CONTENTS IN DETAIL

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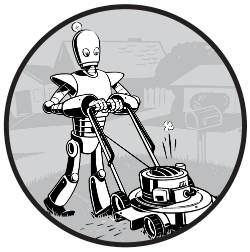
PYTHON BASICS



The Python programming language has a wide range of syntactical constructions, standard library functions, and interactive development environment features. Fortunately, you can ignore most of that; you just need to learn enough to write some handy little programs.

You will, however, have to learn some basic programming concepts before you can do anything. Like a wizard in training, you might think these concepts seem arcane and tedious, but with some knowledge and practice, you'll be able to command your computer like a magic wand and perform incredible feats.

This chapter has a few examples that encourage you to type into the *interactive shell,* also called the *REPL* (Read-Evaluate-Print Loop), which lets you run (or *execute*) Python instructions one at a time and instantly shows you the results. Using the interactive shell is great for learning what basic Python instructions do, so give it a try as you follow along. You'll remember the things you do much better than the things you only read.

Entering Expressions into the Interactive Shell

You can run the interactive shell by launching the Mu editor, which you should have downloaded when going through the setup instructions in the Preface. On Windows, open the Start menu, type "Mu," and open the Mu app. On macOS, open your Applications folder and double-click **Mu**. Click the **New** button and save an empty file as *blank.py*. When you run this blank file by clicking the **Run** button or pressing F5, it will open the interactive shell, which will open as a new pane that opens at the bottom of the Mu editor's window. You should see a >>> prompt in the interactive shell.

Enter **`2 + 2`** at the prompt to have Python do some simple math. The Mu window should now look like this:

```
>>> 2 + 2
4
>>>
```

In Python, `2 + 2` is called an *expression*, which is the most basic kind of programming instruction in the language. Expressions consist of *values* (such as `2`) and *operators* (such as `+`), and they can always *evaluate* (that is, reduce) down to a single value. That means you can use expressions anywhere in Python code that you could also use a value.

In the previous example, `2 + 2` is evaluated down to a single value, `4`. A single value with no operators is also considered an expression, though it evaluates only to itself, as shown here:

```
>>> 2
2
```

ERRORS ARE OKAY!

Programs will crash if they contain code the computer can't understand, which will cause Python to show an error message. An error message won't break your computer, though, so don't be afraid to make mistakes. A *crash* just means the program stopped running unexpectedly.

If you want to know more about an error, you can search for the exact error message text online for more information. You can also check out the resources at *https://nostarch.com/automatestuff2/* to see a list of common Python error messages and their meanings.

You can use plenty of other operators in Python expressions, too. For example, Table 1-1 lists all the math operators in Python.

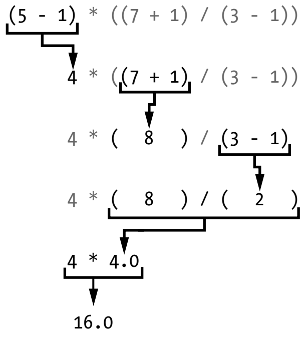
Table 1-1: Math Operators from Highest to Lowest Precedence

Operator	Operation	Example	Evaluates to . . .
**	Exponent	2 ** 3	8
%	Modulus/remainder	22 % 8	6
//	Integer division/floored quotient	22 // 8	2
/	Division	22 / 8	2.75
*	Multiplication	3 * 5	15
-	Subtraction	5 - 2	3
+	Addition	2 + 2	4

The *order of operations* (also called *precedence*) of Python math operators is similar to that of mathematics. The ** operator is evaluated first; the *, /, //, and % operators are evaluated next, from left to right; and the + and - operators are evaluated last (also from left to right). You can use parentheses to override the usual precedence if you need to. Whitespace in between the operators and values doesn't matter for Python (except for the indentation at the beginning of the line), but a single space is convention. Enter the following expressions into the interactive shell:

```
>>> 2 + 3 * 6
20
>>> (2 + 3) * 6
30
>>> 48565878 * 578453
28093077826734
>>> 2 ** 8
256
>>> 23 / 7
3.2857142857142856
>>> 23 // 7
3
>>> 23 % 7
2
>>> 2      +          2
4
>>> (5 - 1) * ((7 + 1) / (3 - 1))
16.0
```

In each case, you as the programmer must enter the expression, but Python does the hard part of evaluating it down to a single value. Python will keep evaluating parts of the expression until it becomes a single value, as shown here:



These rules for putting operators and values together to form expressions are a fundamental part of Python as a programming language, just like the grammar rules that help us communicate. Here's an example:

This is a grammatically correct English sentence.

