云南大学数学与统计学院
上机实践报告

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一、实验目的

1. 熟悉基本的 Python 编程，为数据结构与算法的学习奠定实验基础
2. 熟悉教材第一章的代码片段
3. 与其它程序设计语言（如 C/C++/Java 语言等）作对比。

二、实验内容

1. Python 程序的编辑、编译、运行（建议使用 IDLE）
2. 主讲教材第一章的 Python 程序的调试
3. 其它集成开发环境(IDE)的安装、配置、使用（选做），在熟悉基本操作后，可以转入其它集成开发环境的使用，如可选用 Eclipse。

三、实验平台

Windows 10 1703 Enterprise 中文版；
Python 3.6.0；
Wing IDE Professional 6.0.5-1 集成开发环境。

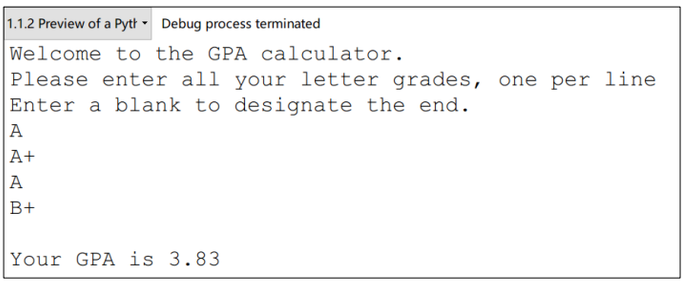
四、实验记录与实验结果分析

1 题
程序代码：

```
1   # 1.1.2 Preview of a Python Program
2
3   print('Welcome to the GPA calculator.')
4   print('Please enter all your letter grades, one per line')
5   print('Enter a blank to designate the end.')
6   # map from letter grade to point value
7   points = {'A+':4.0,'A':4.0,'A-':3.67,'B+':3.33,'B':3.0,'B-':2.67,\
8           'C+':2.33,'C':2.0,'C-':1.67,'D+':1.33,'D':1.0,'F':0.00}
9   num_courses = 0
10  total_points = 0
11  done = False
12  while not done:
13      grade = input()                 # read line from user
14      if grade == '':                 # empty line was entered
15          done = True
16      elif grade not in points:       # unrecognized grade entered
17          print("Unknow grade '{0}' being ignored".format(grade))
18      else:
19          num_courses += 1
20          total_points += points[grade]
21  if num_courses > 0:                 # avoid division by zero
22      print('Your GPA is {0:.3}'.format(total_points / num_courses))
```

程序代码 1

输出结果



运行结果 1

代码分析：

从代码本身来看，可以看出这一段简单代码中包含了很多 Python 的基本操作，比如基本的循环控制，判断，而且相比较于曾经学过的 C 语言，Python 还多了字典这个类型。如果要用 C 语言实现字典功能，可能就要写一个头文件进行预先定义，从语言的应用角度看，功能越丰富的工具更称手，而且更能使人专注于自己的主要目标。

五、教材翻译

Translation

Chapter 1 Python Primer
＊第一章 Python 语言入门

1.1Python Overview
＊1.1Python 概览

Building data structures and algorithms requires that we communicate detailed instructions to a computer. An excellent way to perform such communications is using a high-level computer language, such as Python. The Python programming language was originally developed by Guido van Rossum in the early 1990s, and has since become a prominently used language in industry and education. The second major version of the language, Python 2, was released in 2000, and the third major version, Python 3, released in 2008. We note that there are significant incompatibilities between Python 2 and Python 3. *This book is based on Python 3 (more specifically, Python 3.1 or later)*. The latest version of the language is freely available at www.python.org, along with documentation and tutorials.
＊构建数据结构以及算法的时候，我们需要给计算机下达详细的指令。要想实现这种人机对话，可采取的方式就是采用一门高级计算语言，比如说 Python。Python 这门编程语言是由 Guido van Rossum 在上个世纪九十年代早期建立，而且自此以后成为了一门被广泛用于工业与教育方面的语言。Python 的第二个主要版本，即 Python 2，已经于 2000 年发布，而它的第三个版本也于 2008 年发布，这也就是 Python 3。我们将会注意到两个版本 Python 有着明显的不兼容。这本书是基于 Python 3 （Python 3.1 及以后的版本）编著的。Python 3 的最新版本可以在 www.python.org 进行免费下载，同时这个网站还提供相应文档与教程。

In this chapter, we provided an overview of the Python programming language and we continue this discussion in the next chapter, focusing on object-oriented principles. We assume that readers of this book have prior programming experience, although not necessarily using Python. This book does not provide a complete description of the Python language (there are numerous language references for that purpose), but it does introduce all aspects of the language that are used in code fragments later in this book.
＊在这一章中，我们将给出一些有关 Python 语言的概览，而且我们将会在接下来的一章中重点介绍面向对象原则。我们假定这本书的读者已经有了前期编程经验，当然这不一定必须是 Python 方面的。这本书没有给出有关 Python 语言的完整描述（有关方面的参考是浩如烟海），但是在这本书中将要用到的那些语言知识，我们都会给出介绍。

1.1.1 The Python Interpreter
＊1.1.1 节 Python

Python is formally an ***interpreted*** language. Commands are executed through a piece of software known as the ***Python interpreter***. The interpreter receives a command, evaluates that command, and reports the result of the command. While the interpreter can be used interactively (especially when debugging), a programmer typically defines a series of commands in advance and saves those commands in a plain text file known as ***source code*** or a ***script***. For Python, source code is conventionally stored in a file named with the .py suffix (e.g., demo.py).
＊Python 是解释性语言。命令通过 Python 解释器执行。解释器接收命令，评估该命令，并返回命令的结果。虽然解释器可以交互式地使用（特别是在调试时），但程序员通常会提前定义一系列命令，并将这些命令保存在一个被称为源代码或脚本的纯文本文件中。对于 Python 而言，源代码通常存储在后缀是.py 的文件里（例如，demo.py）。

On most operating systems, the Python interpreter can be started by typing `python` from the command line. By default, the interpreter starts in interactive mode with a clean workspace. Commands from a predefined script saved in a file (e.g., demo.py) are executed by invoking the interpreter with the filename as an argument (e.g., python demo.py), or using an additional -i flag in order to execute a script and then enter interactive mode (e.g., python -i demo.py).
＊在大多数操作系统上，Python 解释器可以通过从命令行键入 python 来启动。默认情况下，解释器从一个空白的工作区启动。通过使用文件名作为参数（例如，python demo.py）调用解释器来执行保存在文件（例如，demo.py）中的命令，或使用-i 附加参数执行脚本，然后进入交互模式（例如，python -i demo.py）。

Many ***integrated development environments*** (IDEs) provide richer software development platforms for Python, including one named IDLE that is included with the standard Python distribution. IDLE provides an embedded text-editor with support for displaying and editing Python code, and a basic debugger, allowing step-by-step execution of a program while examining key variable values.
＊许多集成开发环境（IDE）为 Python 提供了更加丰富的软件开发平台，其中包括标准 Python 发行版中集成的一个名为 IDLE 的 IDE。IDLE 提供了一个嵌入式的文本编辑器，支持显示和编辑 Python 代码，除此之外还支持单步调试。

1.1.2 Preview of a Python Program
＊Python 程序预览

As a simple introduction, Code Fragment 1.1 presents a Python program that computes the grade-point average (GPA) for a student based on letter grades that are entered by a user. Many of the techniques demonstrated in this example will be discussed in the remainder of this chapter. At this point, we draw attention to a few high-level issues, for readers who are new to Python as a programming language.
＊Code Fragment 1.1 提供了一个 Python 程序，它能够根据用户输入的字母等级计算学生的平均几点（GPA）。本示例中展示的许多内容将在本章的其余部分进行讨论。在这一点上，Python 的新手需要注意几个高级的问题。

Python's syntax relies heavily on the use of whitespace. Individual statements are typically concluded with a newline character, although a command can extend to another line, either with a concluding backslash character (\), or if an opening delimiter has not yet been closed, such as the { character in defining value_map.
＊Python 的语法严格依赖空格缩进。单个语句通常以换行符结尾，如果命令太长，那么可以通过反斜杠符号将语句扩展到另一行，例如定义 value_map 的时候。

Whitespace is also key in delimiting the bodies of control structures in Python. Specifically, a block of code is indented to designate it as the body of a control structure, and nested control structures use increasing amounts of indentation. In Code Fragment 1.1, the body of the while loop consists of the subsequent 8 lines, including a nested conditional structure.
＊与此同时，空格也是 Python 中控制结构体的关键。特别地，一个代码块被缩进以将其指定为程序块的主体，而嵌套进其中的结构要在这一缩进级别上再次进行缩进，以此类推。在代码片段 1.1 中，while 循环的主体由后面的 8 行组成，包括嵌套的条件结构。

Comments are annotations provided for human readers, yet ignored by the Python interpreter. The primary syntax for comments in Python is based on use of the # character, which designates the remainder of the line as a comment.
＊为读者提供的代码注释将会 Python 解释器忽略。Python 中的注释是基于#字符的使用，它将该行的#之后的部分指定为注释。

```
print('Welcome to the GPA calculator.')
print('Please enter all your letter grades, one per line.')
print('Enter a blank line to designate the end.')
# map from letter grade to point value
points = {'A+':4.0, 'A':4.0, 'A-':3.67, 'B+':3.33, 'B':3.0, 'B-':2.67,
          'C+':2.33, 'C':2.0, 'C':1.67, 'D+':1.33, 'D':1.0, 'F':0.0}
num_courses = 0
total_points = 0
done = False
while not done:
  grade = input( )                          # read line from user
  if grade == '':                           # empty line was entered
    done = True
  elif grade not in points:                 # unrecognized grade entered
    print("Unknown grade '{0}' being ignored".format(grade))
  else:
    num_courses += 1
    total_points += points[grade]
if num_courses > 0:                         # avoid division by zero
  print('Your GPA is {0:.3}'.format(total_points / num_courses))
```

Code Fragment 1.1: A Python program that computes a grade-point average (GPA).

1.2 Object in Python

＊1.2 节 Python 中的对象

Python is an object-oriented language and ***classes*** form the basis for all data types. In this section, we describe key aspects of Python's object model, and we introduce Python's built-in classes, such as the int class for integers, the float class for floating-point values, and the str class for character strings. A more thorough presentation of object-orientation is the focus of Chapter 2.

＊Python 是面向对象的语言，类是所有数据类型的基础。在本节中，我们将介绍 Python 对象模型的关键方面，并介绍 Python 的内置类，例如整数的 int 类，浮点值的 float 类和字符串的 str 类。第 2 章将更全面地介绍面向对象。

1.2.1 Identifiers, Objects, and the Assignment Statement

＊1.2.1 节 标识符，对象与赋值语句

The most important of all Python commands is an ***assignment statement***, such as

＊最重要的 Python 命令是赋值命令，比如：

```
temperature = 98.6
```

This command establishes temperature as an ***identifier*** (also known as a ***name***), and then associates it with the ***object*** expressed on the right-hand side of the equal sign, in this case a floating-point object with value 98.6. We portray the outcome of this assignment in Figure 1.1.

＊该命令将 temperature 设置为标识符（也称为名字），然后将其与等号右侧表示的对象相关联，在本例中，右侧的对象是值为 98.6 的浮点对象。我们在图 1.1 中描绘了这个语句的结果。

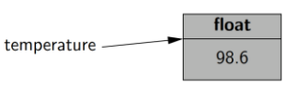


Figure 1.1: The identifier temperature references an instance of the float class having value 98.6.

Identifiers

＊标识符

Identifiers in Python are ***case-sensitive***, so temperature and Temperature are distinct names. Identifiers can be composed of almost any combination of letters, numerals, and underscore characters (or more general Unicode characters). The primary restrictions are that an identifier cannot begin with a numeral (thus 9lives is an illegal name), and that there are 33 specially reserved words that cannot be used as identifiers, as shown in Table 1.1.

＊Python 中的标识符区分大小写，因此 temperature 和 Temperature 是不同的名称。标识符可以由字母，数字和下划线字符（或更一般的 Unicode 字符）的任意组合组成。主要限制是标识符不能以数字开头（因此，9lives 是非法名称），并且有 33 个特别保留的单词不能用作标识符，如表 1.1 所示。

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

Table 1.1: A listing of the reserved words in Python. These names cannot be used as identifiers.

For readers familiar with other programming languages, the semantics of a Python identifier is most similar to a reference variable in Java or a pointer variable in C++. Each identifier is implicitly associated with the memory address of the object to which it refers. A Python identifier may be assigned to a special object named None, serving a similar purpose to a null reference in Java or C++.

＊对于熟悉其他编程语言的读者而言，Python 的标识符与 Java 语言中的引用以及 C++语言中的指针变量很相似。每一个标识符都标记了它所指向的对象在内存中的地址。一个 Python 的标识符被赋值为一个特殊的对象——None，它的作用与 Java 和 C++中的 null 相同。

Unlike Java and C++, Python is a ***dynamically typed*** language, as there is no advance declaration associating an identifier with a particular data type. An identifier can be associated with any type of object, and it can later be reassigned to another object of the same (or different) type. Although an identifier has no declared type, the object to which it refers has a definite type. In our first example, the characters 98.6 are recognized as a floating-point literal, and thus the identifier temperature is associated with an instance of the float class having that value.

＊Python 不像 Java 或者 C++那样，它是一门动态的语言，因为它前期并没有把给定的标识符与某种固定的数据结构绑定。一个标识符可以和任意类型的对象进行绑定，并且之后，这个标识符可以和其他同类型或者不同类型的对象进行重新绑定。尽管一个标识符没有声明自己的类型，但是它指向的对象却有类型。在我们的第一个例子里，字符 98.6 在字面上被理解为一个浮点型，而 temperature 这个标识符就与拥有着这个数值的一个 float 类的实例联系起来了

A programmer can establish an ***alias*** by assigning a second identifier to an existing object. Continuing with our earlier example, Figure 1.2 portrays the result of a subsequent assignment, original = temperature.

＊通过标识符之间赋值的这种方式，一个程序员可以给一个已经存在的对象建立一个别名。继续沿用我们之前的例子，图 1.2 描述了后置赋值的结果，original = temperature.（言外之意就是，两个标识符都指向了内存中同一块区域。）

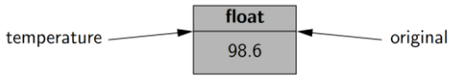


Figure 1.2: Identifiers temperature and original are aliases for the same object.

Once an alias has been established, either name can be used to access the underlying object. If that object supports behaviors that affect its state, changes enacted through one alias will be apparent when using the other alias (because they refer to the same object). However, if one of the *names* is reassigned to a new value using a subsequent assignment statement, that does not affect the aliased object, rather it breaks the alias. Continuing with our concrete example, we consider the command:

＊当一个对象的别名建立之后，原来的名字与别名都可以访问这个对象。如果对象方法中包含能够影响他自身状态的那种，那么通过引用一个别名而产生的变化自然也会作用在另外的别名上，因为它们指向的都是同一个对象。然而，如果这些别名中的一个被后续赋值语句赋予了新的值，那么这就不会影响其他的别名对象，而是中断了这个别名机制（而变成了一个新的对象）。还是举我们之前的实例，思考一下这个命令：

```
temperature = temperature + 5.0
```

The execution of this command begins with the evaluation of the expression on the right-hand side of the = operator. That expression, temperature + 5.0, is evaluated based on the existing binding of the name temperature, and so the result has value 103.6, that is, 98.6 + 5.0. That result is stored as a new floating-point instance, and only then is the name on the left-hand side of the assignment statement, temperature, (re)assignment to the result. The subsequent configuration is diagrammed in Figure 1.3. Of particular note, this last command had no effect on the value of the existing float instance that identifier original continues to reference.

