', 'utf-8')
u'\xe4\xf6\xfc'
```

### 3.1.4 List（串列）

Python 理解數種⬚合型資料型⬚，用來組合不同的數值。當中最多樣變化的型⬚⬚ *list*，可以寫成一系列以逗號分隔的數值（稱之元素，即 item），包含在方括號之中。List 可以包合不同型⬚的元素，但通常這些元素會有相同的型⬚：

```
>>> squares = [1, 4, 9, 16, 25]
>>> squares
[1, 4, 9, 16, 25]
```

如同字串（以及其他⬚建的 *sequence* 型⬚），list 可以被索引和切片 (slice)：

```
>>> squares[0]  # indexing returns the item
1
>>> squares[-1]
25
>>> squares[-3:]  # slicing returns a new list
[9, 16, 25]
```

所有 slice 操作都會回傳一個新的 list 包含要求的元素。這意謂著以下這個 slice ⬚⬚了原本 list（淺⬚⬚，即 shallow copy）：

```
>>> squares[:]
[1, 4, 9, 16, 25]
```

Lists also supports operations like concatenation:

```
>>> squares + [36, 49, 64, 81, 100]
[1, 4, 9, 16, 25, 36, 49, 64, 81, 100]
```

不同於字串是 *immutable*，list 是 *mutable* 型⬚，即改變 list 的⬚容是可能的：

```
>>> cubes = [1, 8, 27, 65, 125]  # something's wrong here
>>> 4 ** 3  # the cube of 4 is 64, not 65!
64
>>> cubes[3] = 64  # replace the wrong value
>>> cubes
[1, 8, 27, 64, 125]
```

你也可以在 list 的最後加入新元素，透過使用 append() 方法 (method)（我們稍後會看到更多方法的⬚明）：

```
>>> cubes.append(216)  # add the cube of 6
>>> cubes.append(7 ** 3)  # and the cube of 7
>>> cubes
[1, 8, 27, 64, 125, 216, 343]
```

也可以對 slice 賦值，這能改變 list 的大小，甚至是清空一個 list：

```
>>> letters = ['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> letters
['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> # replace some values
```

```
>>> letters[2:5] = ['C', 'D', 'E']
>>> letters
['a', 'b', 'C', 'D', 'E', 'f', 'g']
>>> # now remove them
>>> letters[2:5] = []
>>> letters
['a', 'b', 'f', 'g']
>>> # clear the list by replacing all the elements with an empty list
>>> letters[:] = []
>>> letters
[]
```

F建的函式 `len()` 亦可以作用在 list 上：

```
>>> letters = ['a', 'b', 'c', 'd']
>>> len(letters)
4
```

也可以嵌套多層 list（建立 list 包含其他 list），例如：

```
>>> a = ['a', 'b', 'c']
>>> n = [1, 2, 3]
>>> x = [a, n]
>>> x
[['a', 'b', 'c'], [1, 2, 3]]
>>> x[0]
['a', 'b', 'c']
>>> x[0][1]
'b'
```

## 3.2 初探程式設計的前幾步

Of course, we can use Python for more complicated tasks than adding two and two together. For instance, we can write an initial sub-sequence of the *Fibonacci* series as follows:

```
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while b < 10:
...     print b
...     a, b = b, a+b
...
1
1
2
3
5
8
```

這例子引入了許多新的特性。

- 第一行出現了多重賦值：變數 a 與 b 同時得到了新的值 0 與 1。在最後一行同樣的賦值再被使用了一次，示範了等號的右項運算 (expression) 會先被計算 (evaluate)，賦值再發生。右項的運算式由左至右依序被計算。

- The `while` loop executes as long as the condition (here: `b < 10`) remains true. In Python, like in C, any non-zero integer value is true; zero is false. The condition may also be a string or list value, in fact any sequence; anything with a non-zero length is true, empty sequences are false. The test used in the example is a simple comparison. The standard comparison operators are written the same as in C: < (less than), > (greater than), == (equal to), <= (less than or equal to), >= (greater than or equal to) and != (not equal to).

- 🔲圈的主體會縮排：縮排在 Python 中用來關連一群陳述式。在互動式提示符中，你必須在🔲圈🔲的每一行一開始鍵入 tab 或者（數個）空白來維持縮排。實務上，你會先在文字編輯器中准備好比較🔲雜的輸入；多數編輯器都有自動縮排的功能。當一個🔲合陳述式以互動地方式輸入，必須在結束時多加一行空行來代表結束（因🔲語法解析器無法判斷你何時輸入🔲合陳述的最後一行）。注意在一個縮排段落🔲的縮排方式與數量必須維持一致。

- The `print` statement writes the value of the expression(s) it is given. It differs from just writing the expression you want to write (as we did earlier in the calculator examples) in the way it handles multiple expressions and strings. Strings are printed without quotes, and a space is inserted between items, so you can format things nicely, like this:

```
>>> i = 256*256
>>> print 'The value of i is', i
The value of i is 65536
```

A trailing comma avoids the newline after the output:

```
>>> a, b = 0, 1
>>> while b < 1000:
...     print b,
...     a, b = b, a+b
...
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
```

Note that the interpreter inserts a newline before it prints the next prompt if the last line was not completed.

🔲解

# 深入了解流程控制

除了刚刚介绍过的 `while` 语句，Python 中也会使用其他语言中常见的流程控制语句，只是稍有变化。

## 4.1 `if` 陳述式

或許最常見的陳述式種類就是 `if` 了。舉例來F:

```python
>>> x = int(raw_input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print 'Negative changed to zero'
... elif x == 0:
...     print 'Zero'
... elif x == 1:
...     print 'Single'
... else:
...     print 'More'
...
More
```

可以有零個或多個 `elif` 段落，且 `else` 段落可有可無。關鍵字 `elif` 只是「else if」的縮寫，F且用來避免過多的縮排。一個 `if` …`elif` …`elif` …序列可以用來替代其他語言中出現的 `switch` 或 `case` 陳述式。

## 4.2 `for` 陳述式

在 Python 中的 `for` 陳述式可能不同於在 C 或 Pascal 中所看到的使用方式。與其只能⬚代 (iterate) 一個等差級數（如 Pascal），或給與使用者定義⬚代步進方式與結束條件（如 C），Python 的 `for` 陳述⬚代任何序列 (list 或者字串) 的元素，以他們出現在序列中的順序。例如（無意雙關）：

```
>>> # Measure some strings:
... words = ['cat', 'window', 'defenestrate']
>>> for w in words:
...     print w, len(w)
...
cat 3
window 6
defenestrate 12
```

如果你在⬚圈中需要修改一個你正在⬚代的序列（例如重⬚一些選擇的元素），那⬚會建議你先建立一個序列的拷貝。⬚代序列⬚不暗示建立新的拷貝。此時 slice 語法就讓這件事十分容易完成：

```
>>> for w in words[:]:   # Loop over a slice copy of the entire list.
...     if len(w) > 6:
...         words.insert(0, w)
...
>>> words
['defenestrate', 'cat', 'window', 'defenestrate']
```

## 4.3 `range()` 函式

If you do need to iterate over a sequence of numbers, the built-in function `range()` comes in handy. It generates lists containing arithmetic progressions:

```
>>> range(10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

The given end point is never part of the generated list; `range(10)` generates a list of 10 values, the legal indices for items of a sequence of length 10. It is possible to let the range start at another number, or to specify a different increment (even negative; sometimes this is called the 『step』):

```
>>> range(5, 10)
[5, 6, 7, 8, 9]
>>> range(0, 10, 3)
[0, 3, 6, 9]
>>> range(-10, -100, -30)
[-10, -40, -70]
```

欲⬚代一個序列的索引值，你可以搭配使用 `range()` 和 `len()` 如下：

```
>>> a = ['Mary', 'had', 'a', 'little', 'lamb']
>>> for i in range(len(a)):
...     print i, a[i]
...
0 Mary
1 had
2 a
```

```
3 little
4 lamb
```

然而，在多數的情況，使用 enumerate() 函式將更加方便，詳見迴圈技巧。

## 4.4 break 和 continue 陳述、迴圈的 else 段落

break 陳述，如同 C 語言，終止包含其最內部的 for 或 while 迴圈。

迴圈可以帶有一個 else 段落。當迴圈歷遍迭代的 list（在 for 中）或條件成立（在 while 中）時，這個段落會被執行；但迴圈被 break 陳述終止時則不會。底下尋找質數的迴圈即示範了這個行為：

```python
>>> for n in range(2, 10):
...     for x in range(2, n):
...         if n % x == 0:
...             print n, 'equals', x, '*', n/x
...             break
...     else:
...         # loop fell through without finding a factor
...         print n, 'is a prime number'
...
2 is a prime number
3 is a prime number
4 equals 2 * 2
5 is a prime number
6 equals 2 * 3
7 is a prime number
8 equals 2 * 4
9 equals 3 * 3
```

（沒錯，這是正確的程式碼。請看仔細：else 段落屬於 for 迴圈，並非 if 陳述。）

當 else 段落與迴圈使用時，相較於搭配 if 陳述使用，它的行為與搭配 try 陳述使用時更為相似：try 的 else 段落在沒有任何例外 (exception) 時執行，而迴圈的 else 段落在沒有任何 break 時執行。更多有關 try 陳述和例外的介紹，見處理例外。

continue 陳述，亦承襲於 C 語言，讓所屬的迴圈繼續執行下個迭代：

```python
>>> for num in range(2, 10):
...     if num % 2 == 0:
...         print "Found an even number", num
...         continue
...     print "Found a number", num
Found an even number 2
Found a number 3
Found an even number 4
Found a number 5
Found an even number 6
Found a number 7
Found an even number 8
Found a number 9
```

## 4.5 `pass` 陳述式

`pass` 陳述不執行任何動作。它用在語法上需要一個陳述但不需要執行任何動作的時候。例如:

```
>>> while True:
...     pass  # Busy-wait for keyboard interrupt (Ctrl+C)
...
```

這經常用於定義一個最簡單的類⬚:

```
>>> class MyEmptyClass:
...     pass
...
```

`pass` 亦可作⬚一個函式或條件判斷主體的預留位置,它可幫助你以更宏觀的角度思考⬚撰寫新的程式碼。
`pass` 可被忽略:

```
>>> def initlog(*args):
...     pass  # Remember to implement this!
...
```

## 4.6 定義函式 (function)

我們可以建立一個函式來⬚生費式數列到任何一個上界:

```
>>> def fib(n):    # write Fibonacci series up to n
...     """Print a Fibonacci series up to n."""
...     a, b = 0, 1
...     while a < n:
...         print a,
...         a, b = b, a+b
...
>>> # Now call the function we just defined:
... fib(2000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597
```

關鍵字 def 帶入一個函式的定義。它之後必須連著該函式的名稱和置於括號之中的參數。自下一行起,所有縮排的陳述成⬚該函式的主體。

一個函式的第一個陳述可以是一個字串值;此情⬚該字串值被視⬚該函式的⬚明文件字串,即 *docstring*。(關於 docstring 的細節請參見⬚明文件字串段落。) 有些工具可以使用 docstring 來自動⬚生⬚上或可列印的文件,或讓使用者能自由地⬚原始碼中⬚覽文件。在原始碼中加入 docstring 是個好慣例,應該養成這樣的習慣。

函式執行期間會建立一個新的符號表(symbol table)來儲存該函式⬚的區域變數。更精確地⬚,所有在函式⬚的變數賦值都會把該值儲存在一個區域符號表。然而,在讀取一個變數時,會先從區域符號表起搜尋,其次⬚所有包含其函式的區域符號表,其次⬚全域符號表,最後⬚所有⬚建的名稱。因此,在函式中,全域變數無法被直接賦值(除非該變數有被 global 陳述句提及),但它們可以被讀取。

在一個函式被呼叫的時候,實際傳入的參數(引數)會被加入至該函數的區域符號表。因此,引數傳入的方式⬚傳值呼叫 *(call by value)*(這⬚傳遞的「值」永遠是一個物件的參照(*reference*),而不是該物件的值)。[1] 當一個函式呼叫⬚的函式時,在被呼叫的函式中會建立一個新的區域符號表。

---

[1] Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list).

一個函式定義會把該函式名稱加入至當前的符號表。該函式名稱的值帶有一個型別，別被直譯器辨識別使用者自定函式（user-defined function）。該值可以被賦予給別的變數名，而該變數也可以被當作函式使用。這即是常見的重新命名方式：

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

Coming from other languages, you might object that `fib` is not a function but a procedure since it doesn't return a value. In fact, even functions without a `return` statement do return a value, albeit a rather boring one. This value is called `None` (it's a built-in name). Writing the value `None` is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using `print`:

```
>>> fib(0)
>>> print fib(0)
None
```

如果要寫一個函式回傳費式數列的 list 而不是直接印出它，這也很容易：

```
>>> def fib2(n):  # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a)    # see below
...         a, b = b, a+b
...     return result
...
>>> f100 = fib2(100)    # call it
>>> f100                # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

這個例子一樣示範了一些新的 Python 特性：

- `return` 陳述會讓一個函式回傳一個值。單獨使用 `return` 不外加一個表達式作別引數會回傳 `None`。一個函式執行到結束也會回傳 `None`。
- `result.append(a)` 陳述呼叫了一個 list 物件的 `result` *method*（方法）。method 別「屬於」一個物件的函式，命名規則別 `obj.methodname`，其中 `obj` 別某個物件（亦可別一表達式），而 `methodname` 別該 method 的名稱，別由該物件的型別所定義。不同的型別代表不同的 method。不同型別的 method 可以擁有一樣的名稱而不會讓 Python 混淆。（你可以使用 *class* 定義自己的物件型別和 method，見*Classes*）這別 `append()` method 定義在 list 物件中；它會加入一個新的元素在該 list 的末端。這個例子等同於 `result = result + [a]`，但更有效率。

## 4.7 More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1 Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

```python
def ask_ok(prompt, retries=4, complaint='Yes or no, please!'):
    while True:
        ok = raw_input(prompt)
        if ok in ('y', 'ye', 'yes'):
            return True
        if ok in ('n', 'no', 'nop', 'nope'):
            return False
        retries = retries - 1
        if retries < 0:
            raise IOError('refusenik user')
        print complaint
```

This function can be called in several ways:

- giving only the mandatory argument: `ask_ok('Do you really want to quit?')`

- giving one of the optional arguments: `ask_ok('OK to overwrite the file?', 2)`

- or even giving all arguments: `ask_ok('OK to overwrite the file?', 2, 'Come on, only yes or no!')`

This example also introduces the `in` keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

```python
i = 5

def f(arg=i):
    print arg

i = 6
f()
```

will print `5`.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

```python
def f(a, L=[]):
    L.append(a)
    return L

print f(1)
print f(2)
print f(3)
```

This will print

```
[1]
[1, 2]
[1, 2, 3]
```

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

```
def f(a, L=None):
    if L is None:
        L = []
    L.append(a)
    return L
```

## 4.7.2 Keyword Arguments

Functions can also be called using *keyword arguments* of the form kwarg=value. For instance, the following function:

```
def parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):
    print "-- This parrot wouldn't", action,
    print "if you put", voltage, "volts through it."
    print "-- Lovely plumage, the", type
    print "-- It's", state, "!"
```

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

```
parrot(1000)                                          # 1 positional argument
parrot(voltage=1000)                                  # 1 keyword argument
parrot(voltage=1000000, action='VOOOOOM')             # 2 keyword arguments
parrot(action='VOOOOOM', voltage=1000000)             # 2 keyword arguments
parrot('a million', 'bereft of life', 'jump')         # 3 positional arguments
parrot('a thousand', state='pushing up the daisies')  # 1 positional, 1 keyword
```

but all the following calls would be invalid:

```
parrot()                     # required argument missing
parrot(voltage=5.0, 'dead')  # non-keyword argument after a keyword argument
parrot(110, voltage=220)     # duplicate value for the same argument
parrot(actor='John Cleese')  # unknown keyword argument
```

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here's an example that fails due to this restriction:

```
>>> def function(a):
...     pass
...
>>> function(0, a=0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: function() got multiple values for keyword argument 'a'
```

When a final formal parameter of the form **name is present, it receives a dictionary (see typesmapping) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form *name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (*name must occur before **name.) For example, if we define a function like this:

```
def cheeseshop(kind, *arguments, **keywords):
    print "-- Do you have any", kind, "?"
    print "-- I'm sorry, we're all out of", kind
    for arg in arguments:
```

```
        print arg
    print "-" * 40
    keys = sorted(keywords.keys())
    for kw in keys:
        print kw, ":", keywords[kw]
```

It could be called like this:

```
cheeseshop("Limburger", "It's very runny, sir.",
           "It's really very, VERY runny, sir.",
           shopkeeper='Michael Palin',
           client="John Cleese",
           sketch="Cheese Shop Sketch")
```

and of course it would print:

```
-- Do you have any Limburger ?
-- I'm sorry, we're all out of Limburger
It's very runny, sir.
It's really very, VERY runny, sir.
----------------------------------------
client : John Cleese
shopkeeper : Michael Palin
sketch : Cheese Shop Sketch
```

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary's `keys()` method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3 Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see *Tuples 和序列 (Sequences)*). Before the variable number of arguments, zero or more normal arguments may occur.