This grammatically is sentence not English correct a.

The second line is difficult to parse because it doesn't follow the rules of English. Similarly, if you enter a bad Python instruction, Python won't be able to understand it and will display a `SyntaxError` error message, as shown here:

```
>>> 5 +
  File "<stdin>", line 1
    5 +
      ^
SyntaxError: invalid syntax
>>> 42 + 5 + * 2
  File "<stdin>", line 1
    42 + 5 + * 2
             ^
SyntaxError: invalid syntax
```

You can always test to see whether an instruction works by entering it into the interactive shell. Don't worry about breaking the computer: the worst that could happen is that Python responds with an error message. Professional software developers get error messages while writing code all the time.

The Integer, Floating-Point, and String Data Types

Remember that expressions are just values combined with operators, and they always evaluate down to a single value. A *data type* is a category for values, and every value belongs to exactly one data type. The most common data types in Python are listed in Table 1-2. The values `-2` and `30`, for example, are said to be *integer* values. The integer (or *int*) data type indicates values that are whole numbers. Numbers with a decimal point, such as `3.14`, are called *floating-point numbers* (or *floats*). Note that even though the value `42` is an integer, the value `42.0` would be a floating-point number.

Table 1-2: Common Data Types

Data type	Examples
Integers	`-2, -1, 0, 1, 2, 3, 4, 5`
Floating-point numbers	`-1.25, -1.0, -0.5, 0.0, 0.5, 1.0, 1.25`
Strings	`'a', 'aa', 'aaa', 'Hello!', '11 cats'`

Python programs can also have text values called *strings*, or *strs* (pronounced "stirs"). Always surround your string in single quote (`'`) characters (as in `'Hello'` or `'Goodbye cruel world!'`) so Python knows where the string begins and ends. You can even have a string with no characters in it, `''`, called a *blank string* or an *empty string*. Strings are explained in greater detail in Chapter 4.

If you ever see the error message `SyntaxError: EOL while scanning string literal`, you probably forgot the final single quote character at the end of the string, such as in this example:

```
>>> 'Hello, world!
SyntaxError: EOL while scanning string literal
```

String Concatenation and Replication

The meaning of an operator may change based on the data types of the values next to it. For example, `+` is the addition operator when it operates on two integers or floating-point values. However, when `+` is used on two string values, it joins the strings as the *string concatenation* operator. Enter the following into the interactive shell:

```
>>> 'Alice' + 'Bob'
'AliceBob'
```

The expression evaluates down to a single, new string value that combines the text of the two strings. However, if you try to use the + operator on a string and an integer value, Python will not know how to handle this, and it will display an error message.

```
>>> 'Alice' + 42
Traceback (most recent call last):
  File "<pyshell#0>", line 1, in <module>
    'Alice' + 42
TypeError: can only concatenate str (not "int") to str
```

The error message `can only concatenate str (not "int") to str` means that Python thought you were trying to concatenate an integer to the string `'Alice'`. Your code will have to explicitly convert the integer to a string because Python cannot do this automatically. (Converting data types will be explained in "Dissecting Your Program" on page 13 when we talk about the `str()`, `int()`, and `float()` functions.)

The * operator multiplies two integer or floating-point values. But when the * operator is used on one string value and one integer value, it becomes the *string replication* operator. Enter a string multiplied by a number into the interactive shell to see this in action.

```
>>> 'Alice' * 5
'AliceAliceAliceAliceAlice'
```

The expression evaluates down to a single string value that repeats the original string a number of times equal to the integer value. String replication is a useful trick, but it's not used as often as string concatenation.