＊这个语句的执行是从等号的右边开始的。temperature + 5.0 这个语句基于 temperature 所既有的数值，所以运算结果是 103.6，也就是 98.6 + 5.0. 这个结果被储存在了一个新的浮点型实例中，而这之后才是等号左边元素的赋值，即 temperature 被赋予了一个新的浮点型对象。图 1.3 给出了后续的结构。值得注意的是，第二种命令对 original 所指向的浮点型实例并不起作用。

Figure 1.3: The temperature identifier has been assigned to a new value, while original continues to refer to the previously existing value.

1.2.2 Creating and Using Objects

Instantiation

＊实例化

The process of creating a new instance of a class is known as ***instantiation***. In general, the syntax for instantiating an object is to invoke the ***constructor*** of a class. For example, if there were a class named Widget, we could create an instance of that class using a syntax such as w = Widget(), assuming that the constructor does not require any parameters. If the constructor does require parameters, we might use a syntax such as Widget(a, b, c) to construct a new instance.

＊创建类的新实例的过程称为实例化。通常，实例化对象的语法是调用类的构造函数。例如，如果有一个名为 Widget 的类，而且类的构造不需要参数，那我们就可以使用 w = Widget()这个语句来创建该类的实例。如果构造函数确实需要参数，我们就要使用 w = Widget(a,b,c)这样的语法构造一个类的实例。

Many of Python's built-in classes (discussed in Section 1.2.3) support what is known as a ***literal*** form for designating new instances. For example, the command temperature = 98.6 results in the creation of a new instance of the float class; the term 98.6 in that expression is a literal form. We discuss further cases of Python literals in the coming section.

＊许多 Python 的内置类（在 1.2.3 节中讨论）支持字面量形式。例如，使用语句 temperature = 98.6 可以创建一个浮点类的实例；该表达式中的第 98.6 是一个字面的形式。我们在下一节讨论更多有关 Python 字面量的案例。

From a programmer's perspective, yet another way to indirectly create a new instance of a class is to call a function that creates and returns such an instance. For example, Python has a built-in function named sorted (see Section 1.5.2) that takes a sequence of comparable elements as a parameter and returns a new instance of the list class containing those elements in sorted order.

＊从程序员的角度来看，间接创建类的新实例的另一种方法是调用一个函数,该函数可以创建并返回一个实例。例如，Python 里有一个名为 sorted()的内置函数（参见第 1.5.2 节），它的参数是一个序列，而且要求这个序列中的元素是可以比较大小的。调用这个函数，会生成一个列表，表中元素是经过排序的。

Calling Methods

＊调用方法

Python supports traditional functions (see Section 1.5) that are invoked with a syntax such as sorted(data), in which case data is a parameter sent to the function. Python's classes may also define one or more ***methods*** (also known as ***member functions***), which are invoked on a specific instance of a class using the dot (".") operator. For example, Python's list class has a method named sort that can be invoked with a syntax such as data.sort(). This particular method rearranges the contents of the list so that they are sorted.

＊Python 支持传统样式的函数调用，如 sorted(data)（参见第 1.5 节），在这种情况下，data 是参数。在 Python 的类里面也可以定义一个或多个方法（也称为成员函数），这些方法使用点（"."）运算符在类的特定实例上发挥作用。例如，Python 的列表类有一个名为 sort 的方法，可以使用 data.sort()这样的语法进行类方法调用。这个 sort 方法将列表的内容进行重新排列，使之变得有序。

The expression to the left of the dot identifies the object upon which the method is invoked. Often, this will be an identifier (e.g., data), but we can use the dot operator to invoke a method upon the immediate result of some other operation. For example, if response identifies a string instance (we will discuss strings later in this section), the syntax response.lower().startswith('y') first evaluates the method call, response.lower(), which itself returns a new string instance, and then the startswith('y') method is called on that intermediate string.

＊点的左边是对象。而这个对象通常是一个标识符（例如 data），我们可以使用点运算符调用类中方法从而对实例本身直接产生改变。例如，如果 response 是一个字符串实例（我们将在本节稍后讨论字符串），则 response.lower().startswith('y')首先计算 response.lower()，该方法调用本身返回一个新的字符串实例，然后在该过渡字符串上调用 startswith('y')方法。

When using a method of a class, it is important to understand its behavior. Some methods return information about the state of an object, but do not change that state. These are known as ***accessors***. Other methods, such as the sort method of the list class, do change the state of an object. These methods are known as ***mutators*** or ***update methods***.

＊当使用类的方法时，了解方法的具体行为很重要。某些方法会返回对象的状态信息，但并不会更改该状态。这种方法被称为访问器。而其他方法，如列表类的排序方法，会改变对象的状态。这些方法称为变更器或更新方法。

1.2.3 Python's Built-In Classes

＊Python 的内建类

Table 1.2 provides a summary of commonly used, built-in classes in Python; we take particular note of which classes are mutable and which are immutable. A class is ***immutable*** if each object of that class has a fixed value upon instantiation that cannot subsequently be changed. For example, the float class is immutable. Once an instance has been created, its value cannot be changed (although an identifier referencing that object can be reassigned to a different value).

＊表 1.2 提供了有关 Python 中常用的内置类的总结；我们要特别注意哪些类是可变的，哪些是不可变的。如果该类的每个对象在实例化后都具有固定值，而且不能随后更改，那么这个类是不可变的。例如，float 类是不可变的。实例一经创建，其值不能被更改（尽管可以将指向该对象的标识符重新分配给不同的值）。

Class	Description	Immutable?
bool	Boolean value	✓
int	integer (arbitrary magnitude)	✓
float	floating-point number	✓
list	mutable sequence of objects	
tuple	immutable sequence of objects	✓
str	character string	✓
set	unordered set of distinct objects	
frozenset	immutable form of set class	✓
dict	associative mapping (aka dictionary)	

Table 1.2: Commonly used built-in classes for Python

In this section, we provide an introduction to these classes, discussing their purpose and presenting several means for creating instances of the classes. Literal forms (such as 98.6) exist for most of the built-in classes, and all of the classes support a traditional constructor form that creates instances that are based upon one or more existing values. Operators supported by these classes are described in Section 1.3. More detailed information about these classes can be found in later chapters as follows: lists and tuples (Chapter 5); strings (Chapters 5 and 13, and Appendix A); sets and dictionaries (Chapter 10).

＊在本节中，我们将介绍这些类，讨论它们的存在意义以及介绍几种创建类实例的方法。大多数内置类都有字面形式（如 98.6），同时所有类都支持像构建函数那样的构建形式，来创建基于一个或多个现有值的实例。这些类支持的运算符在第 1.3 节中有描述。有关这些类的更多详细信息，请参见以下章节：列表和元组（第 5 章）；字符串（第 5 章和第 13 章以及附录 A）；集合和字典（第 10 章）。

The bool Class

＊布尔类

The bool class is used to manipulate logical (Boolean) values, and the only two instances of that class are expressed as the literals True and False. The default constructor, bool(), returns False, but there is no reason to use that syntax rather than the more direct literal form. Python allows the creation of a Boolean value from a nonboolean type using the syntax bool(foo) for value foo. The interpretation depends upon the type of the parameter. Numbers evaluate to False if zero, and True if nonzero. Sequences and other container types, such as strings and lists, evaluate to False if empty and True if nonempty. An important application of this interpretation is the use of a nonboolean value as a condition in a control structure.

＊bool 类用于操纵逻辑（布尔）值，该类的唯一两个实例表示为 True 和 False。构造函数 bool()默认返回 False，一般直接使用文字形式，而不是调用 bool()函数。Python 允许使用 bool(foo)语句，将非布尔类的值，转化为一个布尔值。函数返回值取决于参数的类型：如果零，则评估为 False，如果非零，则返回 True。序列以及其他的容器类型，如字符串和列表，如果为空，则评估为 False，如果非空，则评估为 True。这种解释，使得非布尔值也可以作为控制结构中的判断条件。

The int Class

＊整数类

The **int** and **float** classes are the primary numeric types in Python. The **int** class is designed to represent integer values with arbitrary magnitude. Unlike Java and C++, which support different integral types with different precisions (e.g., int, short, long), Python automatically chooses the internal representation for an integer based upon the magnitude of its value. Typical literals for integers include 0,137, and -23. In some contexts, it is convenient to express an integral value using binary, octal, or hexadecimal. That can be done by using a prefix of the number 0 and then a character to describe the base. Example of such literals are respectively 0b1011, 0o52, and 0x7f.

＊int 和 float 类是 Python 中的基本数字类型。int 类被设计为表示任意大小的整数值。不像 Java 和 C++那样支持不同精度（例如，int，short，long）的整数类型，Python 会根据其值的大小自动选择整数的占用空间。整数的典型样式包括 0,137 和-23。在某些情况下，使用二进制，八进制或十六进制表达整数值会更加方便。这种非十进制的表示方法可以这样写，用 0 作为前缀，其后跟着表示进位制的英文首字母小写，之后跟着数字。例子中的表达式分别为 0b1011，0o52 以及 0x7f。

The integer constructor, int(), returns value 0 by default. But this constructor can be used to construct an integer value based upon an existing value of another type. For example, if f represents a floating-point value, the syntax int(f) produces the *truncated* value of f. For example, both int(3.14) and int(3.99) produce the value 3, while int(-3.9) produces the value -3. The constructor can also be used to parse a string that is presumed to represent an integral value (such as one entered by a user). If s represents a string, then int(s) produces the integral value that string represents. For example, the expression int('137')

produces the integer value 137. If an invalid string is given as a parameter, as in int('hello'), a ValueError is raised (see Section 1.7 for discussion of Python's exceptions). By default, the string must use base 10. If conversion from a different base is desired, that base can be indicated as a second, optional, parameter. For example, the expression int('7f ',16) evaluates to the integer 127.

＊整数构造函数 int()默认返回值 0。但是，此构造函数可用于根据另一类型的现有值构造整数值。例如，如果 f 表示浮点值，那么命令 int(f)会返回 f 的整数部分截断值。例如，int(3.14)和 int(3.99)都产生值 3，而 int(-3.9)则产生值-3。int()函数也可用于解释表示整数值的字符串（例如由用户输入的字符串）。如果 s 表示一个字符串，则 int(s)将产生字符串表示的整数值。例如，表达式 int('137')产生整数值 137.如果将无效字符串作为参数给出，如 int('hello')中，则会引发 ValueError（有关 Python 的异常的讨论，请参见第 1.7 节）。默认情况下，字符串所表达的整数必须使用十进制。如果需要从不同的进位制进行转换，则该进位制应当被指示为第二个可选参数。例如，表达式 int('7f',16)的计算结果为 127。

The float Class

＊浮点类

The **float** class is the sole floating-point type in Python, using a fixed-precision representation. Its precision is more akin to a double in Java or C++, rather than those languages' float type. We have already discussed a typical literal form, 98.6. We note that the floating-point equivalent of an integral number can be expressed directly as 2.0. Technically, the trailing zero is optional, so some programmers might use the expression 2. to designate this floating-point literal. One other form of literal for floating-point values uses scientific notation. For example, the literal 6.022e23 represents the mathematical value 6.022×10^{23}.

＊float 类是 Python 中唯一的采用固定精度的浮点类型。它的精度更像 Java 或 C++中的 double 类型。我们已经讨论了一个典型的字面形式，98.6。我们注意到，与整数相等的浮点数可以用 2.0 这种样式来表示。从计算机内部原理上讲，后缀 0 是可去的，所以一些程序员可能使用表达式 2.来指定这个浮点数字。另外一种形式的浮点样式借鉴了科学计数法。例如，6.022e23 表示数学值 6.022×1023。

The constructor form of float() returns 0.0. When given a parameter, the constructor attempts to return the equivalent floating-point value. For example, the call float(2) returns the floating-point value 2.0. If the parameter to the constructor is a string, as with float('3.14'), it attempts to parse that string as a floating-point value, raising a ValueError as an exception.

＊函数 float()默认返回 0.0。当给定一个参数时，构造函数尝试返回与之等值的浮点值。例如，调用 float(2)返回浮点型 2.0。如果函数 float()的参数是一个字符串，比如 float('3.14')，这时候函数会尝试将该字符串解析为浮点值，如果不匹配就会抛出 ValueError 异常。

Sequence Types: The list, tuple, and str Classes

＊序列类：列表类、元组类、字符类

The **list**, **tuple**, and **str** classes are ***sequence*** types in Python, representing a collection of values in which the order is significant. The list class is the most general, representing a sequence of arbitrary objects (akin to an "array" in other languages). The tuple class is an ***immutable*** version of the list class, benefiting from a streamlined internal representation. The str class is specially designed for representing an immutable sequence of text characters. We note that Python does not have a separate class for characters; they are just strings with length one.

＊列表，元组和字符串类是 Python 中的序列类型，代表一个或多个有序的集合。列表类是最通用的，表示任意对象的序列（类似于其他语言中的"数组"）。元组类是列表类的不可变版本，因为内部表示很简单，所以有不少好处。字符串类专门用于表示不可变的文本字符序列。我们注意到，Python 中没有单字符类；事实上单个字符只是长度为 1 的特殊字符串。

The list Class

＊列表类

A **list** instance stores a sequence of objects. A list is a ***referential*** structure, as it technically stores a sequence of references to its elements (see Figure 1.4). Elements of a list may be arbitrary objects (including the None object). Lists are ***array-based*** sequences and are ***zero-indexed***, thus a list of length n has elements indexed from 0 to n − 1 inclusive. Lists are perhaps the most used container type in Python and they will be extremely central to our study of data structures and algorithms. They have many valuable behaviors, including the ability to dynamically expand and contract their capacities as needed. In this chapter, we will discuss only the most basic properties of lists. We revisit the inner working of all of Python's sequence types as the focus of Chapter 5.

＊列表可以储存一个对象的实例序列。列表储存的是对象的地址（参见图 1.4）。列表的元素可以是任意对象（包括 None 对象）。列表是基于数组的序列，并且是以 0 为下标开头的，因此长度为 n 的列表具有下标从 0 到 n-1 的元素。列表可能是 Python 中最常用的容器类型，它对我们对数据结构和算法的学习至关重要。列表有许多有价值的行为，包括动态变化。在本章中，我们将仅讨论列表的最基本属性。在第 5 章，我们将要重新审视 Python 所有序列类型的内部机制，而这也将是第五章的重点。

Python uses the characters [] as delimiters for a list literal, with[] itself being an empty list. As another example, ['red', 'green', 'blue'] is a list containing three string instances. The contents of a list literal need not be expressed as literals; if identifiers a and b have been established, then syntax [a,b] is

legitimate.
＊Python 使用字符[]作为列表文字的分隔符，而[]本身是一个空列表。另举一个例子，['red','green','blue']是一个包含三个字符串实例的列表。列表中内容的字面值不需要字面化表示；如果标识符 a 和 b 已经建立，则语句[a,b]就是合法的。

The list() constructor produces an empty list by default. However, the constructor will accept any parameter that is of an ***iterable*** type. We will discuss iteration further in Section 1.8, but examples of iterable types include all of the standard container types (e.g., strings, list, tuples, sets, dictionaries). For example, the syntax list('hello') produces a list of individual characters, ['h','e','l','l','o']. Because an existing list is itself iterable, the syntax backup = list(data) can be used to construct a new list instance referencing the same contents as the original.
＊函数 list()默认生成一个空列表。但是，构造函数将接受任何可迭代类型的参数。我们将在 1.8 节中进一步讨论迭代，可迭代类型包括所有标准容器类型（例如，字符串，列表，元组，集合，字典）。例如，命令 list('hello')可以生成单个字符['h'，'e'，'l'，'l'，'o']的列表。因为现有列表本身是可迭代的，所以语法 backup = list(data)可用于新建一个与原始内容相同的新列表实例。

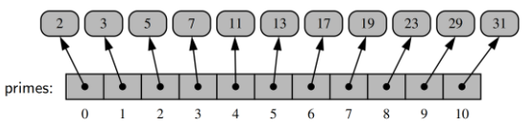


Figure 1.4: Python's internal representation of a list of integers, instantiated as prime = [2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31]. The implicit indices of the elements are shown below each entry.