```
def write_multiple_items(file, separator, *args):
    file.write(separator.join(args))
```

### 4.7.4 Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in `range()` function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the `*`-operator to unpack the arguments out of a list or tuple:

```
>>> range(3, 6)            # normal call with separate arguments
[3, 4, 5]
>>> args = [3, 6]
>>> range(*args)           # call with arguments unpacked from a list
[3, 4, 5]
```

In the same fashion, dictionaries can deliver keyword arguments with the `**`-operator:

```
>>> def parrot(voltage, state='a stiff', action='voom'):
...     print "-- This parrot wouldn't", action,
...     print "if you put", voltage, "volts through it.",
...     print "E's", state, "!"
...
>>> d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}
>>> parrot(**d)
-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin'␣
↪demised !
```

### 4.7.5 Lambda Expressions

Small anonymous functions can be created with the `lambda` keyword. This function returns the sum of its two arguments: `lambda a, b: a+b`. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

```
>>> def make_incrementor(n):
...     return lambda x: x + n
...
>>> f = make_incrementor(42)
>>> f(0)
42
>>> f(1)
43
```

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

```
>>> pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]
>>> pairs.sort(key=lambda pair: pair[1])
>>> pairs
[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]
```

### 4.7.6 明文件字串

There are emerging conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object's purpose. For brevity, it should not explicitly state the object's name or type, since these are available by other means (except if the name happens to be a verb describing a function's operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object's calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can't use the first line since it is generally adjacent to the string's opening quotes so its indentation is not apparent in the string literal.) Whitespace 「equivalent」to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

```
>>> def my_function():
...     """Do nothing, but document it.
...
...     No, really, it doesn't do anything.
...     """
...     pass
...
>>> print my_function.__doc__
Do nothing, but document it.

    No, really, it doesn't do anything.
```

# 4.8 Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about *coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, **PEP 8** has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

- Use 4-space indentation, and no tabs.

  4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

- Wrap lines so that they don'␣t exceed 79 characters.

  This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

- Use blank lines to separate functions and classes, and larger blocks of code inside functions.

- When possible, put comments on a line of their own.

- Use docstrings.

- Use spaces around operators and after commas, but not directly inside bracketing constructs: `a = f(1, 2) + g(3, 4)`.

- Name your classes and functions consistently; the convention is to use `CamelCase` for classes and `lower_case_with_underscores` for functions and methods. Always use `self` as the name for the first method argument (see *A First Look at Classes* for more on classes and methods).

- Don'␣t use fancy encodings if your code is meant to be used in international environments. Plain ASCII works best in any case.

⊞解

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## 資料結構

這個章節將會更深入的介紹一些你已經學過的東西的細節上，Ｆ且加入一些你還Ｆ有接觸過的部分。

## 5.1 進一步了解 List（串列）

List（串列）這個資料型態，具有更多操作的方法。下面條列了所有關於 list 的物件方法：

list.**append**(*x*)
> Add an item to the end of the list; equivalent to a[len(a):] = [x].

list.**extend**(*L*)
> Extend the list by appending all the items in the given list; equivalent to a[len(a):] = L.

list.**insert**(*i*, *x*)
> 將一個項目插入至 list 中給定的位置。第一個引數Ｆ插入處前元素的索引值，所以 a.insert(0, x) 會插入Ｆ list 首位，而 a.insert(len(a), x) 則相當於 a.append(x)。

list.**remove**(*x*)
> Remove the first item from the list whose value is *x*. It is an error if there is no such item.

list.**pop**($[i]$)
> 移除 list 中給定位置的項目，Ｆ回傳它。如果Ｆ有指定位置，a.pop() 將會移除 list 中最後的項目Ｆ回傳它。（在 *i* 周圍的方括號代表這個參數是選用的，Ｆ不代表你應該在該位置輸入方括號。你將會常常在 Python 函式庫參考指南中看見這個表示法）

list.**index**(*x*)
> Return the index in the list of the first item whose value is *x*. It is an error if there is no such item.

list.**count**(*x*)
> 回傳數值Ｆ *x* 在 list 中所出現的次數。

list.**sort**(*cmp=None*, *key=None*, *reverse=False*)
> 將 list 中的項目排序。（有參數可以使用來進行客Ｆ化的排序，請參考 sorted() 部分的解釋）

list.**reverse**()
> Reverse the elements of the list, in place.

以下是一個使用到許多 list 物件方法的例子：

```
>>> a = [66.25, 333, 333, 1, 1234.5]
>>> print a.count(333), a.count(66.25), a.count('x')
2 1 0
>>> a.insert(2, -1)
>>> a.append(333)
>>> a
[66.25, 333, -1, 333, 1, 1234.5, 333]
>>> a.index(333)
1
>>> a.remove(333)
>>> a
[66.25, -1, 333, 1, 1234.5, 333]
>>> a.reverse()
>>> a
[333, 1234.5, 1, 333, -1, 66.25]
>>> a.sort()
>>> a
[-1, 1, 66.25, 333, 333, 1234.5]
>>> a.pop()
1234.5
>>> a
[-1, 1, 66.25, 333, 333]
```

You might have noticed that methods like `insert`, `remove` or `sort` that only modify the list have no return value printed –they return the default `None`. This is a design principle for all mutable data structures in Python.

### 5.1.1 將 List 作⊞ Stack（堆⊞）使用

List 的操作方法使得它非常簡單可以用來實作 stack（堆⊞）。Stack ⊞一個遵守最後加入元素最先被取回（後進先出，」last-in, first-out」）規則的資料結構。你可以使用方法 append() 將一個項目放到堆⊞的頂層。而使用方法 pop() 且不給定索引值去取得堆⊞最上面的項目。舉例而言：

```
>>> stack = [3, 4, 5]
>>> stack.append(6)
>>> stack.append(7)
>>> stack
[3, 4, 5, 6, 7]
>>> stack.pop()
7
>>> stack
[3, 4, 5, 6]
>>> stack.pop()
6
>>> stack.pop()
5
>>> stack
[3, 4]
```

## 5.1.2 將 List 作 $\boxed{F}$ Queue（ $\boxed{F}$ 列）使用

我們也可以將 list 當作 queue（ $\boxed{F}$ 列）使用，即最先加入元素最先被取回（先進先出，」first-in, first-out」）的資料結構。然而，list 在這種使用方式下效率較差。使用 append 和 pop 來加入和取出尾端的元素較快，而使用 insert 和 pop 來插入和取出頭端的元素較慢（因 $\boxed{F}$ 其他元素都需要挪動一格）。

如果要實作 queue，請使用 collections.deque，其被設計成能快速的從頭尾兩端加入和取出。例如：

```
>>> from collections import deque
>>> queue = deque(["Eric", "John", "Michael"])
>>> queue.append("Terry")           # Terry arrives
>>> queue.append("Graham")          # Graham arrives
>>> queue.popleft()                 # The first to arrive now leaves
'Eric'
>>> queue.popleft()                 # The second to arrive now leaves
'John'
>>> queue                           # Remaining queue in order of arrival
deque(['Michael', 'Terry', 'Graham'])
```

## 5.1.3 Functional Programming Tools

There are three built-in functions that are very useful when used with lists: filter(), map(), and reduce().

filter(function, sequence) returns a sequence consisting of those items from the sequence for which function(item) is true. If *sequence* is a str, unicode or tuple, the result will be of the same type; otherwise, it is always a list. For example, to compute a sequence of numbers divisible by 3 or 5:

```
>>> def f(x): return x % 3 == 0 or x % 5 == 0
...
>>> filter(f, range(2, 25))
[3, 5, 6, 9, 10, 12, 15, 18, 20, 21, 24]
```

map(function, sequence) calls function(item) for each of the sequence' s items and returns a list of the return values. For example, to compute some cubes:

```
>>> def cube(x): return x*x*x
...
>>> map(cube, range(1, 11))
[1, 8, 27, 64, 125, 216, 343, 512, 729, 1000]
```

More than one sequence may be passed; the function must then have as many arguments as there are sequences and is called with the corresponding item from each sequence (or None if some sequence is shorter than another). For example:

```
>>> seq = range(8)
>>> def add(x, y): return x+y
...
>>> map(add, seq, seq)
[0, 2, 4, 6, 8, 10, 12, 14]
```

reduce(function, sequence) returns a single value constructed by calling the binary function *function* on the first two items of the sequence, then on the result and the next item, and so on. For example, to compute the sum of the numbers 1 through 10:

```
>>> def add(x,y): return x+y
...
```

```
>>> reduce(add, range(1, 11))
55
```

If there's only one item in the sequence, its value is returned; if the sequence is empty, an exception is raised.

A third argument can be passed to indicate the starting value. In this case the starting value is returned for an empty sequence, and the function is first applied to the starting value and the first sequence item, then to the result and the next item, and so on. For example,

```
>>> def sum(seq):
...     def add(x,y): return x+y
...     return reduce(add, seq, 0)
...
>>> sum(range(1, 11))
55
>>> sum([])
0
```

Don't use this example's definition of `sum()`: since summing numbers is such a common need, a built-in function `sum(sequence)` is already provided, and works exactly like this.

### 5.1.4 List Comprehensions（串列綜合運算）

List Comprehension（串列綜合運算）讓你可以用簡潔的方法創建 list。常見的應用是基於一個 list 或 iterable（可列舉物件），將每一個元素經過某個運算的結果串接起來成⊞一個新的 list。或是創建一個 list 的子序列，其每一個元素皆滿足一個特定的條件。

舉例來⊞，假設我們要創建一個「平方的 list」:

```
>>> squares = []
>>> for x in range(10):
...     squares.append(x**2)
...
>>> squares
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

We can obtain the same result with:

```
squares = [x**2 for x in range(10)]
```

This is also equivalent to `squares = map(lambda x: x**2, range(10))`, but it's more concise and readable.

一個 list comprehension 的組成，是包含著一個 expression（運算式）和一個 for 語句，再接著零個或多個 for 或 if 語句的一對方括號。結果會是一個新的串列，⊞容是在接著的 for 和 if 語句的環境下，執行前面 expression 的結果。例如，這個 list comprehension 是由兩個串列中互相不同的元素組合所組成:

```
>>> [(x, y) for x in [1,2,3] for y in [3,1,4] if x != y]
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

and it's equivalent to:

```
>>> combs = []
>>> for x in [1,2,3]:
...     for y in [3,1,4]:
```

```
...            if x != y:
...                combs.append((x, y))
...
>>> combs
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

注意 for 和 if 在這兩段程式碼的順序是相同的。

如果 expression 是一個 tuple（例如上面例子中的 (x, y)），它必須加上小括弧：

```
>>> vec = [-4, -2, 0, 2, 4]
>>> # create a new list with the values doubled
>>> [x*2 for x in vec]
[-8, -4, 0, 4, 8]
>>> # filter the list to exclude negative numbers
>>> [x for x in vec if x >= 0]
[0, 2, 4]
>>> # apply a function to all the elements
>>> [abs(x) for x in vec]
[4, 2, 0, 2, 4]
>>> # call a method on each element
>>> freshfruit = ['  banana', '  loganberry ', 'passion fruit  ']
>>> [weapon.strip() for weapon in freshfruit]
['banana', 'loganberry', 'passion fruit']
>>> # create a list of 2-tuples like (number, square)
>>> [(x, x**2) for x in range(6)]
[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]
>>> # the tuple must be parenthesized, otherwise an error is raised
>>> [x, x**2 for x in range(6)]
  File "<stdin>", line 1, in <module>
    [x, x**2 for x in range(6)]
               ^
SyntaxError: invalid syntax
>>> # flatten a list using a listcomp with two 'for'
>>> vec = [[1,2,3], [4,5,6], [7,8,9]]
>>> [num for elem in vec for num in elem]
[1, 2, 3, 4, 5, 6, 7, 8, 9]
```

List comprehensions 可以含有複雜的 expression 和巢狀的函式呼叫：

```
>>> from math import pi
>>> [str(round(pi, i)) for i in range(1, 6)]
['3.1', '3.14', '3.142', '3.1416', '3.14159']
```

### 巢狀的 List Comprehensions

最初放在 list comprehesion 中的 expression 可以是任何形式的 expression，包括再寫一個 list comprehension。

考慮以下表示 3x4 矩陣的範例，使用 list 包含 3 個長度為 4 的 list：

```
>>> matrix = [
...     [1, 2, 3, 4],
...     [5, 6, 7, 8],
...     [9, 10, 11, 12],
... ]
```

以下的 list comprehesion 會將矩陣的行與列作轉置：

```
>>> [[row[i] for row in matrix] for i in range(4)]
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

如同我們在上一節看到的，此巢狀的 list comprehension ⬚一個 list comprehension 在 for 之前先被計算，接著再作一次 list comprehension，所以，這個例子和下者相同：

```
>>> transposed = []
>>> for i in range(4):
...     transposed.append([row[i] for row in matrix])
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

因此，也和下者相同：

```
>>> transposed = []
>>> for i in range(4):
...     # the following 3 lines implement the nested listcomp
...     transposed_row = []
...     for row in matrix:
...         transposed_row.append(row[i])
...     transposed.append(transposed_row)
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

在實際運用上，我們傾向於使用⬚建函式 (built-in functions) 而不是⬚雜的流程控制陳述式。在這個例子中，使用 zip() 函式會非常有效率：

```
>>> zip(*matrix)
[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]
```

關於星號的更多細節，請參考*Unpacking Argument Lists* 。

## 5.2 `del` 陳述式

有一個方法可以藉由索引而不是值來⬚除 list 中的項：del 陳述式。這和 pop() 方法傳回一個值不同，del 陳述式可以用來⬚除 list 中的片段或者清空整個 list（我們之前藉由指派一個空的 list 給想⬚除的片段來完成這件事）。例如：

```
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
>>> a
[]
```

del 也可以用來⬚除變數：

```
>>> del a
```

⻔除之後，對 a 的參照將會造成錯誤（至少在另一個值又被指派到它之前）。我們將在後面看到更多關於 del 的其他用法。

## 5.3 Tuples 和序列 (Sequences)

我們看到 lists 和 strings 有許多共同的特性，像是索引操作 (indexing) 以及切片操作 (slicing)。他們是 序列資料結構中的兩個例子（請參考 typesseq）。由於 Python 是個持續發展中的語言，未來可能還會有其他的序列資料結構加入。接著要介紹是下一個標准序列資料結構：*tuple*。

一個 tuple 是由若干個值藉由逗號區隔而組成，例如：