The * operator can be used with only two numeric values (for multiplication), or one string value and one integer value (for string replication). Otherwise, Python will just display an error message, like the following:

```
>>> 'Alice' * 'Bob'
Traceback (most recent call last):
  File "<pyshell#32>", line 1, in <module>
    'Alice' * 'Bob'
TypeError: can't multiply sequence by non-int of type 'str'
>>> 'Alice' * 5.0
Traceback (most recent call last):
  File "<pyshell#33>", line 1, in <module>
    'Alice' * 5.0
TypeError: can't multiply sequence by non-int of type 'float'
```

It makes sense that Python wouldn't understand these expressions: you can't multiply two words, and it's hard to replicate an arbitrary string a fractional number of times.

Storing Values in Variables

A *variable* is like a box in the computer's memory where you can store a single value. If you want to use the result of an evaluated expression later in your program, you can save it inside a variable.

Assignment Statements

You'll store values in variables with an *assignment statement*. An assignment statement consists of a variable name, an equal sign (called the *assignment operator*), and the value to be stored. If you enter the assignment statement `spam = 42`, then a variable named `spam` will have the integer value `42` stored in it.

Think of a variable as a labeled box that a value is placed in, as in Figure 1-1.

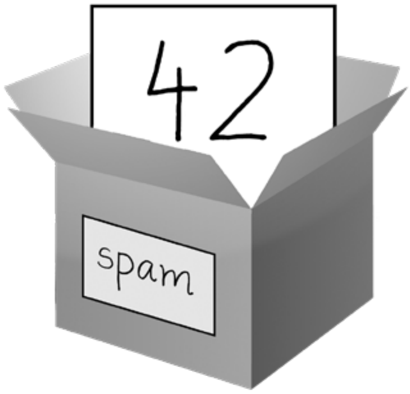


Figure 1-1: `spam = 42` is like telling the program, "The variable `spam` now has the integer value `42` in it."

For example, enter the following into the interactive shell:

```
❶ >>> spam = 40
  >>> spam
  40
  >>> eggs = 2
❷ >>> spam + eggs
  42
  >>> spam + eggs + spam
  82
❸ >>> spam = spam + 2
  >>> spam
  42
```

A variable is *initialized* (or created) the first time a value is stored in it ❶. After that, you can use it in expressions with other variables and values ❷. When a variable is assigned a new value ❸, the old value is forgotten, which is why spam evaluated to 42 instead of 40 at the end of the example. This is called *overwriting* the variable. Enter the following code into the interactive shell to try overwriting a string:

```
>>> spam = 'Hello'
>>> spam
'Hello'
>>> spam = 'Goodbye'
>>> spam
'Goodbye'
```

Just like the box in Figure 1-2, the spam variable in this example stores 'Hello' until you replace the string with 'Goodbye'.

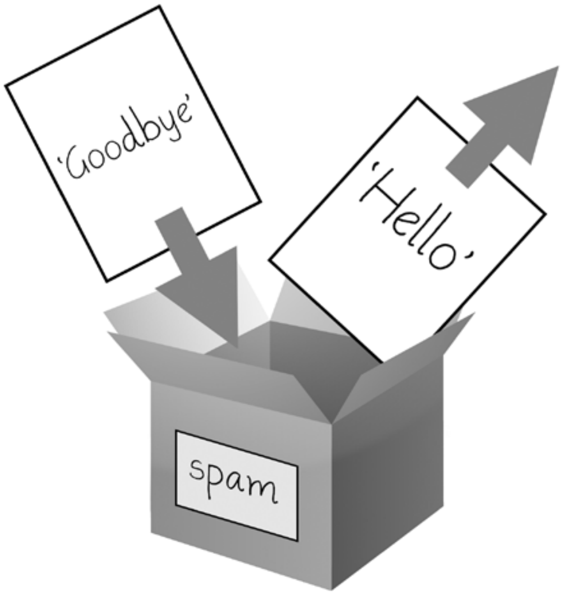


Figure 1-2: When a new value is assigned to a variable, the old one is forgotten.

Variable Names

A good variable name describes the data it contains. Imagine that you moved to a new house and labeled all of your moving boxes as *Stuff*. You'd never find anything! Most of this book's examples (and Python's documentation) use generic variable names like spam, eggs, and bacon, which come from the Monty Python "Spam" sketch. But in your programs, a descriptive name will help make your code more readable.