The tuple Class
＊元组类

The **tuple** class provides an immutable version of a sequence, and therefore its instances have an internal representation that may be more streamlined than that of a list. While Python uses the [] characters to delimit a list, parentheses delimit a tuple, with () being an empty tuple. There is one important subtlety. To express a tuple of length one as a literal, a comma must be placed after the element, but within the parentheses. For example, (17,) is a one-element tuple. The reason for this requirement is that, without the trailing comma, the expression (17) is viewed as a simple parenthesized numeric expression.
＊元组提供了一个不可变的序列版本，因此其表示或许比列表更简洁。Python 使用[]字符来定义列表，()中定义元组，而()是一个空的元组。有一个重要的细节。要表达一个元素个数为 1 而且元素是一个整数的元组，必须把逗号放在元素后面、右括号的前面。例如，(17,)是一个单元素元组。之所以这么做，是因为(17)会被视为一个简单的括号数字表达式，而不是一个元组。

The str class
＊字符串类

Python's str class is specifically designed to efficiently represent an immutable sequence of characters, based upon the Unicode international character set. Strings have a more compact internal representation than the referential lists and tuples, as portrayed in Figure 1.5.
＊Python 的字符串类被专门设计为有效表示 Unicode 字符集的不可变字符序列。字符串具有比参考列表和元组更紧凑的内部表示，如图 1.5 所示。

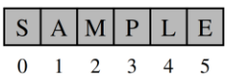


Figure 1.5: A Python string, which is an indexed sequence of characters.

String literals can be enclosed in single quotes, as in 'hello', or double quotes, as in "hello". This choice is convenient, especially when using another of the quotation characters as an actual character in the sequence, as in "Don't worry". Alternatively, the quote delimiter can be designated using a backslash as a so-called ***escape character***, as in 'Don\'t worry'. Because the backslash has this purpose, the backslash must itself be escaped to occur as a natural character of the string literal, as in C:\\Python\\ , for a string that would be displayed as C:\Python\. Other commonly escaped characters are \n for newline and \t for tab. Unicode characters can be included, such as '20\u20AC' for the string 20€.
＊字符串文字可以包含在单引号中，如'hello',当然双引号也可以，如"hello"。后一个选择是合适的，特别是当使用另一个引号作为序列中的实际字符时，比如"Don't worry"。或者采用另一种方法，使用反斜杠作为转义字符来指定引号分隔符，如'Don\'t worry'。因为反斜杠具有这种功能，所以反斜杠作为实际字符时就要采取双写策略，比如'C:\\Python\\'，会显示为 C:\Python\。其他通常转义的字符有用作换行符的\n，用作制表符的\t。甚至转移字符机制里面还包括了 Unicode，例如'20\u20AC'会被解释成 20€。

Python also supports using the delimiter ''' or """ to begin and end a string literal. The advantage of such triple-quoted strings is that newline characters can be embedded naturally (rather than escaped as \n). This can greatly improve the readability of long, multiline strings in source code. For example, at the beginning of Code Fragment 1.1, rather than use separate print statements for each line of introductory output, we can use a single print statement, as follows:
＊在 Python 中，还可以使用分隔符'''或"""来开始和结束一个字符串文字。这样优点是可以直接在编辑器里 enter 换行（而不是转义为\n）。这可以大大提高源代码里那种行数多、容量大的字符串的可读性，例如，在代码片段 1.1 的开头，不必为每一行的内容写一个打印语句，我们使用一个打印语句就可以解决问题，如下所示：

```
print("""Welcome to the GPA calculator.
```

Please enter all your letter grades, one per line.
Enter a blank line to designate the end.""")

The set and frozenset Classes

*集合列与冻结集合类

Python's **set** class represents the mathematical notion of a set, namely a collection of elements, without duplicates, and without an inherent order to those elements. The major advantage of using a set, as opposed to a list, is that it has a highly optimized method for checking whether a specific element is contained in the set. This is based on a data structure known as a ***hash table*** (which will be the primary topic of Chapter 10). However, there are two important restrictions due to the algorithmic underpinnings. The first is that the set does not maintain the elements in any particular order. The second is that only instances of ***immutable*** types can be added to a Python set. Therefore, objects such as integers, floating-point numbers, and character strings are eligible to be elements of a set. It is possible to maintain a set of tuples, but not a set of lists or a set of sets, as lists and sets are mutable. The frozenset class is an immutable form of the set type, so it is legal to have a set of frozensets.

*Python 的集合类表示的是数学概念上的集合，即元素的集合，不重复，无顺序。使用集合而不用列表主要优点是它具有一种高度优化的方法来检查集合中是否包含特定元素。这种优化的方法基于哈希表这一数据结构（这将是第 10 章的主要内容）。然而，由于算法的约束，集合类的使用存在两个重要的限制。首先是集合不以任何特定顺序保存元素。第二个是只有不可变类型的实例才可以添加到集合类中。诸如整数，浮点数和字符串的对象可以成为集合的元素。可以把好多元组放到集合里，但是集合本身或者列表是不能作为集合的元素的，因为列表和集合是可变的。而冻结集合是一种不可变集合类型，所以允许把冻结集合作为一个集合的元素。

Python uses curly braces {and} as delimiters for a set, for example, as {17} or {'red','green','blue'}. The exception to this rule is that {} does not represent an empty set; for historical reasons, it represents an empty dictionary (see next paragraph). Instead, the constructor syntax set() produces an empty set. If an iterable parameter is sent to the constructor, then the set of distinct elements is produced. For example, set('hello') produces {'h','e','l','o'}.

*Python 使用花括号{and}作为一个集合的分隔符，例如{17}或{'red'，'green'，'blue'}。然而{}不表示空集；它代表其实是一个空字典（见下一段），而这是由历史原因造成的。相反，函数 set()产生一个空集。如果将一个可迭代对象作为参数发送给函数 set()，那么会生成一个集合。例如，执行命令 set('hello')会生成{'h'，'e'，'l'，'o'}。

The dict Classes

*字典类

Python's dict class represents a dictionary, or mapping, from a set of distinct keys to associated values. For example, a dictionary might map from unique student ID numbers, to larger student records (such as the student's name, address, and course grades). Python implements a dict using an almost identical approach to that of a set, but with storage of the associated values.

*Python 的字典类表示一个从一组不同的键值到另外一组关联值的映射。例如，字典可以从唯一的学生证号码映射到学生记录（例如学生的姓名，地址和课程等级）。Python 使用与集合几乎相同的方法实现了字典类，只是增加了关联值的存储。

A dictionary literal also uses curly braces, and because dictionaries were introduced in Python prior to sets, the literal form {} produces an empty dictionary. A nonempty dictionary is expressed using a comma-separated series of key: value pairs. For example, the dictionary {'ga': 'Irish', 'de': 'German'} maps 'ga' to 'Irish' and 'de' to 'German'.

*标识字典也用花括号，但是因为字典在集合之前被引入，所以{}代表一个空字典。非空字典用逗号分隔一键值对，键值对之间用':'表示映射关系。例如，{'ga': 'Irish', 'de': 'German'}将'ga'映射到'Irish'，将'de'到'German'。

The constructor for the dict class accepts an existing mapping as a parameter, in which case it creates a new dictionary with identical associations as the existing one. Alternatively, the constructor accepts a sequence of key-value pairs as a parameter, as in dict(pairs) with pairs = [('ga','Irish'), ('de', 'German')].

*字典类的构造函数接受现有映射作为参数，在这种情况下，它将创建一个与现有映射相同的新字典。同样地，构造函数接受一个键值对序列作为参数，如在 dict(pairs)中使用 pairs= [('ga','Irish'),('de','German')]。

1.3 Expressions, Operations, and Precedence
＊表达式、运算符以及优先级

In the previous section, we demonstrated how names can be used to identify existing objects, and how literals and constructors can be used to create instances of built-in classes. Existing values can be combined into larger syntactic ***expressions*** using a variety of special symbols and keywords known as ***operators***. The semantics of an operator depends upon the type of its operands. For example, when a and b are numbers, the syntax a + b indicates addition, while if a and b are strings, the operator indicates concatenation. In this section, we describe Python's operators in various contexts of the built-in types.
＊在上一节中，我们演示了如何用标识符来区分对象，以及如何使用语句和构造函数来创建内置类的实例。已有的值可以使用各种运算符组合成较大的合成表达式。相同运算符的实际含义取决于其可操作的类型。例如，当 a 和 b 是数字时，语法 a + b 表示数的加法，而如果 a 和 b 是字符串，则运算符表示将两个字符串合并。在本节中，我们将介绍有关 Python 内建类的多种运算符，以及这些运算符在不同的上下文里的意义。

We continue, in Section 1.3.1, by discussing ***compound expressions***, such as a + b * c, which rely on the evaluation of two or more operations. The order in which the operations of a compound expression are evaluated can affect the overall value of the expression. For this reason, Python defines a specific order of precedence for evaluating operators, and it allows a programmer to override this order by using explicit parentheses to group subexpressions.
＊在 1.3.1 节中，我们继续讨论依赖于两个或多个操作的联合表达式，如 a + b * c 之类的。复合表达式的运算顺序会影响表达式的总体值。因此，Python 定义了用于评估运算符的特定优先顺序，并允许程序员通过使用括号对子表达式进行编排而覆盖此顺序。

Logical Operators
＊逻辑运算符

Python supports the following keyword operators for Boolean values:
＊对于布尔类型的值，Python 提供了一下几种操作运算符：

not	unary negation ＊否定，单变量操作
and	conditional and ＊蕴含式与
or	conditional or ＊蕴含式或

The **and** and **or** operators ***short-circuit***, in that they do not evaluate the second operand if the result can be determined based on the value of the first operand. This feature is useful when constructing Boolean expressions in which we first test that a certain condition holds (such as a reference not being **None**), and then test a condition that could have otherwise generated an error condition had the prior test not succeeded.
＊对于 and 和 or 操作如果结果可以基于第一个变量而得到，则它们就不会计算第二个变量。这个特性在构造布尔表达式的时候很有用，比如我们首先测试一个特定条件（例如指向是不是为空），然后测试一个可能会在先前的测试不成功的情况下产生错误条件的条件。

Equality Operators
＊相等判断符

Python supports the following operators to test two notions of equality:
＊Python 为两个变量的是否等值提供了以下运算符：

is	same identity ＊指向相同
is not	different identity ＊指向不同
==	equivalent ＊相等
!=	not equivalent ＊不等

The expression a **is** b evaluates to True, precisely when identifiers a and b are aliases for the same object. The expression a == b tests a more general notion of equivalence. If identifiers a and b refer to the same object, then a == b should also evaluate to True. Yet a == b also evaluates to True when the identifiers refer to different objects that happen to have values that are deemed equivalent. The precise notion of equivalence depends on the data type. For example, two strings are considered equivalent if they match character for character. Two sets are quivalent if they have the same contents, irrespective of order. In most programming situations, the equivalence tests == and != are the appropriate operators; use of is and is not should be reserved for situations in which it is necessary to detect true aliasing.
＊当标识符 a 和 b 指向同一对象时，表达式 a is b 的值为 True，。a == b 表达了更一般的等价概念。如果标识符 a 和 b 指向相同的对象，则 a == b 的计算结果也为 True。当 a，b 指向具有相同值的不同对象时，a == b 也会评估为 True。等价与否取决于数据类型。例如，如果两个字符串相同，则这两个字符串被认为是等价的。如果两个集合具有相同的内容，则二者是等价的，而且不论元素顺序如何。在大多数编程情况下，==和!=是相反的运算符；使用 is 和 is not 应该被用在检测别名设置的情形下。

Comparison Operators
＊比较运算符

Data types may define a natural order via the following operators:
＊通过以下的运算符可以确定数据的大小顺序。

<	less than ＊小于
<=	less than or equal to ＊小于等于
>	greater than ＊大于
>=	greater than or equal to ＊大于等于

These operators have expected behavior for numeric types, and are defined lexicographically, and case-sensitively, for strings. An exception is raised if operands have incomparable types, as with 5 < 'hello'.
＊这些操作符可以比较数字的大小，也可以对字符串进行了字典排序和大小写排序。如果变量的类型不相同，比如 5 < 'hello'，那么就会引发异常。

Arithmetic Operators
＊算数运算符

Python supports the following arithmetic operators:
＊Python 支持如下的算数运算符

+	addition ＊加
—	subtraction ＊减
*	multiplication ＊乘
/	true division ＊除
//	integer division ＊整除
%	the modulo operator ＊取余、取模

The use of addition, subtraction, and multiplication is straightforward, noting that if both operands have type int, then the result is an int as well; if one or both operands have type float, the result will be a float.
＊加法，减法和乘法是简单的，如果两个操作数都是整型，那么结果也是整型；如果变量中的一个或两个是浮点型，则结果是浮点型。

Python takes more care in its treatment of division. We first consider the case in which both operands have type int, for example, the quantity 27 divided by 4. In mathematical notation, $27 \div 4 = 6\frac{3}{4} = 6.75$. In Python, the / operator designates ***true division***, returning the floating-point result of the computation. Thus, 27 / 4 results in the float value 6.75. Python supports the pair of operators // and % to perform the integral calculations, with expression 27 // 4 evaluating to int value 6 (the mathematical floor of the quotient), and expression 27 % 4 evaluating to int value 3, the remainder of the integer division. We note that languages such as C, C++, and Java do not support the // operator; instead, the / operator returns the truncated quotient when both operands have integral type, and the result of true division when at least one operand has a floating-point type.
＊Python 在除法方面更加谨慎。我们首先考虑两个操作数都是整型的情况，例如 27 除以 4。在数学中，27 ÷ 4 = 6 3/4 = 6.75。在 Python 中，/运算符指的是真正的除法，返回浮点型结果。因此，27/4 的浮点型表示是 6.75。对于整型，Python 支持//和%操作，27 // 4 的计算值为 6，这是商的向下取整；27 % 4 的结果为 3，这是取模运算。我们注意到 C，C++和 Java 等语言不支持//操作符；不过在这些语言中，当两个变量都是整型时，/运算符返回取整的商，当存在一个变量是浮点类型时，返回真除法的结果。

Python carefully extends the semantics of // and % to cases where one or both operands are negative. For the sake of notation, let us assume that variables n and m represent respectively the ***dividend*** and ***divisor*** of a quotient n/m, and that q = n // m and r = n % m. Python guarantees that q * m + r will equal n. We already saw an example of this identity with positive operands, as $6 * 4 + 3 = 27$. When the divisor m is positive, Python further guarantees that $0 \leq r < m$. As a consequence, we find that -27 // 4 evaluates to -7 and -27 % 4 evaluates to 1, as $(-7) * 4 + 1 = -27$. When the divisor is negative, Python guarantees that $m < r \leq 0$. As an example, 27 // -4 is -7 and 27 % -4 is -1, satisfying the identity $27 = (-7) * (-4) + (-1)$.
＊Python 将//和%扩展到一个或者两个变量为负数的情况。为了避免引入新的符号，我们假定变量 n 和 m 分别表示被除数和除数，q = n // m 和 r = n%m。Python 保证 q * m + r = n。我们已经看到了正数的例子，如 6 * 4 + 3 = 27。当除数 m 为正时，Python 进一步保证 0 ≤ r < m。因此，我们发现-27 // 4 的结果为-7，-27 % 4 的结果为 1，如(-7) * 4 + 1 = -27。当除数为负时，Python 保证 m < r ≤0。例如，27 // -4 是-7，27%-4 是-1，满足 27 = (-7) * (-4)+（-1）。