```
>>> t = 12345, 54321, 'hello!'
>>> t[0]
12345
>>> t
(12345, 54321, 'hello!')
>>> # Tuples may be nested:
... u = t, (1, 2, 3, 4, 5)
>>> u
((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))
>>> # Tuples are immutable:
... t[0] = 88888
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> # but they can contain mutable objects:
... v = ([1, 2, 3], [3, 2, 1])
>>> v
([1, 2, 3], [3, 2, 1])
```

如同我們看到的，被輸出的 tuple 總是以括號包著，如此巢狀的 tuple 才能被正確的直譯 (interpret)；他們可以是以被括號包著或不被包著的方式當作輸入，雖然括號的使用常常是有其必要的（譬如此 tuple 是一個較大的陳述式的一部分）。指派東西給 tuple 中個⻔的項是不行的，但是可以在 tuple 中放入含有可變項的物件，譬如 list 。

雖然 tuple 和 list 看起來很類似，但是他們通常用在不同的情⻔與不同目的。tuple 是*immutable* （不可變的），通常儲存⻔質的序列元素，⻔可經由拆解 (unpacking) （請參考本節後段）或索引 (indexing) 來存取（或者在使用 namedtuples 的時候藉由屬性 (attribute) 來存取）。list 是*mutable* （可變的），其元素通常是同質的且可藉由迭代整個串列來存取。

一個特⻔的議題是，關於創建一個含有 0 個或 1 個項目的 tuple：語法上會⻔納一些奇怪的用法。空的 tuple 藉由一對空括號來創建；含有一個項目的 tuple 經由一個值加上一個逗點來創建（不需要用括號把一個單一的值包住）。醜，但有效率。例如：

```
>>> empty = ()
>>> singleton = 'hello',    # <-- note trailing comma
>>> len(empty)
0
>>> len(singleton)
1
>>> singleton
('hello',)
```

陳述式 `t = 12345, 54321, 'hello!'` 就是一個 *tuple packing* 的例子: `12345`, `54321` 和 `'hello!'` 一起被放進 tuple ⬚。反向操作也可以:

```
>>> x, y, z = t
```

This is called, appropriately enough, *sequence unpacking* and works for any sequence on the right-hand side. Sequence unpacking requires the list of variables on the left to have the same number of elements as the length of the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4 集合 (Sets)

Python 也包含了一種用在集合 (*sets*) 的資料結構。一個 set 是一組無序且⬚有重⬚的元素。基本的使用方式包括了成員測試和消除重⬚項。Set 物件也支援聯集, 交集, 差集和互斥等數學操作。

大括號或 `set()` 函式都可以用來創建 set 。注意: 要創建一個空的 set , 我們必須使用 `set()` 而不是 `{}` ; 後者會創建一個空的 dictionary , 一種我們將在下一節討論的資料結構。

這⬚是一個簡單的演示:

```
>>> basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']
>>> fruit = set(basket)                  # create a set without duplicates
>>> fruit
set(['orange', 'pear', 'apple', 'banana'])
>>> 'orange' in fruit                     # fast membership testing
True
>>> 'crabgrass' in fruit
False

>>> # Demonstrate set operations on unique letters from two words
...
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a                                     # unique letters in a
set(['a', 'r', 'b', 'c', 'd'])
>>> a - b                                 # letters in a but not in b
set(['r', 'd', 'b'])
>>> a | b                                 # letters in either a or b
set(['a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'])
>>> a & b                                 # letters in both a and b
set(['a', 'c'])
>>> a ^ b                                 # letters in a or b but not both
set(['r', 'd', 'b', 'm', 'z', 'l'])
```

和*list comprehensions* 類似, 也有 set comprehensions (集合綜合運算):

```
>>> a = {x for x in 'abracadabra' if x not in 'abc'}
>>> a
set(['r', 'd'])
```

## 5.5 字典（Dictionary）

下一個常用的 python ⊞建資料結構⊞ *dictionary*（請參考 typesmapping）。Dictionary 有時被稱⊞「關聯記憶體」(associative memories) 或「關聯矩陣」(associative arrays)。不像序列是由一個範圍⊞的數字當作索引，dictionary 是由 *key*（鍵）來當索引，key 可以是任何不可變的型態；字串和數字都可以當作 key。Tuple 也可以當作 key 如果他們只含有字串、數字或 tuple；若一個 tuple 直接或間接地含有任何可變的物件，它就不能當作 key。我們無法使用 list 當作 key，因⊞ list 可以經由索引操作、切片操作或是方法像是 append() 和 extend() 來修改。

It is best to think of a dictionary as an unordered set of *key: value* pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

Dict 主要的操作⊞藉由鍵來儲存一個值⊞且可藉由該鍵來取出該值。也可以使用 del 來⊞除鍵值對。如果我們使用用過的鍵來儲存，該鍵所對應的較舊的值會被覆蓋。使用不存在的鍵來取出值會造成錯誤。

The keys() method of a dictionary object returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just apply the sorted() function to it). To check whether a single key is in the dictionary, use the in keyword.

這是個使用一個字典的簡單範例：

```
>>> tel = {'jack': 4098, 'sape': 4139}
>>> tel['guido'] = 4127
>>> tel
{'sape': 4139, 'guido': 4127, 'jack': 4098}
>>> tel['jack']
4098
>>> del tel['sape']
>>> tel['irv'] = 4127
>>> tel
{'guido': 4127, 'irv': 4127, 'jack': 4098}
>>> tel.keys()
['guido', 'irv', 'jack']
>>> 'guido' in tel
True
```

函式 dict() 可直接透過一串鍵值對序列來創建 dict：

```
>>> dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])
{'sape': 4139, 'jack': 4098, 'guido': 4127}
```

此外，dict comprehensions 也可以透過鍵與值的陳述式來創建 dict：

```
>>> {x: x**2 for x in (2, 4, 6)}
{2: 4, 4: 16, 6: 36}
```

當鍵是簡單的字串時，使用關鍵字引數 (keyword arguments) 有時會較⊞簡潔：

```
>>> dict(sape=4139, guido=4127, jack=4098)
{'sape': 4139, 'jack': 4098, 'guido': 4127}
```

## 5.6 ⯐圈技巧

當對序列作⯐圈時，位置索引及其對應的值可以藉由使用 `enumerate()` 函式來同時取得：

```
>>> for i, v in enumerate(['tic', 'tac', 'toe']):
...     print i, v
...
0 tic
1 tac
2 toe
```

要同時對兩個以上的序列作⯐圈，可以將其以成對的方式放入 `zip()` 函式：

```
>>> questions = ['name', 'quest', 'favorite color']
>>> answers = ['lancelot', 'the holy grail', 'blue']
>>> for q, a in zip(questions, answers):
...     print 'What is your {0}?  It is {1}.'.format(q, a)
...
What is your name?  It is lancelot.
What is your quest?  It is the holy grail.
What is your favorite color?  It is blue.
```

要對序列作反向的⯐圈，首先先寫出正向的序列，在對其使用 `reversed()` 函式：

```
>>> for i in reversed(xrange(1,10,2)):
...     print i
...
9
7
5
3
1
```

要以⯐圈對序列作排序，使用 `sorted()` 函式會得到一個新的經排序過的 list，但不會改變原本的序列：

```
>>> basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']
>>> for f in sorted(set(basket)):
...     print f
...
apple
banana
orange
pear
```

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the `iteritems()` method.

```
>>> knights = {'gallahad': 'the pure', 'robin': 'the brave'}
>>> for k, v in knights.iteritems():
...     print k, v
...
gallahad the pure
robin the brave
```

有時我們會想要以⯐圈來改變的一個 list，但是，通常創建一個新的 list 會更簡單且安全：

```
>>> import math
>>> raw_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]
>>> filtered_data = []
>>> for value in raw_data:
...     if not math.isnan(value):
...         filtered_data.append(value)
...
>>> filtered_data
[56.2, 51.7, 55.3, 52.5, 47.8]
```

## 5.7 更多條件式主題

使用在 while 和 if ⊞的陳述式可以包含任何運算子，而不是只有比較運算子(comparisons)。

比較運算子 in 和 not in 檢查一個數值是否存在（不存在）於一個序列中。運算子 is 和 not is 比較兩個物件是否真的是相同的物件；這對可變物件例如 list 來⊞很重要。所有的比較運算子優先度都相同且都低於數值運算子。

比較運算是可以串連在一起的。例如，a < b == c 就是在測試 a 是否小於 b 和 b 是否等於 c。

比較運算可以結合布林運算子 and 和 or，且一個比較運算的結果（或任何其他布林表達式）可以加上 not 來否定。這些運算子的優先度都比比較運算子還低，其中，not 的優先度最高，or 的優先度最低，因此 A and not B or C 等同於 (A and (not B)) or C。一如往常，括號可以用來表示任何想要的組合。

布林運算子 and 和 or 也被稱⊞短路 (*short-circuit*) 運算子：會將其引數從左至右進行運算，當結果出現時即結束運算。例如，若 A 和 C ⊞真但 B ⊞假，則 A and B and C 的運算⊞不會執行到 C。當運算結果被當成一般數值而非布林值時，短路運算子的回傳值⊞最後被運算的引數。

將一個比較運算或其他布林表達式的結果指派給一個變數是可以的。例如：

```
>>> string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'
>>> non_null = string1 or string2 or string3
>>> non_null
'Trondheim'
```

注意，Python 不像 C 語言，在表達式⊞進行指派是不行的。C 語言的程式設計師可能會抱怨這件事，但這樣做避免了在 C 語言⊞常見的一種問題：想要打 == ⊞在表達式⊞輸入 =。

## 5.8 序列和其他資料結構之比較

Sequence objects may be compared to other objects with the same sequence type. The comparison uses *lexicographical* ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the ASCII ordering for individual characters. Some examples of comparisons between sequences of the same type:

```
(1, 2, 3)              < (1, 2, 4)
[1, 2, 3]              < [1, 2, 4]
'ABC' < 'C' < 'Pascal' < 'Python'
(1, 2, 3, 4)          < (1, 2, 4)
(1, 2)                < (1, 2, -1)
```

```
(1, 2, 3)               ==  (1.0, 2.0, 3.0)
(1, 2, ('aa', 'ab'))    <  (1, 2, ('abc', 'a'), 4)
```

Note that comparing objects of different types is legal. The outcome is deterministic but arbitrary: the types are ordered by their name. Thus, a list is always smaller than a string, a string is always smaller than a tuple, etc.[1] Mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc.

⊡解

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[1] The rules for comparing objects of different types should not be relied upon; they may change in a future version of the language.

# 模組

如果從 Python 直譯器離開後又再次進入，之前（幫函式或變數）做的定義都會消失。因此，想要寫一些比較長的程式時，你最好使用編輯器來准備要輸入給直譯器的Ｆ容，Ｆ且用該檔案來運行它。這就是一個Ｆ本（*script*）。隨著你的程式越變越長，你可能會想要把它分開成幾個檔案，讓它比較好維護。你可能也會想用一個你之前已經在其他程式寫好的函式，但不想要ＦＦ該函式的原始定義到所有使用它的程式Ｆ。

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a *module*; definitions from a module can be *imported* into other modules or into the *main* module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix `.py` appended. Within a module, the module's name (as a string) is available as the value of the global variable `__name__`. For instance, use your favorite text editor to create a file called `fibo.py` in the current directory with the following contents:

```python
# Fibonacci numbers module

def fib(n):    # write Fibonacci series up to n
    a, b = 0, 1
    while b < n:
        print b,
        a, b = b, a+b

def fib2(n):   # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result
```

Now enter the Python interpreter and import this module with the following command:

```python
>>> import fibo
```

This does not enter the names of the functions defined in `fibo` directly in the current symbol table; it only enters the module name `fibo` there. Using the module name you can access the functions:

```
>>> fibo.fib(1000)
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
>>> fibo.fib2(100)
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
>>> fibo.__name__
'fibo'
```

If you intend to use a function often you can assign it to a local name:

```
>>> fib = fibo.fib
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

## 6.1 More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the *first* time the module name is encountered in an import statement.[1] (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user's global variables. On the other hand, if you know what you are doing you can touch a module's global variables with the same notation used to refer to its functions, `modname.itemname`.

Modules can import other modules. It is customary but not required to place all `import` statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module's global symbol table.

There is a variant of the `import` statement that imports names from a module directly into the importing module's symbol table. For example:

```
>>> from fibo import fib, fib2
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, `fibo` is not defined).

There is even a variant to import all names that a module defines:

```
>>> from fibo import *
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This imports all names except those beginning with an underscore (_).

Note that in general the practice of importing * from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

If the module name is followed by `as`, then the name following `as` is bound directly to the imported module.

---

[1] In fact function definitions are also 『statements』 that are 『executed』; the execution of a module-level function definition enters the function name in the module's global symbol table.

```
>>> import fibo as fib
>>> fib.fib(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This is effectively importing the module in the same way that `import fibo` will do, with the only difference of it being available as `fib`.

It can also be used when utilising `from` with similar effects:

```
>>> from fibo import fib as fibonacci
>>> fibonacci(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

---

備 F: For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter –or, if it' s just one module you want to test interactively, use `reload()`, e.g. `reload(modulename)`.

---

## 6.1.1 Executing modules as scripts

When you run a Python module with

```
python fibo.py <arguments>
```

the code in the module will be executed, just as if you imported it, but with the __name__ set to "__main__". That means that by adding this code at the end of your module:

```
if __name__ == "__main__":
    import sys
    fib(int(sys.argv[1]))
```

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the 「main」file:

```
$ python fibo.py 50
1 1 2 3 5 8 13 21 34
```

If the module is imported, the code is not run:

```
>>> import fibo
>>>
```

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

## 6.1.2 The Module Search Path

When a module named `spam` is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named `spam.py` in a list of directories given by the variable `sys.path`. `sys.path` is initialized from these locations:

- the directory containing the input script (or the current directory).
- `PYTHONPATH` (a list of directory names, with the same syntax as the shell variable `PATH`).
- the installation-dependent default.

After initialization, Python programs can modify `sys.path`. The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section *Standard Modules* for more information.

## 6.1.3 「Compiled」Python files

As an important speed-up of the start-up time for short programs that use a lot of standard modules, if a file called `spam.pyc` exists in the directory where `spam.py` is found, this is assumed to contain an already-「byte-compiled」 version of the module `spam`. The modification time of the version of `spam.py` used to create `spam.pyc` is recorded in `spam.pyc`, and the `.pyc` file is ignored if these don’t match.

Normally, you don’t need to do anything to create the `spam.pyc` file. Whenever `spam.py` is successfully compiled, an attempt is made to write the compiled version to `spam.pyc`. It is not an error if this attempt fails; if for any reason the file is not written completely, the resulting `spam.pyc` file will be recognized as invalid and thus ignored later. The contents of the `spam.pyc` file are platform independent, so a Python module directory can be shared by machines of different architectures.

Some tips for experts:

- When the Python interpreter is invoked with the `-O` flag, optimized code is generated and stored in `.pyo` files. The optimizer currently doesn’t help much; it only removes `assert` statements. When `-O` is used, *all bytecode* is optimized; `.pyc` files are ignored and `.py` files are compiled to optimized bytecode.
- Passing two `-O` flags to the Python interpreter (`-OO`) will cause the bytecode compiler to perform optimizations that could in some rare cases result in malfunctioning programs. Currently only `__doc__` strings are removed from the bytecode, resulting in more compact `.pyo` files. Since some programs may rely on having these available, you should only use this option if you know what you’re doing.
- A program doesn’t run any faster when it is read from a `.pyc` or `.pyo` file than when it is read from a `.py` file; the only thing that’s faster about `.pyc` or `.pyo` files is the speed with which they are loaded.
- When a script is run by giving its name on the command line, the bytecode for the script is never written to a `.pyc` or `.pyo` file. Thus, the startup time of a script may be reduced by moving most of its code to a module and having a small bootstrap script that imports that module. It is also possible to name a `.pyc` or `.pyo` file directly on the command line.
- It is possible to have a file called `spam.pyc` (or `spam.pyo` when `-O` is used) without a file `spam.py` for the same module. This can be used to distribute a library of Python code in a form that is moderately hard to reverse engineer.
- The module `compileall` can create `.pyc` files (or `.pyo` files when `-O` is used) for all modules in a directory.