Though you can name your variables almost anything, Python does have some naming restrictions. Table 1-3 has examples of legal variable names. You can name a variable anything as long as it obeys the following three rules:

- It can be only one word with no spaces.
- It can use only letters, numbers, and the underscore (_) character.
- It can't begin with a number.

Table 1-3: Valid and Invalid Variable Names

Valid variable names	Invalid variable names
`current_balance`	`current-balance` (hyphens are not allowed)
`currentBalance`	`current balance` (spaces are not allowed)
`account4`	`4account` (can't begin with a number)
`_42`	`42` (can't begin with a number)
`TOTAL_SUM`	`TOTAL_$UM` (special characters like $ are not allowed)
`hello`	`'hello'` (special characters like ' are not allowed)

Variable names are case-sensitive, meaning that `spam`, `SPAM`, `Spam`, and `sPaM` are four different variables. Though `Spam` is a valid variable you can use in a program, it is a Python convention to start your variables with a lowercase letter.

This book uses *camelcase* for variable names instead of underscores; that is, variables `lookLikeThis` instead of `looking_like_this`. Some experienced programmers may point out that the official Python code style, PEP 8, says that underscores should be used. I unapologetically prefer camelcase and point to the "A Foolish Consistency Is the Hobgoblin of Little Minds" section in PEP 8 itself:

> Consistency with the style guide is important. But most importantly: know when to be inconsistent—sometimes the style guide just doesn't apply. When in doubt, use your best judgment.

Your First Program

While the interactive shell is good for running Python instructions one at a time, to write entire Python programs, you'll type the instructions into the file editor. The *file editor* is similar to text editors such as Notepad or TextMate, but it has some features specifically for entering source code. To open a new file in Mu, click the **New** button on the top row.

The window that appears should contain a cursor awaiting your input, but it's different from the interactive shell, which runs Python instructions as soon as you press ENTER. The file editor lets you type in many instructions, save the file, and run the program. Here's how you can tell the difference between the two:

- The interactive shell window will always be the one with the >>> prompt.
- The file editor window will not have the >>> prompt.

Now it's time to create your first program! When the file editor window opens, enter the following into it:

```
❶ # This program says hello and asks for my name.

❷ print('Hello, world!')
  print('What is your name?')    # ask for their name
❸ myName = input()
❹ print('It is good to meet you, ' + myName)
❺ print('The length of your name is:')
  print(len(myName))
❻ print('What is your age?')    # ask for their age
  myAge = input()
  print('You will be ' + str(int(myAge) + 1) + ' in a year.')
```

Once you've entered your source code, save it so that you won't have to retype it each time you start Mu. Click the **Save** button, enter *hello.py* in the File Name field, and then click **Save**.

You should save your programs every once in a while as you type them. That way, if the computer crashes or you accidentally exit Mu, you won't lose the code. As a shortcut, you can press CTRL-S on Windows and Linux or ⌘-S on macOS to save your file.

Once you've saved, let's run our program. Press the **F5** key. Your program should run in the interactive shell window. Remember, you have to press **F5** from the file editor window, not the interactive shell window. Enter your name when your program asks for it. The program's output in the interactive shell should look something like this:

```
Python 3.7.0b4 (v3.7.0b4:eb96c37699, May  2 2018, 19:02:22) [MSC v.1913 64 bit
(AMD64)] on win32
Type "copyright", "credits" or "license()" for more information.
>>> ================================ RESTART ================================
>>>
Hello, world!
What is your name?
Al
It is good to meet you, Al
The length of your name is:
2
What is your age?
4
You will be 5 in a year.
>>>
```

When there are no more lines of code to execute, the Python program *terminates*; that is, it stops running. (You can also say that the Python program *exits*.)

You can close the file editor by clicking the X at the top of the window. To reload a saved program, select **File ▸ Open...** from the menu. Do that now, and in the window that appears, choose ***hello.py*** and click the **Open** button. Your previously saved *hello.py* program should open in the file editor window.

You can view the execution of a program using the Python Tutor visualization tool at *http://pythontutor.com/*. You can see the execution of this particular program at *https://autbor.com/hellopy/*. Click the forward button to move through each step of the program's execution. You'll be able to see how the variables' values and the output change.