The conventions for the // and % operators are even extended to floating- point operands, with the expression q = n // m being the integral floor of the quotient, and r = n % m being the “remainder” to ensure that q * m + r equals n. For example, 8.2 // 3.14 evaluates to 2.0 and 8.2 % 3.14 evaluates to 1.92, as $2.0 * 3.14 + 1.92 = 8.2$.
＊//和%运算符甚至可以扩展到浮点数，q = n // m 是商的向下取整，r = n%m 是“余数”，以确保 qm + r 等于 n。例如，8.2 // 3.14 等于 2.0，8.2%3.14 等于 1.92，满足 2.0 * 3.14 + 1.92 = 8.2。

Bitwise Operators
*位操作符

Python provides the following bitwise operators for integers:
*Python 对整型数字提供了以下几种位操作方式：

~	bitwise complement (prefix unary operator) *
&	bitwise and *按位与
|	bitwise or *按位或
^	bitwise exclusive-or *按位异或
<<	shift bits left, filling in with zeros *左移，0 填充空位
>>	shift bits right, filling in with sign bit *右移，符号填充即算数右移

Sequence Operators
*序列运算符

Each of Python's built-in sequence types (str, tuple, and list) support the following operator syntaxes:
*每个 Python 的内置序列类型（str，tuple 和 list）都支持以下运算符：

s[j]	element at index *j* *处于下标 j 位置的元素
s[start:stop]	slice including indices [start, stop) *从 start 到 stop（但是不包含 stop）的序列片段
s[start: stop: step]	slice including indices start, start + step, start + 2*step, ..., up to but not equaling or stop *步长为 step（第三个参数）的片段
s + t	concatenation of sequences *序列连接
k * s	shorthand for s + s + s + ... (k times) *
val **in** s	containment check *包含检测
val **not in** s	non-containment check *不包含检测

Python relies on ***zero-indexing*** of sequences, thus a sequence of length n has elements indexed from 0 to n − 1 inclusive. Python also supports the use of ***negative indices***, which denote a distance from the end of the sequence; index −1 denotes the last element, index −2 the second to last, and so on. Python uses a ***slicing*** notation to describe subsequences of a sequence. Slices are described as half-open intervals, with a start index that is included, and a stop index that is excluded. For example, the syntax data[3:8] denotes a subsequence including the five indices: 3, 4, 5, 6, 7. An optional "step" value, possibly negative, can be indicated as a third parameter of the slice. If a start index or stop index is omitted in the slicing notation, it is presumed to designate the respective extreme of the original sequence.
*Python 依赖于序列的零索引，因此长度为 n 的序列具有从 0 到 n-1 的下标索引。Python 还支持使用负数下标，借此倒着数的顺序；下标-1 表示最后一个元素，索引-2 表示最后一个元素，依此类推。Python 使用切片符号来描述序列的子序列。片段被划分为半开间隔，其中包含起始索引，但是不包含终结的元素。例如，data[3:8]表示包含五个索引的子序列：3，4，5，6，7。可选的 step 值可被指示为第三个参数。如果在分片符号中省略了开始索引或停止索引，则假设它们指定原始序列的相应首尾。

Because lists are mutable, the syntax s[j] = val can be used to replace an element at a given index. Lists also support a syntax, del s[j], that removes the designated element from the list. Slice notation can also be used to replace or delete a sublist.
*因为列表是可变的，语法 s[j] = val 可以用于替换给定索引处的元素。列表还支持从列表中删除指定元素的语法 del s[j]。切片符号也可用于替换或删除子列表。

The notation val in s can be used for any of the sequences to see if there is an element equivalent to val in the sequence. For strings, this syntax can be used to check for a single character or for a larger substring, as with amp in example.
*s 中的符号 val 可用于任何序列，以查看序列中是否存在等价于 val 的元素。对于字符串，此语法可用于检查单个字符或子串，与示例中的放大器一样。

All sequences define comparison operations based on lexicographic order, performing an element by element comparison until the first difference is found. For example, [5, 6, 9] < [5, 7] because of the entries at index 1. Therefore, the following operations are supported by sequence types:
*所有序列定义了基于字典顺序的比较操作，通过元素比较执行元素，直到找到第一个不同元素。例如，由于下标 1 中的条目，[5,6,9] < [5,7]。因此，序列类型支持以下操作：

s == t	equivalent (element by element) *字符串相等
s != t	not equivalent *字符串不相等
s < t	lexicographically less than *字典排序下的小于
s <= t	lexicographically less than or equal to *字典排序下的小于等于
s > t	lexicographically greater than *字典排序下的大于
s >= t	lexicographically greater than or equal to *字典排序下的大于等于

Operators for Sets and Dictionaries
＊对于集合与字典的操作符

Sets and frozensets support the following operators:
＊集合与冻结集合都支持下面的操作符

key **in** s	containment check ＊包含检测
key **not in** s	non-containment check ＊不包含检测
s1 == s2	s1 is equivalent to s2 ＊集合相等
s1 != s2	s1 is not equivalent to s2 ＊集合不等
s1 <= s2	s1 is subset of s2 ＊s1 是 s2 的子集
s1 < s2	s1 is proper subset of s2 ＊s1 是 s2 的真子集
s1 >= s2	s1 is superset of s2 ＊s1 是 s2 的父集
s1 > s2	s1 is proper superset of s2 ＊＊s1 是 s2 的真父集
s1 | s2	the union of s1 and s2 ＊集合的并
s1 & s2	the intersection of s1 and s2 ＊集合的交
s1 − s2	the set of elements in s1 but not s2 ＊集合的差
s1 ^ s2	the set of elements in precisely one of s1 or s2 ＊集合的对称差（剔除交集）

Note well that sets do not guarantee a particular order of their elements, so the comparison operators, such as <, are not lexicographic; rather, they are based on the mathematical notion of a subset. As a result, the comparison operators define a partial order, but not a total order, as disjoint sets are neither "less than," "equal to," or "greater than" each other. Sets also support many fundamental behaviors through named methods (e.g., add, remove); we will explore their functionality more fully in Chapter 10.
＊请注意，集合不能保证其元素的特定顺序，因此比较运算符（例如<）的结果不是依据字典排序得出的，而是基于子集的概念而得出的。比较运算符定义了一个偏序关系，而不是一个总顺序，因为不相交集之间，既不是"小于"，"等于"或"大于"。集合还通过命名方法支持许多基本行为（例如，add，remove）；我们将在第 10 章中更全面地探讨其功能。

Dictionaries, like sets, do not maintain a well-defined order on their elements. Furthermore, the concept of a subset is not typically meaningful for dictionaries, so the dict class does not support operators such as <. Dictionaries support the notion of equivalence, with d1 == d2 if the two dictionaries contain the same set of key- value pairs. The most widely used behavior of dictionaries is accessing a value associated with a particular key k with the indexing syntax, d[k]. The supported operators are as follows:
＊词典，也像集合一样，不会在其元素上保持一个明确的秩序。此外，子集的概念对于字典通常不是有意义的，因此 dict 类不支持诸如<的比较操作符。字典支持等价的概念，如果两个词典包含相同的键值对集合，则使用 d1 == d2 来表示二者相等。字典中使用最广泛的行为是使用索引语法 d[k]访问与特定密钥 k 相关联的值。支持的操作符如下：

d[key]	value associated with given key ＊与 key 值相关联的 value
d[key] = value	set (or reset) the value associated with given key ＊将 value 链接到 key 上面
del d[key]	remove key and its associated value from dictionary ＊将 k, v pair (key, d[key])删除
key **in** d	containment check ＊包含检查
key **not in** d	non-containment check ＊不包含检查
d1 == d2	d1 is equivalent to d2 ＊字典等价
d1 != d2	d1 is not equivalent to d2 ＊字典不等价

Dictionaries also support many useful behaviors through named methods, which we explore more fully in Chapter 10.
＊词典还支持许多有用的行为，我们在第 10 章中更全面地探讨。

Extended Assignment Operators
＊扩展的赋值运算符

Python supports an extended assignment operator for most binary operators, for example, allowing a syntax such as count += 5. By default, this is a shorthand for the more verbose count = count + 5. For an immutable type, such as a number or a string, one should not presume that this syntax changes the value of the existing object, but instead that it will reassign the identifier to a newly constructed value. (See discussion of Figure 1.3.) However, it is possible for a type to redefine such semantics to mutate the object, as the list class does for the += operator.
＊Python 支持大多数的二元运算符的扩展赋值运算符，例如，count + = 5。默认情况下，这是 count = count + 5 的缩写。对于不可变类型，例如数字或字符串，不要认为这个语法改变了现有对象的值，事实上是将其重新分配给一个新构造的值。（见图 1.3 的讨论）当然，对于可变类这就是可行的了，就像列表类对于+=操作符一样。

```
alpha = [1,2,3]
beta = alpha
# an alias for alpha
beta += [4,5]
# extends the original list with two more elements
beta = beta + [6, 7]
# reassigns beta to a new list [1,2,3,4,5,6,7]
print(alpha)
# will be [1, 2, 3, 4, 5]
```

This example demonstrates the subtle difference between the list semantics for the syntax beta += foo versus beta = beta + foo.

*此示例演示了语法 beta += foo 与 beta = beta + foo 的列表语义之间的微妙差异。

1.3.1 Compound Expressions and Operator Precedence

Programming languages must have clear rules for the order in which compound expressions, such as `5 + 2 * 3`, are evaluated. The formal order of precedence for operators in Python is given in Table 1.3. Operators in a category with higher precedence will be evaluated before those with lower precedence, unless the expression is otherwise parenthesized. Therefore, we see that Python gives precedence to multiplication over addition, and therefore evaluates the expression `5 + 2 * 3` as `5 + (2 * 3)`, with value 11, but the parenthesized expression `(5 + 2) * 3` evaluates to value 21. Operators within a category are typically evaluated from left to right, thus `5 − 2 + 3` has value 6. Exceptions to this rule include that unary operators and exponentiation are evaluated from right to left.

*编程语言必须具有明确的规则，用于对哪些复合表达式（如 5 + 2 * 3）进行计算。Python 中运算符的正式顺序是在表 1.3 中给出的。具有较高优先级的类别中的运算符将在优先级较低的类别之前进行计算，除非表达式被另外表示。因此，我们看到，Python 给出了乘法加法的优先级，因此将 5 + 2 * 3 的表达式计算为 5 +（2 * 3），值为 11，但括号表达式（5 + 2）* 3 计算为值 21。类别中的运算符通常从左到右进行计算，因此 5 - 2 + 3 等于 6。但是这个规则也有例外，一元运算符和幂运算会从右到左进行计算。

Python allows a ***chained assignment***, such as `x = y = 0`, to assign multiple identifiers to the rightmost value. Python also allows the ***chaining*** of comparison operators. For example, the expression `1 <= x + y <= 10` is evaluated as the compound `(1 <= x + y) and (x + y <= 10)`, but without computing the intermediate value `x + y` twice.

*Python 允许链式赋值，例如 x = y = 0 会将多个标识符分配给最右边的值。Python 还允许比较运算符的链式计算。例如，表达式 1 <= x + y <= 10 被认为是(1 <= x + y) and (x + y <= 10)，但是后者会计算中间值 x + y 两次。

Operator Precedence		
	Type	**Symbols**
1	member access	expr.member
2	function/method calls container subscripts/slices	expr(...) expr[...]
3	exponentiation	**
4	unary operators	+expr, −expr, ~expr
5	multiplication, division	*, /, //, %
6	addition, subtraction	+, −
7	bitwise shifting	<<, >>
8	bitwise-and	&
9	bitwise-xor	^
10	bitwise-or	|
11	comparisons containment	**is**, **is not**, ==, !=, <, <=, >, >= **in**, **not in**
12	logical-not	**not** expr
13	logical-and	**and**
14	logical-or	**or**
15	conditional	val1 **if** cond **else** val2
16	assignments	=, +=, −=, *=, etc.

Table 1.3: Operator precedence in Python, with categories ordered from highest precedence to lowest precedence. When stated, we use expr to denote a literal, identifier, or result of a previously evaluated expression. All operators without explicit mention of expr are binary operators, with syntax expr1 operator expr2.

1.4 Control Flow

In this section, we review Python's most fundamental control structures: conditional statements and loops. Common to all control structures is the syntax used in Python for defining blocks of code. The colon character is used to delimit the beginning of a block of code that acts as a body for a control structure. If the body can be stated as a single executable statement, it can technically placed on the same line, to the right of the colon. However, a body is more typically typeset as an ***indented block*** starting on the line following the colon. Python relies on the indentation level to designate the extent of that block of code, or any nested blocks of code within. The same principles will be applied when designating the body of a function (see Section 1.5), and the body of a class (see Section 2.3).

1.4.1 Conditionals

Conditional constructs (also known as if statements) provide a way to execute a chosen block of code based on the run-time evaluation of one or more Boolean expressions. In Python, the most general form of a conditional is written as follows:

```
if first_condition:
    first_body
elif second condition:
    second_body
elif third_condition:
    third_body
else:
    fourth_body
```

Each condition is a Boolean expression, and each body contains one or more commands that are to be executed conditionally. If the first condition succeeds, the first body will be executed; no other conditions or bodies are evaluated in that case. If the first condition fails, then the process continues in similar manner with the evaluation of the second condition. The execution of this overall construct will cause precisely one of the bodies to be executed. There may be any number of **elif** clauses (including zero), and the final **else** clause is optional. As described on page 7, nonboolean types may be evaluated as Booleans with intuitive meanings. For example, if response is a string that was entered by a user, and we want to condition a behavior on this being a nonempty string, we may write

```
if response:
```

as a shorthand for the equivalent,

```
if response !=:
```

As a simple example, a robot controller might have the following logic:

```
if door_is_closed:
    open_door()
advance()
```

Notice that the final command, advance(), is not indented and therefore not part of the conditional body. It will be executed unconditionally (although after opening a closed door).

We may nest one control structure within another, relying on indentation to make clear the extent of the various bodies. Revisiting our robot example, here is a more complex control that accounts for unlocking a closed door.

```
if door_is_closed:
    if door_is_locked:
        unlock_door()
    open_door()
advance()
```

The logic expressed by this example can be diagrammed as a traditional ***flowchart***, as portrayed in Figure 1.6.

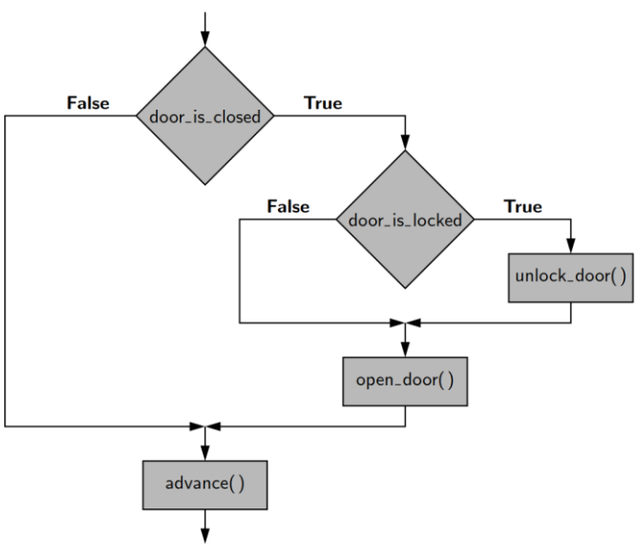


Figure 1.6: A flowchart describing the logic of nested conditional statements.

1.4.2 Loops

Python offers two distinct looping constructs. A **while** loop allows general repetition based upon the repeated testing of a Boolean condition. A **for** loop provides convenient iteration of values from a defined series (such as characters of a string, elements of a list, or numbers within a given range). We discuss both forms in this section.