## 6.2 Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (「Library Reference」hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the `winreg` module is only provided on Windows systems. One particular module deserves some attention: `sys`, which is built into every Python interpreter. The variables `sys.ps1` and `sys.ps2` define the strings used as primary and secondary prompts:

```
>>> import sys
>>> sys.ps1
'>>> '
>>> sys.ps2
'... '
>>> sys.ps1 = 'C> '
C> print 'Yuck!'
Yuck!
C>
```

These two variables are only defined if the interpreter is in interactive mode.

The variable `sys.path` is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable `PYTHONPATH`, or from a built-in default if `PYTHONPATH` is not set. You can modify it using standard list operations:

```
>>> import sys
>>> sys.path.append('/ufs/guido/lib/python')
```

## 6.3 The `dir()` Function

The built-in function `dir()` is used to find out which names a module defines. It returns a sorted list of strings:

```
>>> import fibo, sys
>>> dir(fibo)
['__name__', 'fib', 'fib2']
>>> dir(sys)
['__displayhook__', '__doc__', '__excepthook__', '__name__', '__package__',
 '__stderr__', '__stdin__', '__stdout__', '_clear_type_cache',
 '_current_frames', '_getframe', '_mercurial', 'api_version', 'argv',
 'builtin_module_names', 'byteorder', 'call_tracing', 'callstats',
 'copyright', 'displayhook', 'dont_write_bytecode', 'exc_clear', 'exc_info',
 'exc_traceback', 'exc_type', 'exc_value', 'excepthook', 'exec_prefix',
 'executable', 'exit', 'flags', 'float_info', 'float_repr_style',
 'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',
 'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',
 'getrefcount', 'getsizeof', 'gettotalrefcount', 'gettrace', 'hexversion',
 'long_info', 'maxint', 'maxsize', 'maxunicode', 'meta_path', 'modules',
 'path', 'path_hooks', 'path_importer_cache', 'platform', 'prefix', 'ps1',
 'py3kwarning', 'setcheckinterval', 'setdlopenflags', 'setprofile',
 'setrecursionlimit', 'settrace', 'stderr', 'stdin', 'stdout', 'subversion',
 'version', 'version_info', 'warnoptions']
```

Without arguments, `dir()` lists the names you have defined currently:

```
>>> a = [1, 2, 3, 4, 5]
>>> import fibo
>>> fib = fibo.fib
>>> dir()
['__builtins__', '__name__', '__package__', 'a', 'fib', 'fibo', 'sys']
```

Note that it lists all types of names: variables, modules, functions, etc.

`dir()` does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module `__builtin__`:

```
>>> import __builtin__
>>> dir(__builtin__)
['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',
 'BufferError', 'BytesWarning', 'DeprecationWarning', 'EOFError',
 'Ellipsis', 'EnvironmentError', 'Exception', 'False', 'FloatingPointError',
 'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError', 'ImportWarning',
 'IndentationError', 'IndexError', 'KeyError', 'KeyboardInterrupt',
 'LookupError', 'MemoryError', 'NameError', 'None', 'NotImplemented',
 'NotImplementedError', 'OSError', 'OverflowError',
 'PendingDeprecationWarning', 'ReferenceError', 'RuntimeError',
 'RuntimeWarning', 'StandardError', 'StopIteration', 'SyntaxError',
 'SyntaxWarning', 'SystemError', 'SystemExit', 'TabError', 'True',
 'TypeError', 'UnboundLocalError', 'UnicodeDecodeError',
 'UnicodeEncodeError', 'UnicodeError', 'UnicodeTranslateError',
 'UnicodeWarning', 'UserWarning', 'ValueError', 'Warning',
 'ZeroDivisionError', '_', '__debug__', '__doc__', '__import__',
 '__name__', '__package__', 'abs', 'all', 'any', 'apply', 'basestring',
 'bin', 'bool', 'buffer', 'bytearray', 'bytes', 'callable', 'chr',
 'classmethod', 'cmp', 'coerce', 'compile', 'complex', 'copyright',
 'credits', 'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval',
 'execfile', 'exit', 'file', 'filter', 'float', 'format', 'frozenset',
 'getattr', 'globals', 'hasattr', 'hash', 'help', 'hex', 'id', 'input',
 'int', 'intern', 'isinstance', 'issubclass', 'iter', 'len', 'license',
 'list', 'locals', 'long', 'map', 'max', 'memoryview', 'min', 'next',
 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property', 'quit',
 'range', 'raw_input', 'reduce', 'reload', 'repr', 'reversed', 'round',
 'set', 'setattr', 'slice', 'sorted', 'staticmethod', 'str', 'sum', 'super',
 'tuple', 'type', 'unichr', 'unicode', 'vars', 'xrange', 'zip']
```

## 6.4 Packages

Packages are a way of structuring Python's module namespace by using 「dotted module names」. For example, the module name `A.B` designates a submodule named `B` in a package named `A`. Just like the use of modules saves the authors of different modules from having to worry about each other's global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or Pillow from having to worry about each other's module names.

Suppose you want to design a collection of modules (a 「package」) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: `.wav`, `.aiff`, `.au`), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here's a possible structure for your package (expressed in terms of a hierarchical filesystem):

```
sound/                          Top-level package
      __init__.py               Initialize the sound package
      formats/                  Subpackage for file format conversions
              __init__.py
              wavread.py
              wavwrite.py
              aiffread.py
              aiffwrite.py
              auread.py
              auwrite.py
              ...
      effects/                  Subpackage for sound effects
              __init__.py
              echo.py
              surround.py
              reverse.py
              ...
      filters/                  Subpackage for filters
              __init__.py
              equalizer.py
              vocoder.py
              karaoke.py
              ...
```

When importing the package, Python searches through the directories on `sys.path` looking for the package subdirectory.

The `__init__.py` files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as `string`, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, `__init__.py` can just be an empty file, but it can also execute initialization code for the package or set the `__all__` variable, described later.

Users of the package can import individual modules from the package, for example:

```python
import sound.effects.echo
```

This loads the submodule `sound.effects.echo`. It must be referenced with its full name.

```python
sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)
```

An alternative way of importing the submodule is:

```python
from sound.effects import echo
```

This also loads the submodule `echo`, and makes it available without its package prefix, so it can be used as follows:

```python
echo.echofilter(input, output, delay=0.7, atten=4)
```

Yet another variation is to import the desired function or variable directly:

```python
from sound.effects.echo import echofilter
```

Again, this loads the submodule `echo`, but this makes its function `echofilter()` directly available:

```python
echofilter(input, output, delay=0.7, atten=4)
```

Note that when using `from package import item`, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The `import` statement first tests

**6.4. Packages**                                                            **49**

whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an `ImportError` exception is raised.

Contrarily, when using syntax like `import item.subitem.subsubitem`, each item except for the last must be a package; the last item can be a module or a package but can't be a class or function or variable defined in the previous item.

## 6.4.1 Importing * From a Package

Now what happens when the user writes `from sound.effects import *`? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The `import` statement uses the following convention: if a package's `__init__.py` code defines a list named `__all__`, it is taken to be the list of module names that should be imported when `from package import *` is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don't see a use for importing * from their package. For example, the file `sound/effects/__init__.py` could contain the following code:

```
__all__ = ["echo", "surround", "reverse"]
```

This would mean that `from sound.effects import *` would import the three named submodules of the `sound` package.

If `__all__` is not defined, the statement `from sound.effects import *` does *not* import all submodules from the package `sound.effects` into the current namespace; it only ensures that the package `sound.effects` has been imported (possibly running any initialization code in `__init__.py`) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by `__init__.py`. It also includes any submodules of the package that were explicitly loaded by previous `import` statements. Consider this code:

```
import sound.effects.echo
import sound.effects.surround
from sound.effects import *
```

In this example, the `echo` and `surround` modules are imported in the current namespace because they are defined in the `sound.effects` package when the `from...import` statement is executed. (This also works when `__all__` is defined.)

Although certain modules are designed to export only names that follow certain patterns when you use `import *`, it is still considered bad practice in production code.

请记住，使用 `from package import specific_submodule` 没有任何问题！实际上，除非导入的模块需要使用来自不同包的同名子模块，否则这是推荐的表示法。

### 6.4.2 Intra-package References

The submodules often need to refer to each other. For example, the `surround` module might use the `echo` module. In fact, such references are so common that the `import` statement first looks in the containing package before looking in the standard module search path. Thus, the `surround` module can simply use `import echo` or `from echo import echofilter`. If the imported module is not found in the current package (the package of which the current module is a submodule), the `import` statement looks for a top-level module with the given name.

When packages are structured into subpackages (as with the `sound` package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the module `sound.filters.vocoder` needs to use the `echo` module in the `sound.effects` package, it can use `from sound.effects import echo`.

Starting with Python 2.5, in addition to the implicit relative imports described above, you can write explicit relative imports with the `from module import name` form of import statement. These explicit relative imports use leading dots to indicate the current and parent packages involved in the relative import. From the `surround` module for example, you might use:

```
from . import echo
from .. import formats
from ..filters import equalizer
```

Note that both explicit and implicit relative imports are based on the name of the current module. Since the name of the main module is always `"__main__"`, modules intended for use as the main module of a Python application should always use absolute imports.

### 6.4.3 Packages in Multiple Directories

Packages support one more special attribute, `__path__`. This is initialized to be a list containing the name of the directory holding the package's `__init__.py` before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

F解

# 輸入和輸出

有數種方式可以顯示程式的輸出；資料可以以人類易讀的形式印出，或是寫入檔案以供未來所使用。這章節會討論幾種不同的方式。

## 7.1 更華麗的輸出格式

So far we've encountered two ways of writing values: *expression statements* and the `print` statement. (A third way is using the `write()` method of file objects; the standard output file can be referenced as `sys.stdout`. See the Library Reference for more information on this.)

Often you'll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string types have some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the `str.format()` method.

The `string` module contains a `Template` class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the `repr()` or `str()` functions.

The `str()` function is meant to return representations of values which are fairly human-readable, while `repr()` is meant to generate representations which can be read by the interpreter (or will force a `SyntaxError` if there is no equivalent syntax). For objects which don't have a particular representation for human consumption, `str()` will return the same value as `repr()`. Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings and floating point numbers, in particular, have two distinct representations.

一些範例：

```
>>> s = 'Hello, world.'
>>> str(s)
'Hello, world.'
>>> repr(s)
"'Hello, world.'"
```

```
>>> str(1.0/7.0)
'0.142857142857'
>>> repr(1.0/7.0)
'0.14285714285714285'
>>> x = 10 * 3.25
>>> y = 200 * 200
>>> s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'
>>> print s
The value of x is 32.5, and y is 40000...
>>> # The repr() of a string adds string quotes and backslashes:
... hello = 'hello, world\n'
>>> hellos = repr(hello)
>>> print hellos
'hello, world\n'
>>> # The argument to repr() may be any Python object:
... repr((x, y, ('spam', 'eggs')))
"(32.5, 40000, ('spam', 'eggs'))"
```

Here are two ways to write a table of squares and cubes:

```
>>> for x in range(1, 11):
...     print repr(x).rjust(2), repr(x*x).rjust(3),
...     # Note trailing comma on previous line
...     print repr(x*x*x).rjust(4)
...
 1   1    1
 2   4    8
 3   9   27
 4  16   64
 5  25  125
 6  36  216
 7  49  343
 8  64  512
 9  81  729
10 100 1000

>>> for x in range(1,11):
...     print '{0:2d} {1:3d} {2:4d}'.format(x, x*x, x*x*x)
...
 1   1    1
 2   4    8
 3   9   27
 4  16   64
 5  25  125
 6  36  216
 7  49  343
 8  64  512
 9  81  729
10 100 1000
```

(Note that in the first example, one space between each column was added by the way `print` works: by default it adds spaces between its arguments.)

This example demonstrates the `str.rjust()` method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods `str.ljust()` and `str.center()`. These methods do not write anything, they just return a new string. If the input string is too long, they don't truncate it, but return it unchanged; this will mess up your column lay-out but that's usually better than the alternative, which would be

lying about a value. (If you really want truncation you can always add a slice operation, as in `x.ljust(n)[:n]`.)

There is another method, `str.zfill()`, which pads a numeric string on the left with zeros. It understands about plus and minus signs:

```
>>> '12'.zfill(5)
'00012'
>>> '-3.14'.zfill(7)
'-003.14'
>>> '3.14159265359'.zfill(5)
'3.14159265359'
```

Basic usage of the `str.format()` method looks like this:

```
>>> print 'We are the {} who say "{}!"'.format('knights', 'Ni')
We are the knights who say "Ni!"
```

The brackets and characters within them (called format fields) are replaced with the objects passed into the `str.format()` method. A number in the brackets refers to the position of the object passed into the `str.format()` method.

```
>>> print '{0} and {1}'.format('spam', 'eggs')
spam and eggs
>>> print '{1} and {0}'.format('spam', 'eggs')
eggs and spam
```

If keyword arguments are used in the `str.format()` method, their values are referred to by using the name of the argument.

```
>>> print 'This {food} is {adjective}.'.format(
...       food='spam', adjective='absolutely horrible')
This spam is absolutely horrible.
```

Positional and keyword arguments can be arbitrarily combined:

```
>>> print 'The story of {0}, {1}, and {other}.'.format('Bill', 'Manfred',
...                                                     other='Georg')
The story of Bill, Manfred, and Georg.
```

`'!s'` (apply `str()`) and `'!r'` (apply `repr()`) can be used to convert the value before it is formatted.

```
>>> import math
>>> print 'The value of PI is approximately {}.'.format(math.pi)
The value of PI is approximately 3.14159265359.
>>> print 'The value of PI is approximately {!r}.'.format(math.pi)
The value of PI is approximately 3.141592653589793.
```

An optional `':'` and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

```
>>> import math
>>> print 'The value of PI is approximately {0:.3f}.'.format(math.pi)
The value of PI is approximately 3.142.
```

Passing an integer after the `':'` will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}
>>> for name, phone in table.items():
...     print '{0:10} ==> {1:10d}'.format(name, phone)
...
Jack       ==>        4098
Dcab       ==>        7678
Sjoerd     ==>        4127
```

If you have a really long format string that you don' t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print ('Jack: {0[Jack]:d}; Sjoerd: {0[Sjoerd]:d}; '
...        'Dcab: {0[Dcab]:d}'.format(table))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This could also be done by passing the table as keyword arguments with the 『**』 notation.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print 'Jack: {Jack:d}; Sjoerd: {Sjoerd:d}; Dcab: {Dcab:d}'.format(**table)
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This is particularly useful in combination with the built-in function vars(), which returns a dictionary containing all local variables.

For a complete overview of string formatting with str.format(), see formatstrings.

### 7.1.1 Old string formatting

The % operator can also be used for string formatting. It interprets the left argument much like a sprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

```
>>> import math
>>> print 'The value of PI is approximately %5.3f.' % math.pi
The value of PI is approximately 3.142.
```

More information can be found in the string-formatting section.

## 7.2 Reading and Writing Files

open() returns a file object, and is most commonly used with two arguments: open(filename, mode).

```
>>> f = open('workfile', 'w')
>>> print f
<open file 'workfile', mode 'w' at 80a0960>
```

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. *mode* can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and 'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+' opens the file for both reading and writing. The *mode* argument is optional; 'r' will be assumed if it' s omitted.

On Windows, `'b'` appended to the mode opens the file in binary mode, so there are also modes like `'rb'`, `'wb'`, and `'r+b'`. Python on Windows makes a distinction between text and binary files; the end-of-line characters in text files are automatically altered slightly when data is read or written. This behind-the-scenes modification to file data is fine for ASCII text files, but it'll corrupt binary data like that in `JPEG` or `EXE` files. Be very careful to use binary mode when reading and writing such files. On Unix, it doesn't hurt to append a `'b'` to the mode, so you can use it platform-independently for all binary files.

## 7.2.1 Methods of File Objects

The rest of the examples in this section will assume that a file object called `f` has already been created.

To read a file's contents, call `f.read(size)`, which reads some quantity of data and returns it as a string. *size* is an optional numeric argument. When *size* is omitted or negative, the entire contents of the file will be read and returned; it's your problem if the file is twice as large as your machine's memory. Otherwise, at most *size* bytes are read and returned. If the end of the file has been reached, `f.read()` will return an empty string (`""`).