Dissecting Your Program

With your new program open in the file editor, let's take a quick tour of the Python instructions it uses by looking at what each line of code does.

Comments

The following line is called a *comment*.

```
❶ # This program says hello and asks for my name.
```

Python ignores comments, and you can use them to write notes or remind yourself what the code is trying to do. Any text for the rest of the line following a hash mark (`#`) is part of a comment.

Sometimes, programmers will put a `#` in front of a line of code to temporarily remove it while testing a program. This is called *commenting out* code, and it can be useful when you're trying to figure out why a program isn't working. You can remove the `#` later when you are ready to put the line back in.

Python also ignores the blank line after the comment. You can add as many blank lines to your program as you want. This can make your code easier to read, like paragraphs in a book.

The print() Function

The `print()` function displays the string value inside its parentheses on the screen.

```
❷ print('Hello, world!')
  print('What is your name?') # ask for their name
```

The line `print('Hello, world!')` means "Print out the text in the string `'Hello, world!'`." When Python executes this line, you say that Python is *calling* the `print()` function and the string value is being *passed* to the function. A value that is passed to a function call is an *argument*. Notice that the quotes are not printed to the screen. They just mark where the string begins and ends; they are not part of the string value.

NOTE *You can also use this function to put a blank line on the screen; just call* `print()` *with nothing in between the parentheses.*

When you write a function name, the opening and closing parentheses at the end identify it as the name of a function. This is why in this book, you'll see `print()` rather than `print`. Chapter 3 describes functions in more detail.

The input() Function

The `input()` function waits for the user to type some text on the keyboard and press ENTER.

```
❸ myName = input()
```

This function call evaluates to a string equal to the user's text, and the line of code assigns the `myName` variable to this string value.

You can think of the `input()` function call as an expression that evaluates to whatever string the user typed in. If the user entered `'Al'`, then the expression would evaluate to `myName = 'Al'`.

If you call `input()` and see an error message, like `NameError: name 'Al' is not defined`, the problem is that you're running the code with Python 2 instead of Python 3.

Printing the User's Name

The following call to `print()` actually contains the expression `'It is good to meet you, ' + myName` between the parentheses.

```
❹ print('It is good to meet you, ' + myName)
```

Remember that expressions can always evaluate to a single value. If `'Al'` is the value stored in `myName` on line ❸, then this expression evaluates to `'It is good to meet you, Al'`. This single string value is then passed to `print()`, which prints it on the screen.

The len() Function

You can pass the `len()` function a string value (or a variable containing a string), and the function evaluates to the integer value of the number of characters in that string.

```
❺ print('The length of your name is:')
  print(len(myName))
```

Enter the following into the interactive shell to try this:

```
>>> len('hello')
5
>>> len('My very energetic monster just scarfed nachos.')
46
>>> len('')
0
```

Just like those examples, `len(myName)` evaluates to an integer. It is then passed to `print()` to be displayed on the screen. The `print()` function allows you to pass it either integer values or string values, but notice the error that shows up when you type the following into the interactive shell:

```
>>> print('I am ' + 29 + ' years old.')
Traceback (most recent call last):
  File "<pyshell#6>", line 1, in <module>
    print('I am ' + 29 + ' years old.')
TypeError: can only concatenate str (not "int") to str
```

The `print()` function isn't causing that error, but rather it's the expression you tried to pass to `print()`. You get the same error message if you type the expression into the interactive shell on its own.

```
>>> 'I am ' + 29 + ' years old.'
Traceback (most recent call last):
  File "<pyshell#7>", line 1, in <module>
    'I am ' + 29 + ' years old.'
TypeError: can only concatenate str (not "int") to str
```

Python gives an error because the `+` operator can only be used to add two integers together or concatenate two strings. You can't add an integer to a string, because this is ungrammatical in Python. You can fix this by using a string version of the integer instead, as explained in the next section.