While Loops

The syntax for a **while** loop in Python is as follows:

```
while condition:
    body
```

As with an **if** statement, condition can be an arbitrary Boolean expression, and *body* can be an arbitrary block of code (including nested control structures). The execution of a while loop begins with a test of the Boolean condition. If that condition evaluates to True, the body of the loop is performed. After each execution of the body, the loop condition is retested, and if it evaluates to True, another iteration of the body is performed. When the conditional test evaluates to False (assuming it ever does), the loop is exited and the flow of control continues just beyond the body of the loop.

As an example, here is a loop that advances an index through a sequence of characters until finding an entry with value X or reaching the end of the sequence.

```
j = 0
while j < len(data) and data[j] != 'X':
    j += 1
```

The len function, which we will introduce in Section 1.5.2, returns the length of a sequence such as a list or string. The correctness of this loop relies on the short- circuiting behavior of the and operator, as described on page 12. We intentionally test j < len(data) to ensure that j is a valid index, prior to accessing element data[j]. Had we written that compound condition with the opposite order, the evaluation of data[j] would eventually raise an IndexError when 'X' is not found. (See Section 1.7 for discussion of exceptions.)

As written, when this loop terminates, variable j's value will be the index of the leftmost occurrence of 'X' , if found, or otherwise the length of the sequence (which is recognizable as an invalid index to indicate failure of the search). It is worth noting that this code behaves correctly, even in the special case when the list is empty, as the condition j < len(data) will initially fail and the body of the loop will never be executed.

For Loops

Python's **for**-loop syntax is a more convenient alternative to a while loop when iterating through a series of elements. The **for**-loop syntax can be used on any type of ***iterable*** structure, such as a list, tuple str, set, dict, or file (we will discuss iterators more formally in Section 1.8). Its general syntax appears as follows.

```
for element in iterable:
    body        # body may refer to 'element' as an identifier
```

For readers familiar with Java, the semantics of Python's for loop is similar to the "for each" loop style introduced in Java 1.5.

As an instructive example of such a loop, we consider the task of computing the sum of a list of numbers. (Admittedly, Python has a built-in function, sum, for this purpose.) We perform the calculation with a for loop as follows, assuming that data identifies the list:

```
total = 0
for val in data:
total += val # note use of the loop variable, val
```

The loop body executes once for each element of the data sequence, with the identifier, val, from the for-loop syntax assigned at the beginning of each pass to a respective element. It is worth noting that val is treated as a standard identifier. If the element of the original data happens to be mutable, the val identifier can be used to invoke its methods. But a reassignment of identifier val to a new value has no affect on the original data, nor on the next iteration of the loop.

As a second classic example, we consider the task of finding the maximum value in a list of elements (again, admitting that Python's built-in max function already provides this support). If we can assume that the list, data, has at least one element, we could implement this task as follows:

```
biggest = data[0]    # as we assume nonempty list
for val in data:
    if val > biggest:
        biggest = val
```

Although we could accomplish both of the above tasks with a while loop, the for-loop syntax had an advantage of simplicity, as there is no need to manage an explicit index into the list nor to author a Boolean loop condition. Furthermore, we can use a for loop in cases for which a while loop does not apply, such as when iterating through a collection, such as a set, that does not support any direct form of indexing.

Index-Based For Loops

The simplicity of a standard for loop over the elements of a list is wonderful; how- ever, one limitation of that form is that we do not know where an element resides within the sequence. In

some applications, we need knowledge of the index of an element within the sequence. For example, suppose that we want to know *where* the maximum element in a list resides.

Rather than directly looping over the elements of the list in that case, we prefer to loop over all possible indices of the list. For this purpose, Python provides a built-in class named range that generates integer sequences. (We will discuss generators in Section 1.8.) In simplest form, the syntax range(n) generates the series of n values from 0 to n 1. Conveniently, these are precisely the series of valid indices into a sequence of length n. Therefore, a standard Python idiom for looping through the series of indices of a data sequence uses a syntax,

```
for j in range(len(data)):
```

In this case, identifier j is not an element of the data—it is an integer. But the expression data[j] can be used to retrieve the respective element. For example, we can find the *index* of the maximum element of a list as follows:

```
big index = 0
for j in range(len(data)):
    if data[j] > data[big index]:
        big index = j
```

Break and Continue Statements

Python supports a break statement that immediately terminate a while or for loop when executed within its body. More formally, if applied within nested control structures, it causes the termination of the most immediately enclosing loop. As a typical example, here is code that determines whether a target value occurs in a data set:

```
found = False
for item in data:
    if item == target:
        found = True
        break
```

Python also supports a **continue** statement that causes the current iteration of a loop body to stop, but with subsequent passes of the loop proceeding as expected.

We recommend that the break and continue statements be used sparingly. Yet, there are situations in which these commands can be effectively used to avoid introducing overly complex logical conditions.

1.5 Functions

In this section, we explore the creation of and use of functions in Python. As we did in Section 1.2.2, we draw a distinction between ***functions*** and ***methods***. We use the general term *function* to describe a traditional, stateless function that is invoked without the context of a particular class or an instance of that class, such as sorted(data). We use the more specific term method to describe a member function that is invoked upon a specific object using an object-oriented message passing syntax, such as data.sort(). In this section, we only consider pure functions; methods will be explored with more general object-oriented principles in Chapter 2.

We begin with an example to demonstrate the syntax for defining functions in Python. The following function counts the number of occurrences of a given target value within any form of iterable data set.

```
def count(data, target):
    n = 0
    for item in data:
        if item == target:  # found a match
            n += 1
        return n
```

The first line, beginning with the keyword **def**, serves as the function's ***signature***. This establishes a new identifier as the name of the function (count, in this example), and it establishes the number of parameters that it expects, as well as names identifying those parameters (data and target, in this example). Unlike Java and C++, Python is a dynamically typed language, and therefore a Python signature does not designate the types of those parameters, nor the type (if any) of a return value. Those expectations should be stated in the function's documentation (see Section 2.2.3) and can be enforced within the body of the function, but misuse of a function will only be detected at run-time.

The remainder of the function definition is known as the ***body*** of the function. As is the case with control structures in Python, the body of a function is typically expressed as an indented block of code. Each time a function is called, Python creates a dedicated ***activation record*** that stores information relevant to the current call. This activation record includes what is known as a ***namespace*** (see Section 1.10) to manage all identifiers that have ***local scope*** within the current call. The namespace includes the function's parameters and any other identifiers that are defined locally within the body of the function. An identifier in the local scope of the function caller has no relation to any identifier with the same name in the caller's scope (although identifiers in different scopes may be aliases to the same object). In our first example, the identifier n has scope that is local to the function call, as does the identifier item, which is established as the loop variable.

Return Statement

A **return** statement is used within the body of a function to indicate that the function should immediately cease execution, and that an expressed value should be returned to the caller. If a return statement is executed without an explicit argument, the None value is automatically returned. Likewise, None will be returned if the flow of control ever reaches the end of a function body without having executed a return statement. Often, a return statement will be the final command within the body of the function, as was the case in our earlier example of a count function. However, there can be multiple return statements in the same function, with conditional logic controlling which such command is executed, if any. As a further example, consider the following function that tests if a value exists in a sequence.

```
def contains(data, target):
    for item in target:
        if item == target:  # found a match
            return True
        return False
```

If the conditional within the loop body is ever satisfied, the return True statement is executed and the function immediately ends, with True designating that the target value was found. Conversely, if the for loop reaches its conclusion without ever finding the match, the final return False statement will be executed.

1.5.1 Information Passing

To be a successful programmer, one must have clear understanding of the mechanism in which a programming language passes information to and from a function. In the context of a function signature, the identifiers used to describe the expected parameters are known as ***formal parameters***, and the objects sent by the caller when invoking the function are the ***actual parameters***. Parameter passing in Python follows the semantics of the standard ***assignment statement***. When a function is invoked, each identifier that serves as a formal parameter is assigned, in the function's local scope, to the respective actual parameter that is provided by the caller of the function.

For example, consider the following call to our count function from page 23:

```
prizes = count(grades, 'A' )
```

Just before the function body is executed, the actual parameters, grades and 'A' , are implicitly assigned to the formal parameters, data and target, as follows:

```
data = grades
target = 'A'
```

These assignment statements establish identifier data as an alias for grades and
target as a name for the string literal A . (See Figure 1.7.)

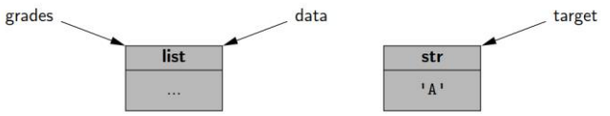


Figure 1.7: A portrayal of parameter passing in Python, for the function call count(grades, 'A'). Identifiers data and target are formal parameters defined within the local scope of the count function.

The communication of a return value from the function back to the caller is similarly implemented as an assignment. Therefore, with our sample invocation of prizes = count(grades, 'A'), the identifier prizes in the caller's scope is assigned to the object that is identified as n in the return statement within our function body.

An advantage to Python's mechanism for passing information to and from a function is that objects are not copied. This ensures that the invocation of a function is efficient, even in a case where a parameter or return value is a complex object.

Mutable Parameters

Python's parameter passing model has additional implications when a parameter is a mutable object. Because the formal parameter is an alias for the actual parameter, the body of the function may interact with the object in ways that change its state. Considering again our sample invocation of the count function, if the body of the function executes the command data.append('F'), the new entry is added to the end of the list identified as data within the function, which is one and the same as the list known to the caller as grades. As an aside, we note that reassigning a new value to a formal parameter with a function body, such as by setting data = [], does not alter the actual parameter; such a reassignment simply breaks the alias.

Our hypothetical example of a count method that appends a new element to a list lacks common sense. There is no reason to expect such a behavior, and it would be quite a poor design to have such an unexpected effect on the parameter. There are, however, many legitimate cases in which a function may be designed (and clearly documented) to modify the state of a parameter. As a concrete example, we present the following implementation of a method named scale that's primary purpose is to multiply all entries of a numeric data set by a given factor.

```
def scale(data, factor):
    for j in range(len(data)):
        data[j] *= factor
```

Default Parameter Values

Python provides means for functions to support more than one possible calling signature. Such a function is said to be ***polymorphic*** (which is Greek for "many forms"). Most notably, functions can declare one or more default values for parameters, thereby allowing the caller to invoke a function with varying numbers of actual parameters. As an artificial example, if a function is declared with signature

```
def foo(a, b=15, c=27):
```

there are three parameters, the last two of which offer default values. A caller is welcome to send three actual parameters, as in foo(4, 12, 8), in which case the de- fault values are not used. If, on the other hand, the caller only sends one parameter, foo(4), the function will execute with parameters values a=4, b=15, c=27. If a caller sends two parameters, they are assumed to be the first two, with the third be- ing the default. Thus, foo(8, 20) executes with a=8, b=20, c=27. However, it is illegal to define a function with a signature such as bar(a, b=15, c) with b having a default value, yet not the subsequent c; if a default parameter value is present for one parameter, it must be present for all further parameters.

As a more motivating example for the use of a default parameter, we revisit the task of computing a student's GPA (see Code Fragment 1.1). Rather than assume direct input and output with the console, we prefer to design a function that computes and returns a GPA. Our original implementation uses a fixed mapping from each letter grade (such as a B−) to a corresponding point value (such as 2.67). While that point system is somewhat common, it may not agree with the system used by all schools. (For example, some may assign an A+ grade a value higher than 4.0.) Therefore, we design a compute gpa function, given in Code Fragment 1.2, which allows the caller to specify a custom mapping from grades to values, while offering the standard point system as a default.

```
def compute_gpa(grades, points={'A+':4.0, 'A':4.0, 'A-':3.67, 'B+':3.33,
                                'B':3.0, 'B-':2.67,'C+':2.33, 'C':2.0,
                                'C':1.67, 'D+':1.33, 'D':1.0, 'F':0.0}):
  num_courses = 0
  total_points = 0
  for g in grades:
    if g in points:                          # a recognizable grade
      num_courses += 1
      total_points += points[g]
  return total_points / num_courses
```

Code Fragment 1.2: A function that computes a student's GPA with a point value system that can be customized as an optional parameter.

As an additional example of an interesting polymorphic function, we consider Python's support for range. (Technically, this is a constructor for the range class, but for the sake of this discussion, we can treat it as a pure function.) Three calling syntaxes are supported. The one-parameter form, range(n), generates a sequence of integers from 0 up to but not including n. A two-parameter form, range(start,stop) generates integers from start up to, but not including, stop. A three-parameter form, range(start, stop, step), generates a similar range as range(start, stop), but with increments of size step rather than

1.

This combination of forms seems to violate the rules for default parameters. In particular, when a single parameter is sent, as in range(n), it serves as the stop value (which is the second parameter); the value of start is effectively 0 in that case. However, this effect can be achieved with some sleight of hand, as follows:

```
def range(start, stop=None, step=1):
    if stop is None:
        stop = start
        start = 0
    ...
```

From a technical perspective, when range(n) is invoked, the actual parameter n will be assigned to formal parameter start. Within the body, if only one parameter is received, the start and stop values are reassigned to provide the desired semantics.

Keyword Parameters

The traditional mechanism for matching the actual parameters sent by a caller, to the formal parameters declared by the function signature is based on the concept of ***positional arguments***. For example, with signature foo(a=10, b=20, c=30), parameters sent by the caller are matched, in the given order, to the formal parameters. An invocation of foo(5) indicates that a=5, while b and c are assigned their default values.

Python supports an alternate mechanism for sending a parameter to a function known as a ***keyword argument***. A keyword argument is specified by explicitly assigning an actual parameter to a formal parameter by name. For example, with the above definition of function foo, a call foo(c=5) will invoke the function with parameters a=10, b=20, c=5.

A function's author can require that certain parameters be sent only through the keyword-argument syntax. We never place such a restriction in our own function definitions, but we will see several important uses of keyword-only parameters in Python's standard libraries. As an example, the built-in max function accepts a keyword parameter, coincidentally named key, that can be used to vary the notion of "maximum" that is used.

By default, max operates based upon the natural order of elements according to the < operator for that type. But the maximum can be computed by comparing some other aspect of the elements. This is done by providing an auxiliary function that converts a natural element to some other value for the sake of comparison. For example, if we are interested in finding a numeric value with magnitude that is maximal (i.e., considering −35 to be larger than +20), we can use the calling syntax max(a, b, key=abs). In this case, the built-in abs function is itself sent as the value associated with the keyword parameter key. (Functions are first-class objects in Python; see Section 1.10.) When max is called in this way, it will compare abs(a) to abs(b), rather than a to b. The motivation for the keyword syntax as an alternate to positional arguments is important in the case of max. This function is polymorphic in the number of arguments, allowing a call such as max(a,b,c,d); therefore, it is not possible to designate a key function as a traditional positional element. Sorting functions in Python also support a similar key parameter for indicating a nonstandard order. (We explore this further in Section 9.4 and in Section 12.6.1, when discussing sorting algorithms).

1.5.2 Python's Built-In Functions

Table 1.4 provides an overview of common functions that are automatically avail- able in Python, including the previously discussed abs, max, and range. When choosing names for the parameters, we use identifiers x, y, z for arbitrary numeric types, k for an integer, and a, b, and c for arbitrary comparable types. We use the identifier, iterable, to represent an instance of any iterable type (e.g., str, list, tuple, set, dict); we will discuss iterators and iterable data types in Section 1.8. A sequence represents a more narrow category of indexable classes, including str, list, and tuple, but neither set nor dict. Most of the entries in Table 1.4 can be categorized according to their functionality as follows:

Input/Output: print, input, and open will be more fully explained in Section 1.6.