```
>>> f.read()
'This is the entire file.\n'
>>> f.read()
''
```

`f.readline()` reads a single line from the file; a newline character (`\n`) is left at the end of the string, and is only omitted on the last line of the file if the file doesn't end in a newline. This makes the return value unambiguous; if `f.readline()` returns an empty string, the end of the file has been reached, while a blank line is represented by `'\n'`, a string containing only a single newline.

```
>>> f.readline()
'This is the first line of the file.\n'
>>> f.readline()
'Second line of the file\n'
>>> f.readline()
''
```

For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:

```
>>> for line in f:
        print line,

This is the first line of the file.
Second line of the file
```

If you want to read all the lines of a file in a list you can also use `list(f)` or `f.readlines()`.

`f.write(string)` writes the contents of *string* to the file, returning `None`.

```
>>> f.write('This is a test\n')
```

To write something other than a string, it needs to be converted to a string first:

```
>>> value = ('the answer', 42)
>>> s = str(value)
>>> f.write(s)
```

`f.tell()` returns an integer giving the file object's current position in the file, measured in bytes from the beginning of the file. To change the file object's position, use `f.seek(offset, from_what)`. The position is computed from adding *offset* to a reference point; the reference point is selected by the *from_what* argument. A *from_what* value

of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. *from_what* can be omitted and defaults to 0, using the beginning of the file as the reference point.

```
>>> f = open('workfile', 'r+')
>>> f.write('0123456789abcdef')
>>> f.seek(5)      # Go to the 6th byte in the file
>>> f.read(1)
'5'
>>> f.seek(-3, 2)  # Go to the 3rd byte before the end
>>> f.read(1)
'd'
```

When you' re done with a file, call `f.close()` to close it and free up any system resources taken up by the open file. After calling `f.close()`, attempts to use the file object will automatically fail.

```
>>> f.close()
>>> f.read()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

It is good practice to use the `with` keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent `try-finally` blocks:

```
>>> with open('workfile', 'r') as f:
...     read_data = f.read()
>>> f.closed
True
```

File objects have some additional methods, such as `isatty()` and `truncate()` which are less frequently used; consult the Library Reference for a complete guide to file objects.

## 7.2.2 Saving structured data with `json`

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the `read()` method only returns strings, which will have to be passed to a function like `int()`, which takes a string like `'123'` and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.

Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called JSON (JavaScript Object Notation). The standard module called `json` can take Python data hierarchies, and convert them to string representations; this process is called *serializing*. Reconstructing the data from the string representation is called *deserializing*. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

備⬚: The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.

If you have an object x, you can view its JSON string representation with a simple line of code:

```
>>> import json
>>> json.dumps([1, 'simple', 'list'])
'[1, "simple", "list"]'
```

Another variant of the `dumps()` function, called `dump()`, simply serializes the object to a file. So if `f` is a *file object* opened for writing, we can do this:

```
json.dump(x, f)
```

To decode the object again, if `f` is a *file object* which has been opened for reading:

```
x = json.load(f)
```

This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the `json` module contains an explanation of this.

**也參考:**

`pickle` - the pickle module

Contrary to *JSON*, *pickle* is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker.

# 錯誤和例外

Until now error messages haven't been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: *syntax errors* and *exceptions*.

## 8.1 語法錯誤

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

```
>>> while True print 'Hello world'
  File "<stdin>", line 1
    while True print 'Hello world'
                   ^
SyntaxError: invalid syntax
```

The parser repeats the offending line and displays a little 『arrow』 pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token *preceding* the arrow: in the example, the error is detected at the keyword `print`, since a colon (`':'`) is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2 例外

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called *exceptions* and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

```
>>> 10 * (1/0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
```

```
ZeroDivisionError: integer division or modulo by zero
>>> 4 + spam*3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'spam' is not defined
>>> '2' + 2
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot concatenate 'str' and 'int' objects
```

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are `ZeroDivisionError`, `NameError` and `TypeError`. The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

bltin-exceptions lists the built-in exceptions and their meanings.

## 8.3 處理例外

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using `Control-C` or whatever the operating system supports); note that a user-generated interruption is signalled by raising the `KeyboardInterrupt` exception.

```
>>> while True:
...     try:
...         x = int(raw_input("Please enter a number: "))
...         break
...     except ValueError:
...         print "Oops!  That was no valid number.  Try again..."
...
```

The `try` statement works as follows.

- First, the *try clause* (the statement(s) between the `try` and `except` keywords) is executed.

- If no exception occurs, the *except clause* is skipped and execution of the `try` statement is finished.

- If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the `except` keyword, the except clause is executed, and then execution continues after the `try` statement.

- If an exception occurs which does not match the exception named in the except clause, it is passed on to outer `try` statements; if no handler is found, it is an *unhandled exception* and execution stops with a message as shown above.

A `try` statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same `try` statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

```
... except (RuntimeError, TypeError, NameError):
...     pass
```

Note that the parentheses around this tuple are required, because `except ValueError, e:` was the syntax used for what is normally written as `except ValueError as e:` in modern Python (described below). The old syntax is still supported for backwards compatibility. This means `except RuntimeError, TypeError` is not equivalent to `except (RuntimeError, TypeError):` but to `except RuntimeError as TypeError:` which is not what you want.

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

```python
import sys

try:
    f = open('myfile.txt')
    s = f.readline()
    i = int(s.strip())
except IOError as e:
    print "I/O error({0}): {1}".format(e.errno, e.strerror)
except ValueError:
    print "Could not convert data to an integer."
except:
    print "Unexpected error:", sys.exc_info()[0]
    raise
```

The `try ⋯except` statement has an optional *else clause*, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

```python
for arg in sys.argv[1:]:
    try:
        f = open(arg, 'r')
    except IOError:
        print 'cannot open', arg
    else:
        print arg, 'has', len(f.readlines()), 'lines'
        f.close()
```

The use of the `else` clause is better than adding additional code to the `try` clause because it avoids accidentally catching an exception that wasn't raised by the code being protected by the `try ⋯except` statement.

When an exception occurs, it may have an associated value, also known as the exception's *argument*. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name (or tuple). The variable is bound to an exception instance with the arguments stored in `instance.args`. For convenience, the exception instance defines `__str__()` so the arguments can be printed directly without having to reference `.args`.

One may also instantiate an exception first before raising it and add any attributes to it as desired.

```python
>>> try:
...     raise Exception('spam', 'eggs')
... except Exception as inst:
...     print type(inst)     # the exception instance
...     print inst.args      # arguments stored in .args
...     print inst           # __str__ allows args to be printed directly
...     x, y = inst.args
```

```
...       print 'x =', x
...       print 'y =', y
...
<type 'exceptions.Exception'>
('spam', 'eggs')
('spam', 'eggs')
x = spam
y = eggs
```

If an exception has an argument, it is printed as the last part (『detail』) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

```
>>> def this_fails():
...       x = 1/0
...
>>> try:
...       this_fails()
... except ZeroDivisionError as detail:
...       print 'Handling run-time error:', detail
...
Handling run-time error: integer division or modulo by zero
```

## 8.4 Raising Exceptions

The `raise` statement allows the programmer to force a specified exception to occur. For example:

```
>>> raise NameError('HiThere')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: HiThere
```

The sole argument to `raise` indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from `Exception`).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the `raise` statement allows you to re-raise the exception:

```
>>> try:
...       raise NameError('HiThere')
... except NameError:
...       print 'An exception flew by!'
...       raise
...
An exception flew by!
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
NameError: HiThere
```

## 8.5 User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see *Classes* for more about Python classes). Exceptions should typically be derived from the Exception class, either directly or indirectly. For example:

```
>>> class MyError(Exception):
...     def __init__(self, value):
...         self.value = value
...     def __str__(self):
...         return repr(self.value)
...
>>> try:
...     raise MyError(2*2)
... except MyError as e:
...     print 'My exception occurred, value:', e.value
...
My exception occurred, value: 4
>>> raise MyError('oops!')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
__main__.MyError: 'oops!'
```

In this example, the default __init__() of Exception has been overridden. The new behavior simply creates the *value* attribute. This replaces the default behavior of creating the *args* attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

```
class Error(Exception):
    """Base class for exceptions in this module."""
    pass

class InputError(Error):
    """Exception raised for errors in the input.

    Attributes:
        expr -- input expression in which the error occurred
        msg  -- explanation of the error
    """

    def __init__(self, expr, msg):
        self.expr = expr
        self.msg = msg

class TransitionError(Error):
    """Raised when an operation attempts a state transition that's not
    allowed.

    Attributes:
        prev -- state at beginning of transition
        next -- attempted new state
        msg  -- explanation of why the specific transition is not allowed
    """

    def __init__(self, prev, next, msg):
```

(下页继续)

```
        self.prev = prev
        self.next = next
        self.msg = msg
```

Most exceptions are defined with names that end in 「Error」, similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter *Classes*.

## 8.6 Defining Clean-up Actions

The `try` statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

```
>>> try:
...     raise KeyboardInterrupt
... finally:
...     print 'Goodbye, world!'
...
Goodbye, world!
KeyboardInterrupt
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
```

A *finally clause* is always executed before leaving the `try` statement, whether an exception has occurred or not. When an exception has occurred in the `try` clause and has not been handled by an `except` clause (or it has occurred in an `except` or `else` clause), it is re-raised after the `finally` clause has been executed. The `finally` clause is also executed 「on the way out」 when any other clause of the `try` statement is left via a `break`, `continue` or `return` statement. A more complicated example (having `except` and `finally` clauses in the same `try` statement works as of Python 2.5):

```
>>> def divide(x, y):
...     try:
...         result = x / y
...     except ZeroDivisionError:
...         print "division by zero!"
...     else:
...         print "result is", result
...     finally:
...         print "executing finally clause"
...
>>> divide(2, 1)
result is 2
executing finally clause
>>> divide(2, 0)
division by zero!
executing finally clause
>>> divide("2", "1")
executing finally clause
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in divide
TypeError: unsupported operand type(s) for /: 'str' and 'str'
```

As you can see, the `finally` clause is executed in any event. The `TypeError` raised by dividing two strings is not handled by the `except` clause and therefore re-raised after the `finally` clause has been executed.

In real world applications, the `finally` clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7 Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

```python
for line in open("myfile.txt"):
    print line,
```

The problem with this code is that it leaves the file open for an indeterminate amount of time after the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The `with` statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

```python
with open("myfile.txt") as f:
    for line in f:
        print line,
```

After the statement is executed, the file *f* is always closed, even if a problem was encountered while processing the lines. Other objects which provide predefined clean-up actions will indicate this in their documentation.

# Classes

Compared with other programming languages, Python's class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are *public* (except see below *Private Variables and Class-local References*), and all member functions are *virtual*. As in Modula-3, there are no shorthands for referencing the object's members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1 A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change —this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2 Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python's scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what's going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let's begin with some definitions.

A *namespace* is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that's normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as `abs()`, and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function `maximize` without confusion — users of the modules must prefix it with the module name.

By the way, I use the word *attribute* for any name following a dot —for example, in the expression `z.real`, `real` is an attribute of the object `z`. Strictly speaking, references to names in modules are attribute references: in the expression `modname.funcname`, `modname` is a module object and `funcname` is an attribute of it. In this case there happens to be a straightforward mapping between the module's attributes and the global names defined in the module: they share the same namespace![1]

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write `modname.the_answer = 42`. Writable attributes may also be deleted with the `del` statement. For example, `del modname.the_answer` will remove the attribute `the_answer` from the object named by `modname`.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called `__main__`, so they have their own global namespace. (The built-in names actually also live in a module; this is called `__builtin__`.)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A *scope* is a textual region of a Python program where a namespace is directly accessible. 「Directly accessible」 here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

- the innermost scope, which is searched first, contains the local names

- the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names

- the next-to-last scope contains the current module's global names

- the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module's global names. Otherwise, all variables found outside of the innermost scope are read-only (an attempt to write to such a variable will simply create a *new* local variable in the innermost scope, leaving the identically named outer variable unchanged).

---

[1] Except for one thing. Module objects have a secret read-only attribute called `__dict__` which returns the dictionary used to implement the module's namespace; the name `__dict__` is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers.

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module' s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module' s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time —however, the language definition is evolving towards static name resolution, at ⌈compile⌋ time, so don' t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that –if no `global` statement is in effect –assignments to names always go into the innermost scope. Assignments do not copy data —they just bind names to objects. The same is true for deletions: the statement `del x` removes the binding of `x` from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, `import` statements and function definitions bind the module or function name in the local scope. (The `global` statement can be used to indicate that particular variables live in the global scope.)

# 9.3 A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

## 9.3.1 Class Definition Syntax

The simplest form of class definition looks like this:

```
class ClassName:
    <statement-1>
    .
    .
    .
    <statement-N>
```

Class definitions, like function definitions (`def` statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an `if` statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful —we' ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods —again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope —thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a *class object* is created. This is basically a wrapper around the contents of the namespace created by the class definition; we' ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (`ClassName` in the example).

## 9.3.2 Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

*Attribute references* use the standard syntax used for all attribute references in Python: `obj.name`. Valid attribute names are all the names that were in the class's namespace when the class object was created. So, if the class definition looked like this:

```python
class MyClass:
    """A simple example class"""
    i = 12345

    def f(self):
        return 'hello world'
```

then `MyClass.i` and `MyClass.f` are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value of `MyClass.i` by assignment. `__doc__` is also a valid attribute, returning the docstring belonging to the class: `"A simple example class"`.

Class *instantiation* uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

```python
x = MyClass()
```

creates a new *instance* of the class and assigns this object to the local variable `x`.

The instantiation operation (「calling」a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named `__init__()`, like this:

```python
def __init__(self):
    self.data = []
```

When a class defines an `__init__()` method, class instantiation automatically invokes `__init__()` for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

```python
x = MyClass()
```

Of course, the `__init__()` method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to `__init__()`. For example,

```python
>>> class Complex:
...     def __init__(self, realpart, imagpart):
...         self.r = realpart
...         self.i = imagpart
...
>>> x = Complex(3.0, -4.5)
>>> x.r, x.i
(3.0, -4.5)
```

### 9.3.3 Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

*data attributes* correspond to ⌈instance variables⌋ in Smalltalk, and to ⌈data members⌋ in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

```python
x.counter = 1
while x.counter < 10:
    x.counter = x.counter * 2
print x.counter
del x.counter
```

The other kind of instance attribute reference is a *method*. A method is a function that ⌈belongs to⌋ an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we'll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.f is not the same thing as MyClass.f —it is a *method object*, not a function object.

### 9.3.4 Method Objects

Usually, a method is called right after it is bound:

```python
x.f()
```

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

```python
xf = x.f
while True:
    print xf()
```

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any —even if the argument isn't actually used …

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent to MyClass.f(x). In general, calling a method with a list of *n* arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method's object before the first argument.