The str(), int(), and float() Functions

If you want to concatenate an integer such as `29` with a string to pass to `print()`, you'll need to get the value `'29'`, which is the string form of `29`. The `str()` function can be passed an integer value and will evaluate to a string value version of the integer, as follows:

```
>>> str(29)
'29'
>>> print('I am ' + str(29) + ' years old.')
I am 29 years old.
```

Because str(29) evaluates to '29', the expression 'I am ' + str(29) + ' years old.' evaluates to 'I am ' + '29' + ' years old.', which in turn evaluates to 'I am 29 years old.'. This is the value that is passed to the print() function.

The str(), int(), and float() functions will evaluate to the string, integer, and floating-point forms of the value you pass, respectively. Try converting some values in the interactive shell with these functions and watch what happens.

```
>>> str(0)
'0'
>>> str(-3.14)
'-3.14'
>>> int('42')
42
>>> int('-99')
-99
>>> int(1.25)
1
>>> int(1.99)
1
>>> float('3.14')
3.14
>>> float(10)
10.0
```

The previous examples call the str(), int(), and float() functions and pass them values of the other data types to obtain a string, integer, or floating-point form of those values.

The str() function is handy when you have an integer or float that you want to concatenate to a string. The int() function is also helpful if you have a number as a string value that you want to use in some mathematics. For example, the input() function always returns a string, even if the user enters a number. Enter **spam = input()** into the interactive shell and enter **101** when it waits for your text.

```
>>> spam = input()
101
>>> spam
'101'
```

The value stored inside spam isn't the integer 101 but the string '101'. If you want to do math using the value in spam, use the int() function to get the integer form of spam and then store this as the new value in spam.

```
>>> spam = int(spam)
>>> spam
101
```

Now you should be able to treat the spam variable as an integer instead of a string.

```
>>> spam * 10 / 5
202.0
```

Note that if you pass a value to `int()` that it cannot evaluate as an integer, Python will display an error message.

```
>>> int('99.99')
Traceback (most recent call last):
  File "<pyshell#18>", line 1, in <module>
    int('99.99')
ValueError: invalid literal for int() with base 10: '99.99'
>>> int('twelve')
Traceback (most recent call last):
  File "<pyshell#19>", line 1, in <module>
    int('twelve')
ValueError: invalid literal for int() with base 10: 'twelve'
```

The `int()` function is also useful if you need to round a floating-point number down.

```
>>> int(7.7)
7
>>> int(7.7) + 1
8
```

You used the `int()` and `str()` functions in the last three lines of your program to get a value of the appropriate data type for the code.

```
❻ print('What is your age?') # ask for their age
myAge = input()
print('You will be ' + str(int(myAge) + 1) + ' in a year.')
```

TEXT AND NUMBER EQUIVALENCE

Although the string value of a number is considered a completely different value from the integer or floating-point version, an integer can be equal to a floating point.

```
>>> 42 == '42'
False
>>> 42 == 42.0
True
>>> 42.0 == 0042.000
True
```

Python makes this distinction because strings are text, while integers and floats are both numbers.

The myAge variable contains the value returned from input(). Because the input() function always returns a string (even if the user typed in a number), you can use the int(myAge) code to return an integer value of the string in myAge. This integer value is then added to 1 in the expression int(myAge) + 1.

The result of this addition is passed to the str() function: str(int(myAge) + 1). The string value returned is then concatenated with the strings 'You will be ' and ' in a year.' to evaluate to one large string value. This large string is finally passed to print() to be displayed on the screen.

Let's say the user enters the string '4' for myAge. The string '4' is converted to an integer, so you can add one to it. The result is 5. The str() function converts the result back to a string, so you can concatenate it with the second string, 'in a year.', to create the final message. These evaluation steps would look something like the following:

```
print('You will be ' + str(int(myAge) + 1) + ' in a year.')

print('You will be ' + str(int( '4' ) + 1) + ' in a year.')

print('You will be ' + str(    4 + 1     ) + ' in a year.')

print('You will be ' + str(      5       ) + ' in a year.')

print('You will be ' +        '5'          + ' in a year.')

print('You will be 5'                      + ' in a year.')

print('You will be 5 in a year.')
```

Summary

You can compute expressions with a calculator or enter string concatenations with a word processor. You can even do string replication easily by copying and pasting text. But expressions, and their component values—operators, variables, and function calls—are the basic building blocks that make programs. Once you know how to handle these elements, you will be able to instruct Python to operate on large amounts of data for you.