Character Encoding: ord and chr relate characters and their integer code points. For example, ord(A) is 65 and chr(65) is A .

Mathematics: abs, divmod, pow, round, and sum provide common mathematical functionality; an additional math module will be introduced in Section 1.11.

Ordering: max and min apply to any data type that supports a notion of comparison, or to any collection of such values. Likewise, sorted can be used to produce an ordered list of elements drawn from any existing collection.

Collections/Iterations: range generates a new sequence of numbers; len reports the length of any existing collection; functions reversed, all, any, and map operate on arbitrary iterations as well; iter and next provide a general framework for iteration through elements of a collection, and are discussed in Section 1.8.

Common Built-In Functions	
Calling Syntax	**Description**
abs(x)	Return the absolute value of a number.
all(iterable)	Return True if bool(e) is True for each element e.
any(iterable)	Return True if bool(e) is True for at least one element e.
chr(integer)	Return a one-character string with the given Unicode code point.
divmod(x, y)	Return (x // y, x % y) as tuple, if x and y are integers.
hash(obj)	Return an integer hash value for the object (see Chapter 10).
id(obj)	Return the unique integer serving as an "identity" for the object.
input(prompt)	Return a string from standard input; the prompt is optional.
isinstance(obj, cls)	Determine if obj is an instance of the class (or a subclass).
iter(iterable)	Return a new iterator object for the parameter (see Section 1.8).
len(iterable)	Return the number of elements in the given iteration.
map(f, iter1, iter2, ...)	Return an iterator yielding the result of function calls f(e1, e2, ...) for respective elements e1 ∈ iter1, e2 ∈ iter2, ...
max(iterable)	Return the largest element of the given iteration.
max(a, b, c, ...)	Return the largest of the arguments.
min(iterable)	Return the smallest element of the given iteration.
min(a, b, c, ...)	Return the smallest of the arguments.
next(iterator)	Return the next element reported by the iterator (see Section 1.8).
open(filename, mode)	Open a file with the given name and access mode.
ord(char)	Return the Unicode code point of the given character.
pow(x, y)	Return the value x^y (as an integer if x and y are integers); equivalent to x ** y.
pow(x, y, z)	Return the value $(x^y \bmod z)$ as an integer.
print(obj1, obj2, ...)	Print the arguments, with separating spaces and trailing newline.
range(stop)	Construct an iteration of values $0, 1, \ldots,$ stop $- 1$.
range(start, stop)	Construct an iteration of values start, start $+ 1, \ldots,$ stop $- 1$.
range(start, stop, step)	Construct an iteration of values start, start + step, start + 2*step, ...
reversed(sequence)	Return an iteration of the sequence in reverse.
round(x)	Return the nearest int value (a tie is broken toward the even value).
round(x, k)	Return the value rounded to the nearest 10^{-k} (return-type matches x).
sorted(iterable)	Return a list containing elements of the iterable in sorted order.
sum(iterable)	Return the sum of the elements in the iterable (must be numeric).
type(obj)	Return the class to which the instance obj belongs.

Table 1.4: Commonly used built-in function in Python.

1.6 Simple Input and Output

In this section, we address the basics of input and output in Python, describing standard input and output through the user console, and Python's support for reading and writing text files.

1.6.1 Console Input and Output

The print Function

The built-in function, print, is used to generate standard output to the console. In its simplest form, it prints an arbitrary sequence of arguments, separated by spaces, and followed by a trailing newline character. For example, the command print('maroon' , 5) outputs the string maroon 5\n . Note that arguments need not be string instances. A nonstring argument x will be displayed as str(x). Without any arguments, the command print() outputs a single newline character.

The print function can be customized through the use of the following keyword parameters (see Section 1.5 for a discussion of keyword parameters):

- By default, the print function inserts a separating space into the output be- tween each pair of arguments. The separator can be customized by providing a desired separating string as a keyword parameter, sep. For example, colon separated output can be produced as print(a, b, c, sep = :). The separating string need not be a single character; it can be a longer string, and it can be the empty string, sep = ' ', causing successive arguments to be directly concatenated.

- By default, a trailing newline is output after the final argument. An alternative trailing string can be designated using a keyword parameter, end. Designating the empty string end = ' ' suppresses all trailing characters.

- By default, the print function sends its output to the standard console. However, output can be directed to a file by indicating an output file stream (see Section 1.6.2) using file as a keyword parameter.

The input Function

The primary means for acquiring information from the user console is a built-in function named input. This function displays a prompt, if given as an optional parameter, and then waits until the user enters some sequence of characters followed by the return key. The formal return value of the function is the string of characters that were entered strictly before the return key (i.e., no newline character exists in the returned string).

When reading a numeric value from the user, a programmer must use the input function to get the string of characters, and then use the int or float syntax to construct the numeric value that character string represents. That is, if a call to response = input() reports that the user entered the characters, 2013 , the syntax int(response) could be used to produce the integer value 2013. It is quite common to combine these operations with a syntax such as

```
year = int(input( 'In what year were you born? '))
```

if we assume that the user will enter an appropriate response. (In Section 1.7 we discuss error handling in such a situation.)

Because input returns a string as its result, use of that function can be combined with the existing functionality of the string class, as described in Appendix A. For example, if the user enters multiple pieces of information on the same line, it is common to call the split method on the result, as in

```
reply = input( 'Enter x and y, separated by spaces: ')
pieces = reply.split( )          # returns a list of strings, as separated by spaces
x = float(pieces[0])
y = float(pieces[1])
```

A Sample Program

Here is a simple, but complete, program that demonstrates the use of the input and print functions. The tools for formatting the final output is discussed in Appendix A.

```
age = int(input( 'Enter your age in years: '))
max_heart_rate = 206.9 – (0.67 * age)
# as per Med Sci Sports Exerc.
target = 0.65 * max_heart_rate
print( 'Your target fat-burning heart rate is' , target)
```

1.6.2 Files

Files are typically accessed in Python beginning with a call to a built-in function, named open, that returns a proxy for interactions with the underlying file. For example, the command, fp = open('sample.txt'), attempts to open a file named sample.txt, returning a proxy that allows read-only access to the text file.

The open function accepts an optional second parameter that determines the access mode. The default mode is 'r' for reading. Other common modes are 'w' for writing to the file (causing any existing file with that name to be overwritten), or 'a' for appending to the end of an existing file. Although we focus on use of text files, it is possible to work with binary files, using access modes such as 'rb' or 'wb'.

When processing a file, the proxy maintains a current position within the file as an offset from the beginning, measured in number of bytes. When opening a file with mode 'r' or 'w' , the position is initially 0; if opened in append mode, 'a' , the position is initially at the end of the file. The syntax fp.close() closes the file associated with proxy fp, ensuring that any written contents are saved. A summary of methods for reading and writing a file is given in Table 1.5

Calling Syntax	Description
fp.read( )	Return the (remaining) contents of a readable file as a string.
fp.read(k)	Return the next k bytes of a readable file as a string.
fp.readline( )	Return (remainder of) the current line of a readable file as a string.
fp.readlines( )	Return all (remaining) lines of a readable file as a list of strings.
for line **in** fp:	Iterate all (remaining) lines of a readable file.
fp.seek(k)	Change the current position to be at the k^{th} byte of the file.
fp.tell( )	Return the current position, measured as byte-offset from the start.
fp.write(string)	Write given string at current position of the writable file.
fp.writelines(seq)	Write each of the strings of the given sequence at the current position of the writable file. This command does *not* insert any newlines, beyond those that are embedded in the strings.
print(..., file=fp)	Redirect output of print function to the file.

Table 1.5: Behaviors for interacting with a text file via a file proxy (named fp).

Reading from a File

The most basic command for reading via a proxy is the read method. When invoked on file proxy fp, as fp.read(k), the command returns a string representing the next k bytes of the file, starting at the current position. Without a parameter, the syntax fp.read() returns the remaining contents of the file in entirety. For convenience, files can be read a line at a time, using the readline method to read one line, or the readlines method to return a list of all remaining lines. Files also support the for-loop syntax, with iteration being line by line (e.g., **for** line **in** fp:).

Writing to a File

When a file proxy is writable, for example, if created with access mode 'w' or 'a' , text can be written using methods write or writelines. For example, if we define fp = open('results.txt' , w), the syntax fp.write('Hello World.\n') writes a single line to the file with the given string. Note well that write does not explicitly add a trailing newline, so desired newline characters must be embedded directly in the string parameter. Recall that the output of the print method can be redirected to a file using a keyword parameter, as described in Section 1.6.

1.7 Exception Handling

＊1.7 节 异常处理

Exceptions are unexpected events that occur during the execution of a program. An exception might result from a logical error or an unanticipated situation. In Python, ***exceptions*** (also known as ***errors***) are objects that are ***raised*** (or ***thrown***) by code that encounters an unexpected circumstance. The Python interpreter can also raise an exception should it encounter an unexcepted condition, like running out of memory. A raised error may be caught by a surrounding context that "handles" the exception in an appropriate fashion. If uncaught, an exception causes the interpreter to stop executing the program to report an appropriate message to the console.

＊我们把程序执行过程中发生的未预料到的事件称为"异常"。能导致异常的原因有很多，比如逻辑错误或者未预料到的情形。在 Python 语言中，异常（即 C 语言中与之相同的 error）是以对象的形式、被发生了不可预知情形的代码抛出的。当遇到像内存溢出一样的情形时，Python 的解释器也能抛出异常。当一个错误被抛出，它可以被周围的上下文捕获并以恰当的方式处理。如果异常未能被捕获，那么这将会导致程序停止运行并且向控制台提交相关信息。

Common Exception Types

Python includes a rich hierarchy of exception classes that designate various categories of errors; Table 1.6 shows many of those classes. The Exception class serves as a base class for most other error types. An instance of the various subclasses encodes details about a problem that has occurred. Several of these errors may be raised in exceptional cases by behaviors introduced in this chapter. For example, use of an undefined identifier in an expression causes a NameError, and errant use of the dot notation, as in foo.bar(), will generate an AttributeError if object foo does not support a member named bar.

Class	Description
Exception	A base class for most error types
AttributeError	Raised by syntax obj.foo, if obj has no member named foo
EOFError	Raised if "end of file" reached for console or file input
IOError	Raised upon failure of I/O operation (e.g., opening file)
IndexError	Raised if index to sequence is out of bounds
KeyError	Raised if nonexistent key requested for set or dictionary
KeyboardInterrupt	Raised if user types ctrl-C while program is executing
NameError	Raised if nonexistent identifier used
StopIteration	Raised by next(iterator) if no element; see Section 1.8
TypeError	Raised when wrong type of parameter is sent to a function
ValueError	Raised when parameter has invalid value (e.g., sqrt(−5))
ZeroDivisionError	Raised when any division operator used with 0 as divisor

Table 1.6: Common exception classes in Python

Sending the wrong number, type, or value of parameters to a function is another common cause for an exception. For example, a call to abs('hello') will raise a TypeError because the parameter is not numeric, and a call to abs(3, 5) will raise a TypeError because one parameter is expected. A ValueError is typically raised when the correct number and type of parameters are sent, but a value is illegitimate for the context of the function. For example, the int constructor accepts a string, as with int('137'), but a ValueError is raised if that string does not represent an integer, as with int('3.14') or int('hello').

Python's sequence types (e.g., list, tuple, and str) raise an IndexError when syntax such as data[k] is used with an integer k that is not a valid index for the given sequence (as described in Section 1.2.3). Sets and dictionaries raise a KeyError when an attempt is made to access a nonexistent element.

1.7.1 Raising an Exception

An exception is thrown by executing the **raise** statement, with an appropriate in- stance of an exception class as an argument that designates the problem. For example, if a function for computing a square root is sent a negative value as a parameter, it can raise an exception with the command:

```
raise ValueError( 'x cannot be negative' )
```

This syntax raises a newly created instance of the ValueError class, with the error message serving as a parameter to the constructor. If this exception is not caught within the body of the function, the execution of the function immediately ceases and the exception is propagated to the calling context (and possibly beyond).

When checking the validity of parameters sent to a function, it is customary to first verify that a parameter is of an appropriate type, and then to verify that it has an appropriate value. For example, the sqrt function in Python's math library performs error-checking that might be implemented as follows:

```
def sqrt(x):
    if not isinstance(x, (int, float)):
        raise TypeError( x must be numeric )
    elif x < 0:
        raise ValueError( x cannot be negative )
    # do the real work here...
```

Checking the type of an object can be performed at run-time using the built-in function, isinstance. In simplest form, isinstance(obj, cls) returns True if object, obj, is an instance of class, cls, or any subclass of that type. In the above example, a more general form is used with a tuple of allowable types indicated with the second parameter. After confirming that the parameter is numeric, the function enforces an expectation that the number be nonnegative, raising a ValueError otherwise.

How much error-checking to perform within a function is a matter of debate. Checking the type and value of each parameter demands additional execution time and, if taken to an extreme, seems counter to the nature of Python. Consider the built-in sum function, which computes a sum of a collection of

numbers. An implementation with rigorous error-checking might be written as follows:

```
def sum(values):
    if not isinstance(values, collections.Iterable):
        raise TypeError( parameter must be an iterable type )
    total = 0
    for v in values:
        if not isinstance(v, (int, float)):
            raise TypeError( elements must be numeric )
        total = total+ v
    return total
```

The abstract base class, collections.Iterable, includes all of Python's iterable containers types that guarantee support for the for-loop syntax (e.g., list, tuple, set); we discuss iterables in Section 1.8, and the use of modules, such as collections, in Section 1.11. Within the body of the for loop, each element is verified as numeric before being added to the total. A far more direct and clear implementation of this function can be written as follows:

```
def sum(values): total = 0
    for v in values:
    total = total + v
return total
```

Interestingly, this simple implementation performs exactly like Python's built-in version of the function. Even without the explicit checks, appropriate exceptions are raised naturally by the code. In particular, if values is not an iterable type, the attempt to use the for-loop syntax raises a TypeError reporting that the object is not iterable. In the case when a user sends an iterable type that includes a nonnumerical element, such as sum([3.14, oops]), a TypeError is naturally raised by the evaluation of expression total + v. The error message

```
unsupported operand type(s) for +:  'float' and 'str'
```

should be sufficiently informative to the caller. Perhaps slightly less obvious is the error that results from sum(['alpha' , 'beta']). It will technically report a failed attempt to add an int and str, due to the initial evaluation of total + 'alpha' , when total has been initialized to 0.

In the remainder of this book, we tend to favor the simpler implementations in the interest of clean presentation, performing minimal error-checking in most situations.

1.7.2 Catching an Exception
＊1.7.2 节 捕获异常

There are several philosophies regarding how to cope with possible exceptional cases when writing code. For example, if a division x/y is to be computed, there is clear risk that a ZeroDivisionError will be raised when variable y has value 0. In an ideal situation, the logic of the program may dictate that y has a nonzero value, thereby removing the concern for error. However, for more complex code, or in a case where the value of y depends on some external input to the program, there remains some possibility of an error.

One philosophy for managing exceptional cases is to ***"look before you leap."*** The goal is to entirely avoid the possibility of an exception being raised through the use of a proactive conditional test. Revisiting our division example, we might avoid the offending situation by writing:

```
if y != 0:
    ratio = x / y
else:
    ... do something else ...
```

A second philosophy, often embraced by Python programmers, is that "***it is easier to ask for forgiveness than it is to get permission.***" This quote is attributed to Grace Hopper, an early pioneer in computer science. The sentiment is that we need not spend extra execution time safeguarding against every possible exceptional case, as long as there is a mechanism for coping with a problem after it arises. In Python, this philosophy is implemented using a ***try-except*** control structure. Revising our first example, the division operation can be guarded as follows:

```
try:
    ratio = x / y
except ZeroDivisionError:
    ... do something else ...
```

In this structure, the "try" block is the primary code to be executed. Although it is a single command in this example, it can more generally be a larger block of indented code. Following the try-block are one or more "except" cases, each with an identified error type and an indented block of code that should be executed if the designated error is raised within the try-block.