If you still don't understand how methods work, a look at the implementation can perhaps clarify matters. When a non-data attribute of an instance is referenced, the instance's class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5 Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

```python
class Dog:

    kind = 'canine'         # class variable shared by all instances

    def __init__(self, name):
        self.name = name    # instance variable unique to each instance

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.kind                  # shared by all dogs
'canine'
>>> e.kind                  # shared by all dogs
'canine'
>>> d.name                  # unique to d
'Fido'
>>> e.name                  # unique to e
'Buddy'
```

As discussed in *A Word About Names and Objects*, shared data can have possibly surprising effects with involving *mutable* objects such as lists and dictionaries. For example, the *tricks* list in the following code should not be used as a class variable because just a single list would be shared by all *Dog* instances:

```python
class Dog:

    tricks = []             # mistaken use of a class variable

    def __init__(self, name):
        self.name = name

    def add_trick(self, trick):
        self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks                # unexpectedly shared by all dogs
['roll over', 'play dead']
```

Correct design of the class should use an instance variable instead:

```python
class Dog:

    def __init__(self, name):
        self.name = name
        self.tricks = []    # creates a new empty list for each dog

    def add_trick(self, trick):
        self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
```

```
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks
['roll over']
>>> e.tricks
['play dead']
```

## 9.4 Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users ( 「clients」 ) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding —it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care —clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided —again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called `self`. This is nothing more than a convention: the name `self` has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a *class browser* program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

```python
# Function defined outside the class
def f1(self, x, y):
    return min(x, x+y)

class C:
    f = f1

    def g(self):
        return 'hello world'

    h = g
```

Now `f`, `g` and `h` are all attributes of class `C` that refer to function objects, and consequently they are all methods of instances of `C` —h being exactly equivalent to `g`. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the `self` argument:

```
class Bag:
    def __init__(self):
        self.data = []

    def add(self, x):
        self.data.append(x)

    def addtwice(self, x):
        self.add(x)
        self.add(x)
```

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we' ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a *class* (also called its *type*). It is stored as `object.__class__`.

## 9.5 Inheritance

Of course, a language feature would not be worthy of the name ⌜class⌟ without supporting inheritance. The syntax for a derived class definition looks like this:

```
class DerivedClassName(BaseClassName):
    <statement-1>
    .
    .
    .
    <statement-N>
```

The name `BaseClassName` must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

```
class DerivedClassName(modname.BaseClassName):
```

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There' s nothing special about instantiation of derived classes: `DerivedClassName()` creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively `virtual`.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just call `BaseClassName.`

`methodname(self, arguments)`. This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as `BaseClassName` in the global scope.)

Python has two built-in functions that work with inheritance:

- Use `isinstance()` to check an instance's type: `isinstance(obj, int)` will be `True` only if `obj.__class__` is `int` or some class derived from `int`.

- Use `issubclass()` to check class inheritance: `issubclass(bool, int)` is `True` since `bool` is a subclass of `int`. However, `issubclass(unicode, str)` is `False` since `unicode` is not a subclass of `str` (they only share a common ancestor, `basestring`).

### 9.5.1 Multiple Inheritance

Python supports a limited form of multiple inheritance as well. A class definition with multiple base classes looks like this:

```
class DerivedClassName(Base1, Base2, Base3):
    <statement-1>
    .
    .
    .
    <statement-N>
```

For old-style classes, the only rule is depth-first, left-to-right. Thus, if an attribute is not found in `DerivedClassName`, it is searched in `Base1`, then (recursively) in the base classes of `Base1`, and only if it is not found there, it is searched in `Base2`, and so on.

(To some people breadth first —searching `Base2` and `Base3` before the base classes of `Base1` —looks more natural. However, this would require you to know whether a particular attribute of `Base1` is actually defined in `Base1` or in one of its base classes before you can figure out the consequences of a name conflict with an attribute of `Base2`. The depth-first rule makes no differences between direct and inherited attributes of `Base1`.)

For *new-style class*es, the method resolution order changes dynamically to support cooperative calls to `super()`. This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

With new-style classes, dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all new-style classes inherit from `object`, so any case of multiple inheritance provides more than one path to reach `object`. To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see https://www.python.org/download/releases/2.3/mro/.

## 9.6 Private Variables and Class-local References

「Private」 instance variables that cannot be accessed except from inside an object don't exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. `_spam`) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called *name mangling*. Any identifier of the form `__spam` (at

least two leading underscores, at most one trailing underscore) is textually replaced with _classname__spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

```python
class Mapping:
    def __init__(self, iterable):
        self.items_list = []
        self.__update(iterable)

    def update(self, iterable):
        for item in iterable:
            self.items_list.append(item)

    __update = update   # private copy of original update() method

class MappingSubclass(Mapping):

    def update(self, keys, values):
        # provides new signature for update()
        # but does not break __init__()
        for item in zip(keys, values):
            self.items_list.append(item)
```

The above example would work even if MappingSubclass were to introduce a __update identifier since it is replaced with _Mapping__update in the Mapping class and _MappingSubclass__update in the MappingSubclass class respectively.

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec, eval() or execfile() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(), setattr() and delattr(), as well as when referencing __dict__ directly.

## 9.7 Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal「record」or C「struct」, bundling together a few named data items. An empty class definition will do nicely:

```python
class Employee:
    pass

john = Employee()  # Create an empty employee record

# Fill the fields of the record
john.name = 'John Doe'
john.dept = 'computer lab'
john.salary = 1000
```

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: `m.im_self` is the instance object with the method `m()`, and `m.im_func` is the function object corresponding to the method.

## 9.8 Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the `raise` statement:

```python
raise Class, instance

raise instance
```

In the first form, `instance` must be an instance of `Class` or of a class derived from it. The second form is a shorthand for:

```python
raise instance.__class__, instance
```

A class in an `except` clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around —an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

```python
class B:
    pass
class C(B):
    pass
class D(C):
    pass

for c in [B, C, D]:
    try:
        raise c()
    except D:
        print "D"
    except C:
        print "C"
    except B:
        print "B"
```

Note that if the except clauses were reversed (with `except B` first), it would have printed B, B, B —the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception's class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function `str()`.

## 9.9 Iterators

By now you have probably noticed that most container objects can be looped over using a `for` statement:

```python
for element in [1, 2, 3]:
    print element
for element in (1, 2, 3):
    print element
for key in {'one':1, 'two':2}:
    print key
for char in "123":
    print char
for line in open("myfile.txt"):
    print line,
```

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the `for` statement calls `iter()` on the container object. The function returns an iterator object that defines the method `next()` which accesses elements in the container one at a time. When there are no more elements, `next()` raises a `StopIteration` exception which tells the `for` loop to terminate. This example shows how it all works:

```python
>>> s = 'abc'
>>> it = iter(s)
>>> it
<iterator object at 0x00A1DB50>
>>> it.next()
'a'
>>> it.next()
'b'
>>> it.next()
'c'
>>> it.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    it.next()
StopIteration
```

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an `__iter__()` method which returns an object with a `next()` method. If the class defines `next()`, then `__iter__()` can just return `self`:

```python
class Reverse:
    """Iterator for looping over a sequence backwards."""
    def __init__(self, data):
        self.data = data
        self.index = len(data)

    def __iter__(self):
        return self

    def next(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]
```

```
>>> rev = Reverse('spam')
>>> iter(rev)
<__main__.Reverse object at 0x00A1DB50>
>>> for char in rev:
...     print char
...
m
a
p
s
```

## 9.10 Generators

*Generator*s are a simple and powerful tool for creating iterators. They are written like regular functions but use the `yield` statement whenever they want to return data. Each time `next()` is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

```
def reverse(data):
    for index in range(len(data)-1, -1, -1):
        yield data[index]
```

```
>>> for char in reverse('golf'):
...     print char
...
f
l
o
g
```

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the `__iter__()` and `next()` methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like `self.index` and `self.data`.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise `StopIteration`. In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11 Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of square brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

```
>>> sum(i*i for i in range(10))                 # sum of squares
285
```

```
>>> xvec = [10, 20, 30]
>>> yvec = [7, 5, 3]
>>> sum(x*y for x,y in zip(xvec, yvec))        # dot product
260

>>> from math import pi, sin
>>> sine_table = dict((x, sin(x*pi/180)) for x in range(0, 91))

>>> unique_words = set(word  for line in page  for word in line.split())

>>> valedictorian = max((student.gpa, student.name) for student in graduates)

>>> data = 'golf'
>>> list(data[i] for i in range(len(data)-1,-1,-1))
['f', 'l', 'o', 'g']
```

⬚解

# Python 標准函式庫概覽

## 10.1 作業系統介面

os 模組提供了數十個與作業系統溝通的函式：

```
>>> import os
>>> os.getcwd()          # Return the current working directory
'C:\\Python26'
>>> os.chdir('/server/accesslogs')   # Change current working directory
>>> os.system('mkdir today')   # Run the command mkdir in the system shell
0
```

務必使用 import os 而非 from os import *。這將避免因系統不同而實作有差異的 os.open() 覆蓋內建函式 open()。

在使用 os 諸如此類大型模組時搭配內建函式 dir() 和 help() 是非常有用的：

```
>>> import os
>>> dir(os)
<returns a list of all module functions>
>>> help(os)
<returns an extensive manual page created from the module's docstrings>
```

對於日常檔案和目錄管理任務，shutil 模組提供了更容易使用的高階介面：

```
>>> import shutil
>>> shutil.copyfile('data.db', 'archive.db')
>>> shutil.move('/build/executables', 'installdir')
```

## 10.2 檔案之萬用字元

The `glob` module provides a function for making file lists from directory wildcard searches:

```
>>> import glob
>>> glob.glob('*.py')
['primes.py', 'random.py', 'quote.py']
```

## 10.3 命令列引數

通用工具⬚本常需要處理命令列引數。這些引數會以串列形式存放在 `sys` 模組的 *argv* 此變數中。例如在命令列執行 `python demo.py one two three` 會有以下輸出結果:

```
>>> import sys
>>> print sys.argv
['demo.py', 'one', 'two', 'three']
```

`getopt` 模組使用 Unix `getopt()` 函式來處理 *sys.argv*。更⬚大且具有彈性的命令列處理可由 `argparse` 模組提供。

## 10.4 錯誤輸出重新導向與程式終止

`sys` 模組也有 *stdin*，*stdout*，和 *stderr* 等變數。即使當 *stdout* 被重新導向時，後者 *stderr* 可輸出發送警告和錯誤訊息。

```
>>> sys.stderr.write('Warning, log file not found starting a new one\n')
Warning, log file not found starting a new one
```

終止⬚本最直接的方式就是利用 `sys.exit()`。

## 10.5 字串樣式比對

`re` 模組提供正規表示式 (regular expression) 做進階的字串處理。當要處理⬚雜的比對以及操作時，正規表示式是簡潔且經過最佳化的解⬚方案。

```
>>> import re
>>> re.findall(r'\bf[a-z]*', 'which foot or hand fell fastest')
['foot', 'fell', 'fastest']
>>> re.sub(r'(\b[a-z]+) \1', r'\1', 'cat in the the hat')
'cat in the hat'
```

當只需要簡單的字串操作時，因⬚可讀性以及方便除錯，字串本身的方法是比較建議的。

```
>>> 'tea for too'.replace('too', 'two')
'tea for two'
```

## 10.6 數學相關

`math` 模組提供了 C 函式庫中底層的浮點數運算的函式。

```
>>> import math
>>> math.cos(math.pi / 4.0)
0.70710678118654757
>>> math.log(1024, 2)
10.0
```

`random` 模組提供了隨機選擇的工具。

```
>>> import random
>>> random.choice(['apple', 'pear', 'banana'])
'apple'
>>> random.sample(xrange(100), 10)   # sampling without replacement
[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]
>>> random.random()     # random float
0.17970987693706186
>>> random.randrange(6)     # random integer chosen from range(6)
4
```

## 10.7 網路存取

There are a number of modules for accessing the internet and processing internet protocols. Two of the simplest are `urllib2` for retrieving data from URLs and `smtplib` for sending mail:

```
>>> import urllib2
>>> for line in urllib2.urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl'):
...     if 'EST' in line or 'EDT' in line:  # look for Eastern Time
...         print line

<BR>Nov. 25, 09:43:32 PM EST

>>> import smtplib
>>> server = smtplib.SMTP('localhost')
>>> server.sendmail('soothsayer@example.org', 'jcaesar@example.org',
... """To: jcaesar@example.org
... From: soothsayer@example.org
...
... Beware the Ides of March.
... """)
>>> server.quit()
```

（注意第二個例子中需要在本地端執行一個郵件伺服器）

## 10.8 日期與時間

`datetime` 模組中有許多類⬚供以操作日期以及時間，從簡單從⬚雜都有。模組支援日期與時間的運算，而實作的重點是有效率的成員⬚取以達到輸出格式化以及操作。模組也提供支援時區⬚算的類⬚。

```
>>> # dates are easily constructed and formatted
>>> from datetime import date
>>> now = date.today()
>>> now
datetime.date(2003, 12, 2)
>>> now.strftime("%m-%d-%y. %d %b %Y is a %A on the %d day of %B.")
'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

>>> # dates support calendar arithmetic
>>> birthday = date(1964, 7, 31)
>>> age = now - birthday
>>> age.days
14368
```

## 10.9 資料壓縮

Common data archiving and compression formats are directly supported by modules including: `zlib`, `gzip`, `bz2`, `zipfile` and `tarfile`.

```
>>> import zlib
>>> s = 'witch which has which witches wrist watch'
>>> len(s)
41
>>> t = zlib.compress(s)
>>> len(t)
37
>>> zlib.decompress(t)
'witch which has which witches wrist watch'
>>> zlib.crc32(s)
226805979
```

## 10.10 效能量測

有一些 Python 使用者很想了解同個問題的不同實作方法的效能差⬚。Python 提供評估了效能差⬚的工具。

舉例來⬚，有人可能會試著用 tuple 的打包機制來交⬚引數代替傳統的方式。`timeit` 模組可以迅速地展示效能的進步。

```
>>> from timeit import Timer
>>> Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()
0.57535828626024577
>>> Timer('a,b = b,a', 'a=1; b=2').timeit()
0.54962537085770791
```

相對於 `timeit` 模組提供這⬚細的粒度，`profile` 模組以及 `pstats` 模組則提供了一些在大型的程式碼識⬚關鍵臨界區間（Critical Section）的工具。

## 10.11 品質控管

達到高品質軟體的一個方法當開發時對每個函式寫測試以及在開發過程中要不斷的跑這些測試。

`doctest` 模組提供了一個工具，掃描模組⬚根據程式中⬚嵌的文件字符串執行測試。測試構造如同簡單的將它的輸出結果剪下⬚貼上到文件字符串中。通過用⬚提供的例子，它⬚化了文件，允許 doctest 模塊組認代碼的結果是否與文件一致：

```python
def average(values):
    """Computes the arithmetic mean of a list of numbers.

    >>> print average([20, 30, 70])
    40.0
    """
    return sum(values, 0.0) / len(values)

import doctest
doctest.testmod()   # automatically validate the embedded tests
```

`unittest` 模組不像 `doctest` 模組這般容易，但是它提供了更完整的測試集⬚且可以整合在不同的檔案間。

```python
import unittest

class TestStatisticalFunctions(unittest.TestCase):

    def test_average(self):
        self.assertEqual(average([20, 30, 70]), 40.0)
        self.assertEqual(round(average([1, 5, 7]), 1), 4.3)
        with self.assertRaises(ZeroDivisionError):
            average([])
        with self.assertRaises(TypeError):
            average(20, 30, 70)

unittest.main()  # Calling from the command line invokes all tests
```

## 10.12 標準模組庫

「batteries included」是 Python 設計哲學。它的好處是可以透過這些套件使用⬚雜與⬚大的功能。例如：

- The `xmlrpclib` and `SimpleXMLRPCServer` modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.

- The `email` package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike `smtplib` and `poplib` which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.

- The `xml.dom` and `xml.sax` packages provide robust support for parsing this popular data interchange format. Likewise, the `csv` module supports direct reads and writes in a common database format. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.