It is good to remember the different types of operators (+, -, *, /, //, %, and ** for math operations, and + and * for string operations) and the three data types (integers, floating-point numbers, and strings) introduced in this chapter.

I introduced a few different functions as well. The print() and input() functions handle simple text output (to the screen) and input (from the keyboard). The len() function takes a string and evaluates to an int of the number of characters in the string. The str(), int(), and float() functions will evaluate to the string, integer, or floating-point number form of the value they are passed.

In the next chapter, you'll learn how to tell Python to make intelligent decisions about what code to run, what code to skip, and what code to repeat based on the values it has. This is known as *flow control*, and it allows you to write programs that make intelligent decisions.

Practice Questions

1. Which of the following are operators, and which are values?

```
*
'hello'
-88.8
-
/
+
5
```

2. Which of the following is a variable, and which is a string?

```
spam
'spam'
```

3. Name three data types.
4. What is an expression made up of? What do all expressions do?
5. This chapter introduced assignment statements, like `spam = 10`. What is the difference between an expression and a statement?
6. What does the variable `bacon` contain after the following code runs?

```
bacon = 20
bacon + 1
```

7. What should the following two expressions evaluate to?

```
'spam' + 'spamspam'
'spam' * 3
```

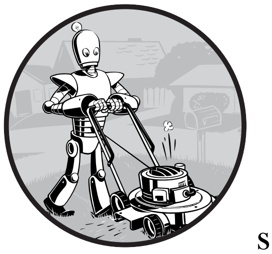
8. Why is `eggs` a valid variable name while `100` is invalid?
9. What three functions can be used to get the integer, floating-point number, or string version of a value?

10. Why does this expression cause an error? How can you fix it?

```
'I have eaten ' + 99 + ' burritos.'
```

Extra credit: Search online for the Python documentation for the `len()` function. It will be on a web page titled “Built-in Functions.” Skim the list of other functions Python has, look up what the `round()` function does, and experiment with it in the interactive shell.

2
FLOW CONTROL



So, you know the basics of individual instructions and that a program is just a series of instructions. But programming's real strength isn't just running one instruction after another like a weekend errand list. Based on how expressions evaluate, a program can decide to skip instructions, repeat them, or choose one of several instructions to run. In fact, you almost never want your programs to start from the first line of code and simply execute every line, straight to the end. *Flow control statements* can decide which Python instructions to execute under which conditions.

These flow control statements directly correspond to the symbols in a flowchart, so I'll provide flowchart versions of the code discussed in this chapter. Figure 2-1 shows a flowchart for what to do if it's raining. Follow the path made by the arrows from Start to End.