The relative advantage of using a try-except structure is that the non-exceptional case runs efficiently, without extraneous checks for the exceptional condition. However, handling the exceptional case requires slightly more time when using a try- except structure than with a standard conditional statement. For this reason, the try-except clause is best used when there is reason to believe that the exceptional case is relatively unlikely, or when it is prohibitively expensive to proactively evaluate a condition to avoid the exception.

Exception handling is particularly useful when working with user input, or when reading from or writing to files, because such interactions are inherently less predictable. In Section 1.6.2, we suggest the syntax, fp = open(sample.txt), for opening a file with read access. That command may raise an IOEeror for a variety of reasons, such as a non-existent file, or lack of sufficient privilege for opening a file. It is significantly easier to attempt the command and catch the resulting error than it is to accurately predict whether the command will succeed.

We continue by demonstrating a few other forms of the try-except syntax. Exceptions are objects that can be examined when caught. To do so, an identifier must be established with a syntax as follows:

```
try:
    fp = open( sample.txt )
except IOError as e:
    print( Unable to open the file: , e)
```

In this case, the name, e, denotes the instance of the exception that was thrown, and printing it causes a detailed error message to be displayed (e.g., "file not found").

A try-statement may handle more than one type of exception. For example, consider the following command from Section 1.6.1:

```
age = int(input( 'Enter your age in years: '))
```

This command could fail for a variety of reasons. The call to input will raise an EOFError if the console input fails. If the call to input completes successfully, the int constructor raises a ValueError if the user has not entered characters representing a valid integer. If we want to handle two or more types of errors in the same way, we can use a single except-statement, as in the following example:

```
age = −1    # an initially invalid choice
while age <= 0:
    try:
        age = int(input( 'Enter your age in years: '))
    if age <= 0:
        print( 'Your age must be positive )
    except (ValueError, EOFError'):
        print( 'Invalid response )
```

We use the tuple, (ValueError, EOFError), to designate the types of errors that we wish to catch with the except-clause. In this implementation, we catch either error, print a response, and continue with another pass of the enclosing while loop. We note that when an error is raised within the try-block, the remainder of that body is immediately skipped. In this example, if the exception arises within the call to input, or the subsequent call to the int constructor, the assignment to age never

occurs, nor the message about needing a positive value. Because the value of age will be unchanged, the while loop will continue. If we preferred to have the while loop continue without printing the 'Invalid response' message, we could have written the exception-clause as

```
except (ValueError, EOFError):
    pass
```

The keyword, **pass**, is a statement that does nothing, yet it can serve syntactically as a body of a control structure. In this way, we quietly catch the exception, thereby allowing the surrounding while loop to continue.

In order to provide different responses to different types of errors, we may use two or more except-clauses as part of a try-structure. In our previous example, an EOFError suggests a more insurmountable error than simply an errant value being entered. In that case, we might wish to provide a more specific error message, or perhaps to allow the exception to interrupt the loop and be propagated to a higher context. We could implement such behavior as follows:

```
age = -1 # an initially invalid choice
while age <= 0:
    try:
        age = int(input( 'Enter your age in years: '))
        if age <= 0:
            print( Your age must be positive )
    except ValueError:
        print( That is an invalid age specification )
    except EOFError:
        print( There was an unexpected error reading input. )
        raise    # let s re-raise this exception
```

In this implementation, we have separate except-clauses for the ValueError and EOFError cases. The body of the clause for handling an EOFError relies on another technique in Python. It uses the raise statement without any subsequent argument, to re-raise the same exception that is currently being handled. This allows us to provide our own response to the exception, and then to interrupt the while loop and propagate the exception upward.

In closing, we note two additional features of try-except structures in Python. It is permissible to have a final except-clause without any identified error types, using syntax **except:**, to catch any other exceptions that occurred. However, this technique should be used sparingly, as it is difficult to suggest how to handle an error of an unknown type. A try-statement can have a **finally** clause, with a body of code that will always be executed in the standard or exceptional cases, even when an uncaught or re-raised exception occurs. That block is typically used for critical cleanup work, such as closing an open file.

1.8 Iterators and Generators

＊ 1.8 节 迭代器与生成器

In section 1.4.2, we introduced the for-loop syntax beginning as:

＊在 1.4.2 节中，我们介绍了 for 循环的语句：

```
for element in iterable:
＊for element in iterable:
```

and we noted that there are many types of objects in Python that qualify as being iterable. Basic container types, such as list, tuple, and set, qualify as iterable types. Furthermore, a string can produce an iteration of its characters, a dictionary can produce an iteration of its keys, and a file can produce an iteration of its lines. User-defined types may also support iteration. In Python, the mechanism for iteration is based upon the following conventions:

＊我们注意到，Python 中有许多类型的对象被认为是可迭代的。基本容器类型，如列表，元组和集合，都可以被定义为可迭代类型。此外，字符串可以产生其字符的迭代，字典可以产生其 keys 的迭代，并且文件可以产生其行的迭代。用户定义的类型也可以支持迭代。在 Python 中，迭代的机制基于以下约定

- An ***iterator*** is an object that manages an iteration through a series of values. If variable, i, identifies an iterator object, then each call to the build-in function, next(i), produce a subsequent element from the underlying series, with a StopIteration exception raised to indicate that there are no further elements.
  ＊迭代器是通过一系列值来实现对迭代对象的管理的。如果变量 i 代表一个迭代器对象，那么每次调用内建函数 next(i)都会从底层产生一个后续元素，直到抛出 StopIteration 异常来表示没有其他元素。

- An ***iterable*** is an object, obj, that produces an iterator via the syntax iter(obj)
  ＊可迭代的对象 obj，可以通过 iter(obj)语句生成一个迭代器对象。

By these definitions, an instance of a list is an iterable, but not itself an iterator. With data = [1, 2, 4, 8], it is not legal to call next(data). However, an iterator object can be produced with syntax, I = iter(data), and then each subsequent call to next(i) will return an element of that list. The for-loop syntax in Python simply automates this process, creating an iterator for the give iterable, and then repeatedly calling for the next element until catching the StopIteration exception.

＊通过这些约定可以看到，列表是可迭代的，但是列表本身并不是一个迭代器。定义列表 data = [1, 2, 4, 8]，然后调用 next(data)是不合法的。然而，可以使用语法 I = iter(data)生成迭代器对象，然后每个后续调用 next(i)将返回该列表的元素。Python 中的 for 循环已经比较简单地将这个过程自动化了，先是为可迭代对象创建一个迭代器，然后重复调用下一个元素，直到抛出 StopIteration 异常。

More generally, it is possible to create multiple iterators based upon the same iterable object, with each iterator maintaining its own state of progress. However, iterators typically maintain their state with indirect reference back to the original collection of elements. For example, calling iter(data) on a list instance produces an instance of the list_iterator class. That iterator does not store its own copy of the list of elements. Instead, it maintains a current *index* into the original list, representing the next element to be reported. Therefore, if the contents of the original list are modified after the iterator is constructed, but before the iteration is complete, the iterator will be reporting the *updated* contents of the list.

＊更一般地，可以基于一个的可迭代对象而创建多个迭代器，并且每个迭代器都可以保持其自身的进度状态。然而，迭代器通常将间接引用的状态保留在原始的元素集合中。例如，在列表实例上调用 iter(data)会生成 list_iterator 类的实例。该迭代器不存储其自己的元素列表的副本。相反，它将当前索引植入到原始列表中，借此表示要抛出的下一个元素。因此，如果在构建迭代器之后、但又是在在迭代过程完成之前修改了原始列表的内容，那么迭代器将报告列表的更新内容。

Python also supports functions and classes that produce an implicit iterable series of values, that is, without constructing a data structure to store all of its values at once. For example, the call range(1000000) does not return a list of numbers; it returns a range object that is iterable. This object generates the million values one at a time, and only as needed. Such a ***lazy evaluation*** technique has great advantage. In the case of range, it allows a loop of the form, **for** j **in** range(1000000):, to execute without setting aside memory for storing one million values. Also, if such a loop were to be interrupted in some fashion, no time will have been spent computing unused values of the range.

＊Python 还支持产生隐式迭代值的函数和类，也就是说，并不需要构造一个数据结构来存储其所有值。例如，调用语句 range(1000000)并不返回数字列表; 它返回一个可迭代的 range 对象。此对象每次生成一个值，并且仅在需要时生成。这样一个惰性取值的技术有很大的优势。在 range 这个例子下，它允许循环的形式：for j in range (1000000):中的 j 去进行循环取值，而不设置存储一百万个值的内存。而且，如果这样一个循环以某种方式中断，那么并没有花费时间去计算未使用的值的范围。

We see lazy evaluation used in many of Python's libraries. For example, the dictionary class supports methods keys(), values(), and items(), which respectively produce a "view" of all keys, values, or (key, value) pairs within a dictionary. None of these methods produces an explicit list of results. Instead, the

views that are produced are iterable objects based upon the actual contents of the dictionary. An explicit list of values from such an iteration can be immediately constructed by calling the list class constructor with the iteration as a parameter. For example, the syntax list(range(1000)) produces a list with value from 0 to 999, while the syntax list(d.values()) produces a list that has elements based upon the current values of dictionary d. We can similarly construct a tuple or set instance based upon a given iterable.

＊我们看到许多 Python 库中使用了惰性取值。例如，词典支持方法 keys()，values()和 items()，它们分别产生字典中的 key，value 或(key,value)二元组。这些方法都不产生实际的结果列表。恰恰相反，生成的是基于字典的实际内容的可迭代对象。可以把迭代器作为列表类的参数，来构造这种迭代的值的显式列表。例如，语句 list(range(1000))会产生一个值为 0 到 999 的列表，而语句(d.values())则会根据字典 d 的当前值产生一个包含元素的列表。我们可以基于给定的可迭代对象，来类似地构造元组或生成实例。

Generators

In Section 2.3.4, we will explain how to define a class whose instances serve as iterators. However, the most convenient technique for creating iterators in Python is through the use of generators. A generator is implemented with a syntax that is very similar to a function, but instead of returning values, a yield statement is executed to indicate each element of the series. As an example, consider the goal of determining all factors of a positive integer. For example, the number 100 has factors 1, 2, 4, 5, 10, 20, 25, 50, 100. A traditional function might produce and return a list containing all factors, implemented as:

＊在 2.3.4 节中，我们将要介绍如何定义实例是迭代器的那种类。然而，在 Python 中创建迭代器的最方便的方式是使用生成器。生成器的语法看起来与函数相似，但是生成器不是返回数值，生成器中的 yield 语句指示序列中的每个元素。例如，要生成所有一个正整数的所有因数，比如说，数字 100 具有 1，2，4，5，10，20，25，50，100 这些因数。传统函数可能产生并返回包含所有因数的列表，代码一般这样写：

```
def factors(n):    # traditional function that computes factors
    results = []  # store factors in a new list
    for k in range(1,n+1):
        if n % k == 0:      # divides evenly, thus k is a factor
            results.append(k)       # add k to the list of factors
    return results          # return the entire list
```

In contrast, an implementation of a *generator* for computing those factors could be implemented as follows:

＊相比之下，用于计算这些因子的生成器可以如下实现：

```
def factors(n):    # generator that computes factors
    for k in range(1,n+1):
        if n % k == 0:    # divides evenly, thus k is a factor
            yield k       # yield this factor as next result
```

Notice use of the keyword **yield** rather than **return** to indicate a result. This indicates to Python that we are defining a generator, rather than a traditional function. It is illegal to combine yield and return statements in the same implementation, other than a zero-argument return statement to cause a generator to end its execution. If a programmer writes a loop such as **for** factor **in** factors(100):, an instance of our generator is created. For each iteration of the loop, Python executes our procedure until a yield statement indicates the next value. At that point, the procedure is temporarily interrupted, only to be resumed when another value is requested. When the flow of control naturally reaches the end of our procedure (or a zero-argument return statement), a StopIteration exception is automatically raised. Although this particular example uses a single yield statement in the source code, a generator can rely on multiple yield statements in different constructs, with the generated series determined by the natural flow of control. For example, we can greatly improve the efficiency of our generator for computing factors of a number, n, by only testing values up to the square root of that number, while reporting the factor n//k that is associated with each k (unless n//k equals k). We might implement such a generator as follows:

＊请注意使用关键字 yield 而不是用 return 返回结果。这表明了我们定义了一个发生器，而不是一个普通的函数。将 yield 和 return 语句组合在相同的实现中是非法的，生成器的结束执行也不是通过零参数的 return 语句完成的。如果一个程序员写了一个循环，例如 for factor in factors(100):，那么就会创建一个生成器。对于循环的每次迭代，Python 会一直执行程序语句，如果在执行过程中遇到指示下一个数值的 yield 语句，进程就停止。此时，进程只是暂时被中断，只有在请求另一个值时才会恢复该过程。当程序运行到了我们的过程结束时（或零参数返回语句时），会自动引发 StopIteration 异常。尽管该特定示例在源代码中使用单个 yield 语句，但生成器可以依赖于不同结构中的多个 yield 语句。例如，我们可以通过将循环控制到 n 的平方根，而在循环过程中报告每个 n//k，这可以大大提高生成器的计算效率。根据这个分析可以写出如下的生成器程序代码：

```
def factors(n):    # generator that computes factors
    k = 1
    while k * k < n:        while k < sqrt(n)
        if n % k == 0:
            yield k
            yield n // k
        k += 1
    if k * k == n:          # special case if n is perfect square
        yield k
```

We should note that this generator differs from our first version

in that the factors are not generated in strictly increasing order. For example, factors(100) generates the series 1, 100, 2, 50, 4, 25, 5, 20, 10.

＊我们应该注意到，这种生成器与我们的第一个版本不同，因为这些因数不是以严格的增加顺序生成的。例如，factor(100)产生 1，100，2，50，4，25，5，20，10。

In closing, we wish to emphasize the benefits of lazy evaluation when using a generator rather than a traditional function. The results are only computed if requested, and the entire series need not reside in memory at one time. In fact, a generator can effectively produce an infinite series of values. As an example, the Fibonacci numbers form a classic mathematical sequence, starting with value 0, then value 1, and then each subsequent value being the sum of the two preceding values. Hence, the Fibonacci series begins as: 0, 1, 1, 2, 3, 5, 8, 13, ... The following generator produces this infinite series.

＊最后，我们强调一下使用生成器而非一般函数的好处。而好处就是数值只有在需要的时候才会被计算出来，整个序列不需要一次性全部保存在内存中。事实上，生成器可以高效生成一个无穷序列（译者按：这真的是太惊人了！）。例如，斐波纳契数列是一个经典的数学序列，从值 0 开始，然后是值 1，然后每个后续值是前面两个值的和。因此，斐波纳契系列的样式为：0，1，1，2，3，5，8，13，...。下面的生成器可以生成这个无穷的数列。

```
def fibonacci( ):
    a = 0
    b = 1
    while True:          # keep going...
        yield a          # report value, a, during this pass
        future = a + b
        a = b            # this will be next value reported
        b = future       # and subsequently this
```

1.9 Additional Python Convenience

In this section, we introduce several features of Python that are particularly convenient for writing clean, concise code. Each of these syntaxes provide functionality that could otherwise be accomplished using functionality that we have introduced earlier in this chapter. However, at times, the new syntax is a more clear and direct expression of the logic.

1.9.1 Conditional

Python supports a conditional expression syntax that can replace a simple control structure. The general syntax is an expression of the form:

expr1 **if** *condition* **else** *expr2*

This compound expression evaluates to expr1 if the condition is true, and otherwise evaluates to expr2. For those familiar with Java or C++, this is equivalent to the syntax, *condition* ? *expr1* : *expr2*, in those languages.