- 有數種支援國際化模組 `gettext`, `locale`, 和 `codecs` 等套件。

# Brief Tour of the Standard Library —Part II

第二部分涵蓋更多支援專業程式設計所需要的進階模組。這些模組很少出現在小F本中。

## 11.1 Output Formatting

The `repr` module provides a version of `repr()` customized for abbreviated displays of large or deeply nested containers:

```
>>> import repr
>>> repr.repr(set('supercalifragilisticexpialidocious'))
"set(['a', 'c', 'd', 'e', 'f', 'g', ...])"
```

The `pprint` module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the 「pretty printer」 adds line breaks and indentation to more clearly reveal data structure:

```
>>> import pprint
>>> t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',
...     'yellow'], 'blue']]]
...
>>> pprint.pprint(t, width=30)
[[[['black', 'cyan'],
   'white',
   ['green', 'red']],
  [['magenta', 'yellow'],
   'blue']]]
```

The `textwrap` module formats paragraphs of text to fit a given screen width:

```
>>> import textwrap
>>> doc = """The wrap() method is just like fill() except that it returns
... a list of strings instead of one big string with newlines to separate
... the wrapped lines."""
...
```

```
>>> print textwrap.fill(doc, width=40)
The wrap() method is just like fill()
except that it returns a list of strings
instead of one big string with newlines
to separate the wrapped lines.
```

The `locale` module accesses a database of culture specific data formats. The grouping attribute of locale's format function provides a direct way of formatting numbers with group separators:

```
>>> import locale
>>> locale.setlocale(locale.LC_ALL, 'English_United States.1252')
'English_United States.1252'
>>> conv = locale.localeconv()          # get a mapping of conventions
>>> x = 1234567.8
>>> locale.format("%d", x, grouping=True)
'1,234,567'
>>> locale.format_string("%s%.*f", (conv['currency_symbol'],
...                      conv['frac_digits'], x), grouping=True)
'$1,234,567.80'
```

## 11.2 Templating

The `string` module includes a versatile `Template` class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by `$` with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing `$$` creates a single escaped `$`:

```
>>> from string import Template
>>> t = Template('${village}folk send $$10 to $cause.')
>>> t.substitute(village='Nottingham', cause='the ditch fund')
'Nottinghamfolk send $10 to the ditch fund.'
```

The `substitute()` method raises a `KeyError` when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the `safe_substitute()` method may be more appropriate —it will leave placeholders unchanged if data is missing:

```
>>> t = Template('Return the $item to $owner.')
>>> d = dict(item='unladen swallow')
>>> t.substitute(d)
Traceback (most recent call last):
  ...
KeyError: 'owner'
>>> t.safe_substitute(d)
'Return the unladen swallow to $owner.'
```

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

```
>>> import time, os.path
>>> photofiles = ['img_1074.jpg', 'img_1076.jpg', 'img_1077.jpg']
>>> class BatchRename(Template):
```

```
...        delimiter = '%'
>>> fmt = raw_input('Enter rename style (%d-date %n-seqnum %f-format):  ')
Enter rename style (%d-date %n-seqnum %f-format):  Ashley_%n%f

>>> t = BatchRename(fmt)
>>> date = time.strftime('%d%b%y')
>>> for i, filename in enumerate(photofiles):
...        base, ext = os.path.splitext(filename)
...        newname = t.substitute(d=date, n=i, f=ext)
...        print '{0} --> {1}'.format(filename, newname)

img_1074.jpg --> Ashley_0.jpg
img_1076.jpg --> Ashley_1.jpg
img_1077.jpg --> Ashley_2.jpg
```

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3 Working with Binary Data Record Layouts

The `struct` module provides `pack()` and `unpack()` functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the `zipfile` module. Pack codes `"H"` and `"I"` represent two and four byte unsigned numbers respectively. The `"<"` indicates that they are standard size and in little-endian byte order:

```
import struct

data = open('myfile.zip', 'rb').read()
start = 0
for i in range(3):                      # show the first 3 file headers
    start += 14
    fields = struct.unpack('<IIIHH', data[start:start+16])
    crc32, comp_size, uncomp_size, filenamesize, extra_size = fields

    start += 16
    filename = data[start:start+filenamesize]
    start += filenamesize
    extra = data[start:start+extra_size]
    print filename, hex(crc32), comp_size, uncomp_size

    start += extra_size + comp_size     # skip to the next header
```

## 11.4 Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level `threading` module can run tasks in background while the main program continues to run:

```
import threading, zipfile

class AsyncZip(threading.Thread):
    def __init__(self, infile, outfile):
        threading.Thread.__init__(self)
        self.infile = infile
        self.outfile = outfile

    def run(self):
        f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP_DEFLATED)
        f.write(self.infile)
        f.close()
        print 'Finished background zip of: ', self.infile

background = AsyncZip('mydata.txt', 'myarchive.zip')
background.start()
print 'The main program continues to run in foreground.'

background.join()    # Wait for the background task to finish
print 'Main program waited until background was done.'
```

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the `Queue` module to feed that thread with requests from other threads. Applications using `Queue.Queue` objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

# 11.5 Logging

The `logging` module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to `sys.stderr`:

```
import logging
logging.debug('Debugging information')
logging.info('Informational message')
logging.warning('Warning:config file %s not found', 'server.conf')
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')
```

This produces the following output:

```
WARNING:root:Warning:config file server.conf not found
ERROR:root:Error occurred
CRITICAL:root:Critical error -- shutting down
```

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO, WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6 Weak References

Python does automatic memory management (reference counting for most objects and *garbage collection* to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The `weakref` module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

```
>>> import weakref, gc
>>> class A:
...     def __init__(self, value):
...         self.value = value
...     def __repr__(self):
...         return str(self.value)
...
>>> a = A(10)                  # create a reference
>>> d = weakref.WeakValueDictionary()
>>> d['primary'] = a           # does not create a reference
>>> d['primary']               # fetch the object if it is still alive
10
>>> del a                      # remove the one reference
>>> gc.collect()               # run garbage collection right away
0
>>> d['primary']               # entry was automatically removed
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    d['primary']               # entry was automatically removed
  File "C:/python26/lib/weakref.py", line 46, in __getitem__
    o = self.data[key]()
KeyError: 'primary'
```

## 11.7 Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The `array` module provides an `array()` object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode `"H"`) rather than the usual 16 bytes per entry for regular lists of Python int objects:

```
>>> from array import array
>>> a = array('H', [4000, 10, 700, 22222])
>>> sum(a)
26932
>>> a[1:3]
array('H', [10, 700])
```

The `collections` module provides a `deque()` object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

```
>>> from collections import deque
>>> d = deque(["task1", "task2", "task3"])
>>> d.append("task4")
>>> print "Handling", d.popleft()
Handling task1
```

```
unsearched = deque([starting_node])
def breadth_first_search(unsearched):
    node = unsearched.popleft()
    for m in gen_moves(node):
        if is_goal(m):
            return m
        unsearched.append(m)
```

In addition to alternative list implementations, the library also offers other tools such as the `bisect` module with functions for manipulating sorted lists:

```
>>> import bisect
>>> scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]
>>> bisect.insort(scores, (300, 'ruby'))
>>> scores
[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]
```

The `heapq` module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

```
>>> from heapq import heapify, heappop, heappush
>>> data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]
>>> heapify(data)                          # rearrange the list into heap order
>>> heappush(data, -5)                     # add a new entry
>>> [heappop(data) for i in range(3)]      # fetch the three smallest entries
[-5, 0, 1]
```

## 11.8 Decimal Floating Point Arithmetic

The `decimal` module offers a `Decimal` datatype for decimal floating point arithmetic. Compared to the built-in `float` implementation of binary floating point, the class is especially helpful for

- financial applications and other uses which require exact decimal representation,

- control over precision,

- control over rounding to meet legal or regulatory requirements,

- tracking of significant decimal places, or

- applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

```
>>> from decimal import *
>>> x = Decimal('0.70') * Decimal('1.05')
>>> x
Decimal('0.7350')
```

```
>>> x.quantize(Decimal('0.01'))   # round to nearest cent
Decimal('0.74')
>>> round(.70 * 1.05, 2)          # same calculation with floats
0.73
```

The `Decimal` result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the `Decimal` class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

```
>>> Decimal('1.00') % Decimal('.10')
Decimal('0.00')
>>> 1.00 % 0.10
0.09999999999999995

>>> sum([Decimal('0.1')]*10) == Decimal('1.0')
True
>>> sum([0.1]*10) == 1.0
False
```

The `decimal` module provides arithmetic with as much precision as needed:

```
>>> getcontext().prec = 36
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857')
```

# CHAPTER 12

## 現在可以來學習些什麼?

閱讀本教學可能增進您對於使用 Python 的興趣—您應該非常渴望使用 Python 來解決在現實生活中所遭遇的問題。該從哪裡學習更多呢?

本教學是 Python 文件中的一部分。這份文件集裡頭的其他文件包含:

- library-index:

  你該好好的瀏覽這份手冊,它提供了完整的(但簡潔)參考素材像是型別、函式與標准函式庫裡的模組。標准的 Python 發行版本會包含大量的附加程式碼。有些模組可以讀取 Unix 信箱、通過 HTTP 來檢索文件、產生亂數、分析命令列選項、編寫 CGI 程式、壓縮資料、及許多其他任務。瀏覽函式庫參考手冊可以讓你了解有哪些模組可以用。

- install-index explains how to install external modules written by other Python users.

- reference-index:Python 語法以及語意的詳細說明。這份文件閱讀起來會有些吃力,但作為一個語言本身的完整指南是非常有用的。

更多 Python 的資源:

- https://www.python.org:Python 的主要網站。它包含程式碼、文件以及連結到 Python 相關聯的網頁。網站的鏡像的都設置於世界各地,像是歐洲、日本以及澳大利亞;鏡像網站也許會比主網站來得更快,不過具體速度則還是取決於你所在的地理位置。

- https://docs.python.org:快速訪問 Python 的文件。

- https://pypi.org:Python 套件索引(The Python Package Index),之前也被暱稱為 Cheese Shop,彙總了使用者開發 Python 模組的索引,並提供模組能夠被下載。一旦開始發佈相關程式碼,你可以將開發的作品發佈到這裡並且讓其他人找到。

- https://code.activestate.com/recipes/langs/python/:Python Cookbook 是一個相當大的程式碼範例集,大量的模組以及有用的腳本。一些值得注意與特別貢獻則被收集在一本名為 Python Cookbook (O' Reilly & Associates, ISBN 0-596-00797-3.) 的書籍中。

For Python-related questions and problem reports, you can post to the newsgroup *comp.lang.python*, or send them to the mailing list at python-list@python.org. The newsgroup and mailing list are gatewayed, so messages posted to one will automatically be forwarded to the other. There are around 120 postings a day (with peaks up to several hundred), asking (and answering) questions, suggesting new features, and announcing new modules. Before posting, be sure to check the list of Frequently Asked Questions (also called the FAQ). Mailing list archives are available at https://mail.python.

org/pipermail/. The FAQ answers many of the questions that come up again and again, and may already contain the solution for your problem.

## Interactive Input Editing and History Substitution

Some versions of the Python interpreter support editing of the current input line and history substitution, similar to facilities found in the Korn shell and the GNU Bash shell. This is implemented using the GNU Readline library, which supports Emacs-style and vi-style editing. This library has its own documentation which I won't duplicate here; however, the basics are easily explained. The interactive editing and history described here are optionally available in the Unix and Cygwin versions of the interpreter.

This chapter does *not* document the editing facilities of Mark Hammond's PythonWin package or the Tk-based environment, IDLE, distributed with Python. The command line history recall which operates within DOS boxes on NT and some other DOS and Windows flavors is yet another beast.

## 13.1 Line Editing

If supported, input line editing is active whenever the interpreter prints a primary or secondary prompt. The current line can be edited using the conventional Emacs control characters. The most important of these are: `C-A` (Control-A) moves the cursor to the beginning of the line, `C-E` to the end, `C-B` moves it one position to the left, `C-F` to the right. Backspace erases the character to the left of the cursor, `C-D` the character to its right. `C-K` kills (erases) the rest of the line to the right of the cursor, `C-Y` yanks back the last killed string. `C-underscore` undoes the last change you made; it can be repeated for cumulative effect.

## 13.2 History Substitution

History substitution works as follows. All non-empty input lines issued are saved in a history buffer, and when a new prompt is given you are positioned on a new line at the bottom of this buffer. `C-P` moves one line up (back) in the history buffer, `C-N` moves one down. Any line in the history buffer can be edited; an asterisk appears in front of the prompt to mark a line as modified. Pressing the `Return` key passes the current line to the interpreter. `C-R` starts an incremental reverse search; `C-S` starts a forward search.

## 13.3 Key Bindings

The key bindings and some other parameters of the Readline library can be customized by placing commands in an initialization file called `~/.inputrc`. Key bindings have the form

```
key-name: function-name
```

or

```
"string": function-name
```

and options can be set with

```
set option-name value
```

For example:

```
# I prefer vi-style editing:
set editing-mode vi

# Edit using a single line:
set horizontal-scroll-mode On

# Rebind some keys:
Meta-h: backward-kill-word
"\C-u": universal-argument
"\C-x\C-r": re-read-init-file
```

Note that the default binding for `Tab` in Python is to insert a `Tab` character instead of Readline's default filename completion function. If you insist, you can override this by putting

```
Tab: complete
```

in your `~/.inputrc`. (Of course, this makes it harder to type indented continuation lines if you're accustomed to using `Tab` for that purpose.)

Automatic completion of variable and module names is optionally available. To enable it in the interpreter's interactive mode, add the following to your startup file:[1]

```
import rlcompleter, readline
readline.parse_and_bind('tab: complete')
```

This binds the `Tab` key to the completion function, so hitting the `Tab` key twice suggests completions; it looks at Python statement names, the current local variables, and the available module names. For dotted expressions such as `string.a`, it will evaluate the expression up to the final `'.'` and then suggest completions from the attributes of the resulting object. Note that this may execute application-defined code if an object with a `__getattr__()` method is part of the expression.

A more capable startup file might look like this example. Note that this deletes the names it creates once they are no longer needed; this is done since the startup file is executed in the same namespace as the interactive commands, and removing the names avoids creating side effects in the interactive environment. You may find it convenient to keep some of the imported modules, such as `os`, which turn out to be needed in most sessions with the interpreter.

---

[1] Python will execute the contents of a file identified by the `PYTHONSTARTUP` environment variable when you start an interactive interpreter. To customize Python even for non-interactive mode, see *The Customization Modules*.

```
# Add auto-completion and a stored history file of commands to your Python
# interactive interpreter. Requires Python 2.0+, readline. Autocomplete is
# bound to the Esc key by default (you can change it - see readline docs).
#
# Store the file in ~/.pystartup, and set an environment variable to point
# to it:  "export PYTHONSTARTUP=~/.pystartup" in bash.

import atexit
import os
import readline
import rlcompleter

historyPath = os.path.expanduser("~/.pyhistory")

def save_history(historyPath=historyPath):
    import readline
    readline.write_history_file(historyPath)

if os.path.exists(historyPath):
    readline.read_history_file(historyPath)

atexit.register(save_history)
del os, atexit, readline, rlcompleter, save_history, historyPath
```

## 13.4 Alternatives to the Interactive Interpreter

This facility is an enormous step forward compared to earlier versions of the interpreter; however, some wishes are left: It would be nice if the proper indentation were suggested on continuation lines (the parser knows if an indent token is required next). The completion mechanism might use the interpreter's symbol table. A command to check (or even suggest) matching parentheses, quotes, etc., would also be useful.

One alternative enhanced interactive interpreter that has been around for quite some time is IPython, which features tab completion, object exploration and advanced history management. It can also be thoroughly customized and embedded into other applications. Another similar enhanced interactive environment is bpython.

# 浮點數運算：問題與限制

在計算機架構中，浮點數透過二進位小數表示。例如Ｆ，在十進位小數中：

```
0.125
```

可被分Ｆ 1/10 + 2/100 + 5/1000，同樣的道理，二進位小數：

```
0.001
```

可被分Ｆ 0/2 + 0/4 + 1/8。這兩個小數有相同的數值，而唯一真正的不同在於前者以十進位表示，後者以二進位表示。

不幸的是，大多數十進位小數無法精准地以二進位小數表示。一般的結果Ｆ，您輸入的十進位浮點數由實際存在計算機中的二進位浮點數近似。

在十進位中，這個問題更容易被理解。以分數 1/3 Ｆ例，您可以將其近似Ｆ十進位小數：

```
0.3
```

或者，更好的近似：

```
0.33
```

或者，更好的近似：

```
0.333
```

依此類推，不論你使用多少位數表示小數，最後的結果都無法精准地表示 1/3，但你還是能越來越精准地表示 1/3。

同樣的道理，不論你願意以多少位數表示二進位小數，十進位小數 0.1 都無法被二進位小數精准地表達。在二進位小數中，1/10 會是一個無限循環小數：

```
0.0001100110011001100110011001100110011001100110011001100110011...
```

Stop at any finite number of bits, and you get an approximation.