As an example, consider the goal of sending the absolute value of a variable, n, to a function (and without relying on the built-in abs function, for the sake of ex- ample). Using a traditional control structure, we might accomplish this as follows:

```
if n >= 0:
    param = n
else:
    param = −n
result = foo(param)       # call the function
```

With the conditional expression syntax, we can directly assign a value to variable, param, as follows:

```
param = n if n >= 0 else −n   # pick the appropriate value
result = foo(param)           # call the function
```

In fact, there is no need to assign the compound expression to a variable. A conditional expression can itself serve as a parameter to the function, written as follows:

```
result = foo(n if n >= 0 else −n)
```

Sometimes, the mere shortening of source code is advantageous because it avoids the distraction of a more cumbersome control structure. However, we recommend that a conditional expression be used only when it improves the readability of the source code, and when the first of the two options is the more "natural" case, given its prominence in the syntax. (We prefer to view the alternative value as more exceptional.)

1.9.2 Comprehension Syntax

A very common programming task is to produce one series of values based upon the processing of another series. Often, this task can be accomplished quite simply in Python using what is known as a ***comprehension syntax***. We begin by demonstrating ***list comprehension***, as this was the first form to be supported by Python. Its general form is as follows:

[*expression* **for** *value* **in** *iterable* if *condition*]

We note that both *expression* and *condition* may depend on *value*, and that the if-clause is optional. The evaluation of the comprehension is logically equivalent to the following traditional control structure for computing a resulting list:

```
result = [ ]
for value in iterable:
    if condition:
        result.append(expression)
```

As a concrete example, a list of the squares of the numbers from 1 to n, that is [1, 4, 9, 16, 25,... , n^2], can be created by traditional means as follows:

```
squares = [ ]
for k in range(1, n+1):
    squares.append(k * k)
```

With list comprehension, this logic is expressed as follows:

```
squares = [k * k for k in range(1, n+1)]
```

As a second example, Section 1.8 introduced the goal of producing a list of factors for an integer n. That task is accomplished with the following list comprehension:

```
factors = [k for k in range(1,n+1) if n % k == 0]
```

Python supports similar comprehension syntaxes that respectively produce a set, generator, or dictionary. We compare those syntaxes using our example for producing the squares of numbers.

```
[ k * k for k in range(1, n+1) ]      list comprehension
{ k * k for k in range(1, n+1) }      set comprehension
( k * k for k in range(1, n+1) )      generator comprehension
{ k : k * k for k in range(1, n+1) }  dictionary comprehension
```

The generator syntax is particularly attractive when results do not need to be stored in memory. For example, to compute the sum of the first n squares, the genera- tor syntax, `total = sum(k * k for k in range(1, n+1))`, is preferred to the use of an explicitly instantiated list comprehension as the parameter.

1.9.3 Packing and Unpacking of Sequence

Python provides two additional conveniences involving the treatment of tuples and other sequence types. The first is rather cosmetic. If a series of comma-separated expressions are given in a larger context, they will be treated as a single tuple, even if no enclosing parentheses are provided. For example, the assignment

```
data = 2, 4, 6, 8
```

results in identifier, data, being assigned to the tuple (2, 4, 6, 8). This behavior is called ***automatic packing*** of a tuple. One common use of packing in Python is when returning multiple values from a function. If the body of a function executes the command,

```
return x, y
```

it will be formally returning a single object that is the tuple (x, y).

As a dual to the packing behavior, Python can automatically ***unpack*** a sequence, allowing one to assign a series of individual identifiers to the elements of sequence. As an example, we can write

```
a, b, c, d = range(7, 11)
```

which has the effect of assigning a=7, b=8, c=9, and d=10, as those are the four values in the sequence returned by the call to range. For this syntax, the right-hand side expression can be any *iterable* type, as long as the number of variables on the left-hand side is the same as the number of elements in the iteration.

This technique can be used to unpack tuples returned by a function. For example, the built-in function, divmod(a, b), returns the pair of values (a // b, a % b) associated with an integer division. Although the caller can consider the return value to be a single tuple, it is possible to write

```
quotient, remainder = divmod(a, b)
```

to separately identify the two entries of the returned tuple. This syntax can also be used in the context of a for loop, when iterating over a sequence of iterables, as in

```
for x, y in [ (7, 2), (5, 8), (6, 4) ]:
```

In this example, there will be three iterations of the loop. During the first pass, x=7 and y=2, and so on. This style of loop is quite commonly used to iterate through key-value pairs that are returned by the items() method of the dict class, as in:

```
for k, v in mapping.items():
```

Simultaneous Assignments

The combination of automatic packing and unpacking forms a technique known as ***simultaneous assignment***, whereby we explicitly assign a series of values to a series of identifiers, using a syntax:

```
x, y, z = 6, 2, 5
```

In effect, the right-hand side of this assignment is automatically packed into a tuple, and then automatically unpacked with its elements assigned to the three identifiers on the left-hand side.

When using a simultaneous assignment, all of the expressions are evaluated on the right-hand side before any of the assignments are made to the left-hand variables. This is significant, as it provides a convenient means for swapping the values associated with two variables:

```
j, k = k, j
```

With this command, j will be assigned to the old value of k, and k will be assigned to the old value of j. Without simultaneous assignment, a swap typically requires more delicate use of a temporary variable, such as

```
temp = j
j = k
k = temp
```

With the simultaneous assignment, the unnamed tuple representing the packed values on the right-hand side implicitly serves as the temporary variable when performing such a swap.

The use of simultaneous assignments can greatly simplify the presentation of code. As an example, we reconsider the generator on page 41 that produces the Fibonacci series. The original code requires separate initialization of variables a and b to begin the series. Within each pass of the loop, the goal was to reassign a and b, respectively, to the values of b and a+b. At the time, we accomplished this with brief use of a third variable. With simultaneous assignments, that generator can be implemented more directly as follows:

```
def fibonacci( ):
    a, b = 0, 1
    while True:
        yield a
        a, b = b, a+b
```

1.10 Scopes and Namespace

When computing a sum with the syntax x + y in Python, the names x and y must have been previously associated with objects that serve as values; a NameError will be raised if no such definitions are found. The process of determining the value associated with an identifier is known as ***name resolution***.

Whenever an identifier is assigned to a value, that definition is made with a specific scope. Top-level assignments are typically made in what is known as ***global*** scope. Assignments made within the body of a function typically have scope that is ***local*** to that function call. Therefore, an assignment, `x = 5`, within a function has no effect on the identifier, x, in the broader scope.

Each distinct scope in Python is represented using an abstraction known as a ***namespace***. A namespace manages all identifiers that are currently defined in a given scope. Figure 1.8 portrays two namespaces, one being that of a caller to our count function from Section 1.5, and the other being the local namespace during the execution of that function.

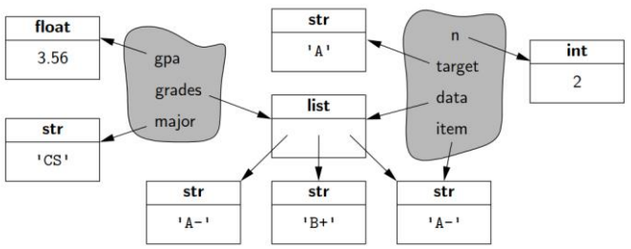


Figure 1.8: A portrayal of the two namespaces associated with a user's call count(grades, 'A'), as defined in Section 1.5. The left namespace is the caller's and the right namespace represents the local scope of the function.

Python implements a namespace with its own dictionary that maps each identifying string (e.g., 'n') to its associated value. Python provides several ways to examine a given namespace. The function, dir, reports the names of the identifiers in a given namespace (i.e., the keys of the dictionary), while the function, vars, returns the full dictionary. By default, calls to dir() and vars() report on the most locally enclosing namespace in which they are executed.

When an identifier is indicated in a command, Python searches a series of namespaces in the process of name resolution. First, the most locally enclosing scope is searched for a given name. If not found there, the next outer scope is searched, and so on. We will continue our examination of namespaces, in Section 2.5, when discussing Python's treatment of object-orientation. We will see that each object has its own namespace to store its attributes, and that classes each have a namespace as well.

First-Class Objects

In the terminology of programming languages, ***first-class objects*** are instances of a type that can be assigned to an identifier, passed as a parameter, or returned by a function. All of the data types we introduced in Section 1.2.3, such as int and list, are clearly first-class types in Python. In Python, functions and classes are also treated as first-class objects. For example, we could write the following:

```
scream = print          # assign name 'scream' to the function denoted as 'print'
scream( Hello )         # call that function
```

In this case, we have not created a new function, we have simply defined scream as an alias for the existing print function. While there is little motivation for precisely this example, it demonstrates the mechanism that is used by Python to al- low one function to be passed as a parameter to another. On page 28, we noted that the built-in function, max, accepts an optional keyword parameter to specify a non-default order when computing a maximum. For example, a caller can use the syntax, max(a, b, key=abs), to determine which value has the larger absolute value. Within the body of that function, the formal parameter, key, is an identifier that will be assigned to the actual parameter, abs.

In terms of namespaces, an assignment such as scream = print, introduces the identifier, scream, into the current namespace, with its value being the object that represents the built-in function, print. The same mechanism is applied when a user-defined function is declared. For example, our count function from Section 1.5 beings with the following syntax:

```
def count(data, target):
    ...
```

Such a declaration introduces the identifier, count, into the current namespace, with the value being a function instance representing its implementation. In similar fashion, the name of a newly defined class is associated with a representation of that class as its value. (Class definitions will be introduced in the next chapter.)

1.11 Modules and the Import Statements

We have already introduced many functions (e.g., max) and classes (e.g., list) that are defined within Python's built-in namespace. Depending on the version of Python, there are approximately 130–150 definitions that were deemed significant enough to be included in that built-in namespace.

Beyond the built-in definitions, the standard Python distribution includes per- haps tens of thousands of other values, functions, and classes that are organized in additional libraries, known as ***modules***, that can be ***imported*** from within a program. As an example, we consider the math module. While the built-in namespace includes a few mathematical functions (e.g., abs, min, max, round), many more are relegated to the math module (e.g., sin, cos, sqrt). That module also defines approximate values for the mathematical constants, pi and e.

Python's **import** statement loads definitions from a module into the current namespace. One form of an import statement uses a syntax such as the following:

```
from math import pi, sqrt
```

This command adds both pi and sqrt, as defined in the math module, into the current namespace, allowing direct use of the identifier, pi, or a call of the function, sqrt(2). If there are many definitions from the same module to be imported, an asterisk may be used as a wild card, as in, **from** math **import** * , but this form should be used sparingly. The danger is that some of the names defined in the module may conflict with names already in the current namespace (or being imported from another module), and the import causes the new definitions to replace existing ones.

Another approach that can be used to access many definitions from the same module is to import the module itself, using a syntax such as:

```
import math
```

Formally, this adds the identifier, math, to the current namespace, with the module as its value. (Modules are also first-class objects in Python.) Once imported, individual definitions from the module can be accessed using a fully-qualified name, such as math.pi or math.sqrt(2).

Creating a New Module

To create a new module, one simply has to put the relevant definitions in a file named with a .py suffix. Those definitions can be imported from any other .py file within the same project directory. For example, if we were to put the definition of our count function (see Section 1.5) into a file named utility.py, we could import that function using the syntax, **from** utility **import** count.

It is worth noting that top-level commands with the module source code are executed when the module is first imported, almost as if the module were its own script. There is a special construct for embedding commands within the module that will be executed if the module is directly invoked as a script, but not when the module is imported from another script. Such commands should be placed in a body of a conditional statement of the following form,

```
if __name__ == '__main__':
```

Using our hypothetical utility.py module as an example, such commands will be executed if the interpreter is started with a command python utility.py, but not when the utility module is imported into another context. This approach is often used to embed what are known as ***unit tests*** within the module; we will discuss unit testing further in Section 2.2.4.

1.11.1 Existing Modules

Table 1.7 provides a summary of a few available modules that are relevant to a study of data structures. We have already discussed the math module briefly. In the remainder of this section, we highlight another module that is particularly important for some of the data structures and algorithms that we will study later in this book.

Existing Modules	
Module Name	**Description**
array	Provides compact array storage for primitive types.
collections	Defines additional data structures and abstract base classes involving collections of objects.
copy	Defines general functions for making copies of objects.
heapq	Provides heap-based priority queue functions (see Section 9.3.7).
math	Defines common mathematical constants and functions.
os	Provides support for interactions with the operating system.
random	Provides random number generation.
re	Provides support for processing regular expressions.
sys	Provides additional level of interaction with the Python interpreter.
time	Provides support for measuring time, or delaying a program.

Table 1.7: Some existing Python modules relevant to data structures and algorithms.

Pseudo-Random Number Generation

Python's random module provides the ability to generate pseudo-random numbers, that is, numbers that are statistically random (but not necessarily truly random). A ***pseudo-random number generator*** uses a deterministic formula to generate the next number in a sequence based upon one or more past numbers that it has generated. Indeed, a simple yet popular pseudo-random number generator chooses its next number based solely on the most recently chosen number and some additional parameters using the following formula.

```
next = (a*current + b) % n;
```

where a, b, and n are appropriately chosen integers. Python uses a more advanced technique known as a ***Mersenne twister***. It turns out that the sequences generated by these techniques

can be proven to be statistically uniform, which is usually good enough for most applications requiring random numbers, such as games. For applications, such as computer security settings, where one needs unpredictable random sequences, this kind of formula should not be used. Instead, one should ideally sample from a source that is actually random, such as radio static coming from outer space.

Since the next number in a pseudo-random generator is determined by the previous number(s), such a generator always needs a place to start, which is called its ***seed***. The sequence of numbers generated for a given seed will always be the same. One common trick to get a different sequence each time a program is run is to use a seed that will be different for each run. For example, we could use some timed input from a user or the current system time in milliseconds.

Python's random module provides support for pseudo-random number generation by defining a Random class; instances of that class serve as generators with independent state. This allows different aspects of a program to rely on their own pseudo-random number generator, so that calls to one generator do not affect the sequence of numbers produced by another. For convenience, all of the methods supported by the Random class are also supported as stand-alone functions of the random module (essentially using a single generator instance for all top-level calls).

Syntax	Description
seed(hashable)	Initializes the pseudo-random number generator based upon the hash value of the parameter
random( )	Returns a pseudo-random floating-point value in the interval $[0.0, 1.0)$.
randint(a,b)	Returns a pseudo-random integer in the closed interval $[a, b]$.
randrange(start, stop, step)	Returns a pseudo-random integer in the standard Python range indicated by the parameters.
choice(seq)	Returns an element of the given sequence chosen pseudo-randomly.
shuffle(seq)	Reorders the elements of the given sequence pseudo-randomly.

Table 1.8: Methods supported by instances of the Random class, and as top-level functions of the random module.

END

六、实验体会

Python 是动态的语言，没有预先声明变量的类型。这一点刚从 C 语言转过来人可能感到很不适应，后来我才知道，Python 的内存管理机制与 C 语言已经完全不一样了，这是因为 C 语言作为静态语言的代表，是将变量固定在某一内存的区域中，任何数值的变化都在这块区域改变。但是 Python 不同，它本身是从 C 语言进行二次开发得到的一门新的解释性语言，它很好地借用了 C 语言中的指针的概念，在设计 Python 的过程中，C 语言中的 `malloc` 函数被广泛使用，从而使得变量的自增或者赋值基本上都会新开辟另外大小的内存片段，从而直接避开了声明数值类型的麻烦，而且旧的区域在赋值或者自增后，将会被 `free` 函数清空，从而可以被再次调用。

七、参考文献

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