On a typical machine running Python, there are 53 bits of precision available for a Python float, so the value stored internally when you enter the decimal number `0.1` is the binary fraction

```
0.0001100110011001100110011001100110011001100110011010
```

which is close to, but not exactly equal to, 1/10.

It's easy to forget that the stored value is an approximation to the original decimal fraction, because of the way that floats are displayed at the interpreter prompt. Python only prints a decimal approximation to the true decimal value of the binary approximation stored by the machine. If Python were to print the true decimal value of the binary approximation stored for 0.1, it would have to display

```
>>> 0.1
0.1000000000000000055511151231257827021181583404541015625
```

這比一般人感到有用的位數還多，所以 Python 將位數保持在可以接受的範圍，只顯示舍入後的數值：

```
>>> 0.1
0.1
```

It's important to realize that this is, in a real sense, an illusion: the value in the machine is not exactly 1/10, you're simply rounding the *display* of the true machine value. This fact becomes apparent as soon as you try to do arithmetic with these values

```
>>> 0.1 + 0.2
0.30000000000000004
```

注意，這是二進位浮點數理所當然的特性，⬚不是 Python 的錯誤 (bug)，更不是您程式碼的錯誤。只要有程式語言支持硬體的浮點數運算，您將會看到同樣的事情出現在其中（雖然某些程式語言預設不顯示差⬚，或者預設全部輸出）。

Other surprises follow from this one. For example, if you try to round the value 2.675 to two decimal places, you get this

```
>>> round(2.675, 2)
2.67
```

The documentation for the built-in `round()` function says that it rounds to the nearest value, rounding ties away from zero. Since the decimal fraction 2.675 is exactly halfway between 2.67 and 2.68, you might expect the result here to be (a binary approximation to) 2.68. It's not, because when the decimal string `2.675` is converted to a binary floating-point number, it's again replaced with a binary approximation, whose exact value is

```
2.67499999999999982236431605997495353221893310546875
```

Since this approximation is slightly closer to 2.67 than to 2.68, it's rounded down.

If you're in a situation where you care which way your decimal halfway-cases are rounded, you should consider using the `decimal` module. Incidentally, the `decimal` module also provides a nice way to 「see」 the exact value that's stored in any particular Python float

```
>>> from decimal import Decimal
>>> Decimal(2.675)
Decimal('2.67499999999999982236431605997495353221893310546875')
```

Another consequence is that since 0.1 is not exactly 1/10, summing ten values of 0.1 may not yield exactly 1.0, either:

```
>>> sum = 0.0
>>> for i in range(10):
```

```
...        sum += 0.1
...
>>> sum
0.999999999999999
```

二進位浮點數架構擁有很多這樣的驚喜。底下的「表示法錯誤」章節，詳細的解釋了「0.1」的問題。如果想要其他常見驚喜更完整的描述，可以參考 The Perils of Floating Point（浮點數的風險）。

As that says near the end, 「there are no easy answers.」Still, don't be unduly wary of floating-point! The errors in Python float operations are inherited from the floating-point hardware, and on most machines are on the order of no more than 1 part in 2**53 per operation. That's more than adequate for most tasks, but you do need to keep in mind that it's not decimal arithmetic, and that every float operation can suffer a new rounding error.

While pathological cases do exist, for most casual use of floating-point arithmetic you'll see the result you expect in the end if you simply round the display of your final results to the number of decimal digits you expect. For fine control over how a float is displayed see the str.format() method's format specifiers in formatstrings.

## 14.1 Representation Error

This section explains the 「0.1」 example in detail, and shows how you can perform an exact analysis of cases like this yourself. Basic familiarity with binary floating-point representation is assumed.

*Representation error* refers to the fact that some (most, actually) decimal fractions cannot be represented exactly as binary (base 2) fractions. This is the chief reason why Python (or Perl, C, C++, Java, Fortran, and many others) often won't display the exact decimal number you expect:

```
>>> 0.1 + 0.2
0.30000000000000004
```

Why is that? 1/10 and 2/10 are not exactly representable as a binary fraction. Almost all machines today (July 2010) use IEEE-754 floating point arithmetic, and almost all platforms map Python floats to IEEE-754 「double precision」. 754 doubles contain 53 bits of precision, so on input the computer strives to convert 0.1 to the closest fraction it can of the form $J/2**N$ where $J$ is an integer containing exactly 53 bits. Rewriting

```
1 / 10 ~= J / (2**N)
```

as

```
J ~= 2**N / 10
```

and recalling that $J$ has exactly 53 bits (is >= 2**52 but < 2**53), the best value for $N$ is 56:

```
>>> 2**52
4503599627370496
>>> 2**53
9007199254740992
>>> 2**56/10
7205759403792793
```

That is, 56 is the only value for $N$ that leaves $J$ with exactly 53 bits. The best possible value for $J$ is then that quotient rounded:

```
>>> q, r = divmod(2**56, 10)
>>> r
6
```

Since the remainder is more than half of 10, the best approximation is obtained by rounding up:

```
>>> q+1
7205759403792794
```

Therefore the best possible approximation to 1/10 in 754 double precision is that over 2**56, or

```
7205759403792794 / 72057594037927936
```

Note that since we rounded up, this is actually a little bit larger than 1/10; if we had not rounded up, the quotient would have been a little bit smaller than 1/10. But in no case can it be *exactly* 1/10!

So the computer never 「sees」1/10: what it sees is the exact fraction given above, the best 754 double approximation it can get:

```
>>> .1 * 2**56
7205759403792794.0
```

If we multiply that fraction by 10**30, we can see the (truncated) value of its 30 most significant decimal digits:

```
>>> 7205759403792794 * 10**30 // 2**56
100000000000000005551115123125L
```

meaning that the exact number stored in the computer is approximately equal to the decimal value 0.100000000000000005551115123125. In versions prior to Python 2.7 and Python 3.1, Python rounded this value to 17 significant digits, giving 『0.10000000000000001』. In current versions, Python displays a value based on the shortest decimal fraction that rounds correctly back to the true binary value, resulting simply in 『0.1』.

附Ｆ

## 15.1 互動模式

### 15.1.1 Error Handling

When an error occurs, the interpreter prints an error message and a stack trace. In interactive mode, it then returns to the primary prompt; when input came from a file, it exits with a nonzero exit status after printing the stack trace. (Exceptions handled by an `except` clause in a `try` statement are not errors in this context.) Some errors are unconditionally fatal and cause an exit with a nonzero exit; this applies to internal inconsistencies and some cases of running out of memory. All error messages are written to the standard error stream; normal output from executed commands is written to standard output.

Typing the interrupt character (usually `Control-C` or `Delete`) to the primary or secondary prompt cancels the input and returns to the primary prompt.[1]  Typing an interrupt while a command is executing raises the `KeyboardInterrupt` exception, which may be handled by a `try` statement.

### 15.1.2 Executable Python Scripts

On BSD'ish Unix systems, Python scripts can be made directly executable, like shell scripts, by putting the line

```
#!/usr/bin/env python
```

(assuming that the interpreter is on the user's `PATH`) at the beginning of the script and giving the file an executable mode. The `#!` must be the first two characters of the file. On some platforms, this first line must end with a Unix-style line ending (`'\n'`), not a Windows (`'\r\n'`) line ending. Note that the hash, or pound, character, `'#'`, is used to start a comment in Python.

The script can be given an executable mode, or permission, using the **chmod** command.

```
$ chmod +x myscript.py
```

---

[1] A problem with the GNU Readline package may prevent this.

On Windows systems, there is no notion of an 「executable mode」. The Python installer automatically associates `.py` files with `python.exe` so that a double-click on a Python file will run it as a script. The extension can also be `.pyw`, in that case, the console window that normally appears is suppressed.

## 15.1.3 The Interactive Startup File

When you use Python interactively, it is frequently handy to have some standard commands executed every time the interpreter is started. You can do this by setting an environment variable named `PYTHONSTARTUP` to the name of a file containing your start-up commands. This is similar to the `.profile` feature of the Unix shells.

This file is only read in interactive sessions, not when Python reads commands from a script, and not when `/dev/tty` is given as the explicit source of commands (which otherwise behaves like an interactive session). It is executed in the same namespace where interactive commands are executed, so that objects that it defines or imports can be used without qualification in the interactive session. You can also change the prompts `sys.ps1` and `sys.ps2` in this file.

If you want to read an additional start-up file from the current directory, you can program this in the global start-up file using code like `if os.path.isfile('.pythonrc.py'): exec(open('.pythonrc.py').read())`. If you want to use the startup file in a script, you must do this explicitly in the script:

```python
import os
filename = os.environ.get('PYTHONSTARTUP')
if filename and os.path.isfile(filename):
    with open(filename) as fobj:
        startup_file = fobj.read()
    exec(startup_file)
```

## 15.1.4 The Customization Modules

Python provides two hooks to let you customize it: `sitecustomize` and `usercustomize`. To see how it works, you need first to find the location of your user site-packages directory. Start Python and run this code:

```python
>>> import site
>>> site.getusersitepackages()
'/home/user/.local/lib/python2.7/site-packages'
```

Now you can create a file named `usercustomize.py` in that directory and put anything you want in it. It will affect every invocation of Python, unless it is started with the `-s` option to disable the automatic import.

`sitecustomize` works in the same way, but is typically created by an administrator of the computer in the global site-packages directory, and is imported before `usercustomize`. See the documentation of the `site` module for more details.

⌧F解

# 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, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

**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` module), numbers (in the `numbers` module), and streams (in the `io` 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 types of arguments:

- *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 and the FAQ question on the difference between arguments and parameters.

**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*.

**BDFL** Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

**bytes-like object** An object that supports the buffer protocol, like `str`, `bytearray` or `memoryview`. Bytes-like objects can be used for various operations that expect binary data, such as compression, saving to a binary file or sending over a socket. Some operations need the binary data to be mutable, in which case not all bytes-like objects can apply.

**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` and `.pyo` 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.

**classic class** Any class which does not inherit from `object`. See *new-style class*. Classic classes have been removed in Python 3.

**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`. Coercion between two operands can be performed with the `coerce` built-in function; thus, `3+4.5` is equivalent to calling `operator.add(*coerce(3, 4.5))` and results in `operator.add(3.0, 4.5)`. 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**.

**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:

```python
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 *new-style* 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 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.viewkeys()`, `dict.viewvalues()`, and `dict.viewitems()` 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 *statement*s which cannot be used as expressions, such as `print` or `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.

**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. It must implement a method named `find_module()`. See **PEP 302** for details.

**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 section.

**__future__** A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter. For example, the expression `11/4` currently evaluates to `2`. If the module in which it is executed had enabled *true division* by executing:

```
from __future__ import division
```

the expression `11/4` would evaluate to `2.75`. 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 will become 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 an iterator. It looks like a normal function except that it contains `yield` statements for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function. Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the generator 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
```

**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__()` or `__cmp__()` 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, while no mutable containers (such as lists or dictionaries) are. 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.

**integer division**  Mathematical division discarding any remainder. For example, the expression `11/4` currently evaluates to `2` in contrast to the `2.75` returned by float division. Also called *floor division*. When dividing two integers the outcome will always be another integer (having the floor function applied to it). However, if one of the operands is another numeric type (such as a `float`), the result will be coerced (see *coercion*) to a common type. For example, an integer divided by a float will result in a float value, possibly with a decimal fraction. Integer division can be forced by using the `//` operator instead of the `/` operator. See also *__future__*.

**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*.

**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` and `file` 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 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.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, an ad-hoc 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 [parameters]: 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 is 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 = ["0x%02x" % 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.

**magic method** –魔术方法 *special method* 的非正式同义词。

**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`.

**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*.

**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 `__builtin__.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.izip()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**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 work only for reference and not for assignment which will always write to the innermost scope. In contrast, local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace.

**new-style class** Any class which inherits from `object`. This includes all built-in types like `list` and `dict`. Only new-style classes can use Python's newer, versatile features like `__slots__`, descriptors, properties, and `__getattribute__()`.

More information can be found in newstyle.

**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.

**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 four types of parameters:

- *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:

```python
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()`).

- *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:

```python
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, and the function section.

**PEP** Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible

for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

**positional argument** See *argument*.

**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
```

**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.

**__slots__** A declaration inside a *new-style 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 `unicode`. 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.

**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 (or in older versions, `__getslice__()` and `__setslice__()`).

**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 specialnames.

**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 similiar to *named tuple* in that elements can 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()`.

**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 `str.splitlines()` for an additional use.

**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.

**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.

關於這些⬚明文件

這些⬚明文件是透過 Sphinx （一個專⬚ Python ⬚明文件所撰寫的文件處理器）將使用 reStructuredText 撰寫的原始檔轉⬚而成。

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致謝：

- Fred L. Drake, Jr.，原始 Python 文件工具集的創造者以及一大部份⬚容的作者。

- 創造 reStructuredText 和 Docutils 工具組的 Docutils 專案；

- Fredrik Lundh 先生，Sphinx 從他的 Alternative Python Reference 計劃中獲得許多的好主意。

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## 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.

2000 年五月，Guido 和 Python 核心开发团队转到 BeOpen.com 并组建了 BeOpen PythonLabs 团队。同年十月，PythonLabs 团队转到 Digital Creations (现为 Zope Corporation；见 https://www.zope.org/)。2001 年，Python 软件基金会 (PSF，见 https://www.python.org/psf/) 成立，这是一个专为拥有 Python 相关知识产权而创建的非营利组织。Zope Corporation 现在是 PSF 的赞助成员。

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| 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 |
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## C.3.1 Mersenne Twister

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)
or init_by_array(init_key, key_length).

Copyright (C) 1997 – 2002, Makoto Matsumoto and Takuji Nishimura,
```

## 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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   --------------------------------------------------------------------
```

## C.3.4  MD5 message digest algorithm

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L. Peter Deutsch
ghost@aladdin.com


Independent implementation of MD5 (RFC 1321).

This code implements the MD5 Algorithm defined in RFC 1321, whose
text is available at
      http://www.ietf.org/rfc/rfc1321.txt
The code is derived from the text of the RFC, including the test suite
(section A.5) but excluding the rest of Appendix A.  It does not include
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The original and principal author of md5.h is L. Peter Deutsch
<ghost@aladdin.com>.  Other authors are noted in the change history
that follows (in reverse chronological order):

2002-04-13 lpd Removed support for non-ANSI compilers; removed
      references to Ghostscript; clarified derivation from RFC 1321;
      now handles byte order either statically or dynamically.
1999-11-04 lpd Edited comments slightly for automatic TOC extraction.
1999-10-18 lpd Fixed typo in header comment (ansi2knr rather than md5);
      added conditionalization for C++ compilation from Martin
      Purschke <purschke@bnl.gov>.
1999-05-03 lpd Original version.
```

## C.3.5 Asynchronous socket services

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
  between ascii and binary. This results in a 1000-fold speedup. The C
```

```
    version is still 5 times faster, though.
- Arguments more compliant with Python standard
```

## C.3.9  XML Remote Procedure Calls

The `xmlrpclib` module contains the following notice:

```
    The XML-RPC client interface is

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```

## C.3.11 Select kqueue

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```

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```

## C.3.13 OpenSSL

The modules `hashlib`, `posix`, `ssl`, `crypt` use the OpenSSL library for added performance if made available by the operating system. Additionally, the Windows and Mac OS X installers for Python may include a copy of the OpenSSL libraries, so we include a copy of the OpenSSL license here:

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```

# APPENDIX D

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