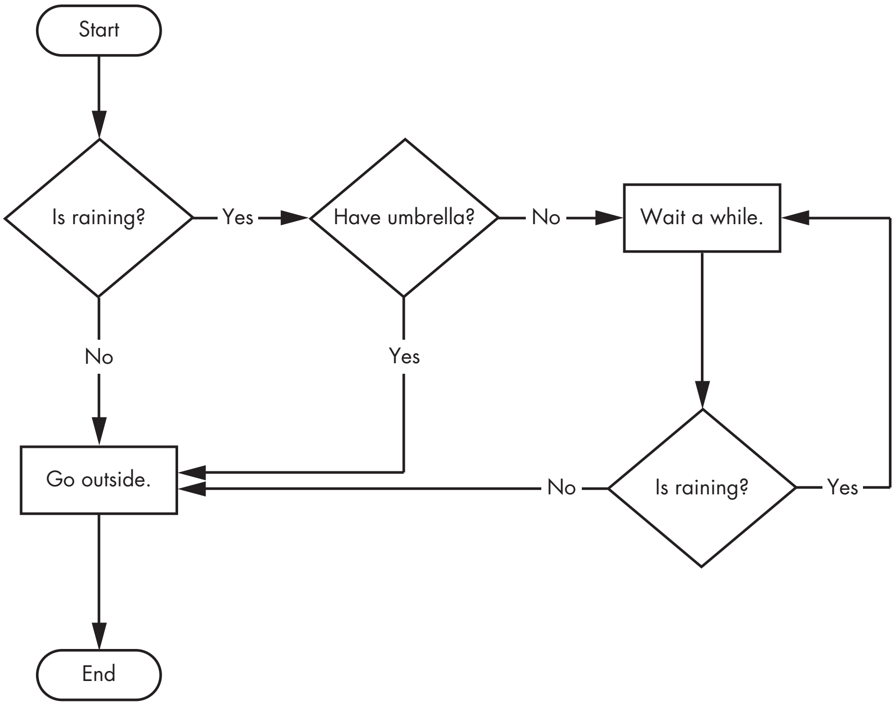


Figure 2-1: A flowchart to tell you what to do if it is raining

In a flowchart, there is usually more than one way to go from the start to the end. The same is true for lines of code in a computer program. Flowcharts represent these branching points with diamonds, while the other steps are represented with rectangles. The starting and ending steps are represented with rounded rectangles.

But before you learn about flow control statements, you first need to learn how to represent those *yes* and *no* options, and you need to understand how to write those branching points as Python code. To that end, let's explore Boolean values, comparison operators, and Boolean operators.

Boolean Values

While the integer, floating-point, and string data types have an unlimited number of possible values, the *Boolean* data type has only two values: `True` and `False`. (Boolean is capitalized because the data type is named after mathematician George Boole.) When entered as Python code, the Boolean values `True` and `False` lack the quotes you place around strings, and they always start with a capital *T* or *F*, with the rest of the word in lowercase. Enter the following into the interactive shell. (Some of these instructions are intentionally incorrect, and they'll cause error messages to appear.)

```
❶ >>> spam = True
  >>> spam
  True
❷ >>> true
  Traceback (most recent call last):
    File "<pyshell#2>", line 1, in <module>
      true
  NameError: name 'true' is not defined
❸ >>> True = 2 + 2
  SyntaxError: can't assign to keyword
```

Like any other value, Boolean values are used in expressions and can be stored in variables ❶. If you don't use the proper case ❷ or you try to use `True` and `False` for variable names ❸, Python will give you an error message.

Comparison Operators

Comparison operators, also called *relational operators*, compare two values and evaluate down to a single Boolean value. Table 2-1 lists the comparison operators.

Table 2-1: Comparison Operators

Operator	Meaning
`==`	Equal to
`!=`	Not equal to
`<`	Less than
`>`	Greater than
`<=`	Less than or equal to
`>=`	Greater than or equal to

These operators evaluate to `True` or `False` depending on the values you give them. Let's try some operators now, starting with `==` and `!=`.

```
>>> 42 == 42
True
>>> 42 == 99
False
>>> 2 != 3
True
>>> 2 != 2
False
```

As you might expect, `==` (equal to) evaluates to `True` when the values on both sides are the same, and `!=` (not equal to) evaluates to `True` when the two values are different. The `==` and `!=` operators can actually work with values of any data type.

```
>>> 'hello' == 'hello'
True
>>> 'hello' == 'Hello'
False
>>> 'dog' != 'cat'
True
>>> True == True
True
>>> True != False
True
>>> 42 == 42.0
True
❶ >>> 42 == '42'
False
```

Note that an integer or floating-point value will always be unequal to a string value. The expression `42 == '42'` ❶ evaluates to `False` because Python considers the integer `42` to be different from the string `'42'`.

The `<`, `>`, `<=`, and `>=` operators, on the other hand, work properly only with integer and floating-point values.

```
>>> 42 < 100
True
>>> 42 > 100
False
>>> 42 < 42
False
>>> eggCount = 42
❶ >>> eggCount <= 42
True
>>> myAge = 29
❷ >>> myAge >= 10
True
```

THE DIFFERENCE BETWEEN THE == AND = OPERATORS

You might have noticed that the == operator (equal to) has two equal signs, while the = operator (assignment) has just one equal sign. It's easy to confuse these two operators with each other. Just remember these points:

- The == operator (equal to) asks whether two values are the same as each other.
- The = operator (assignment) puts the value on the right into the variable on the left.

To help remember which is which, notice that the == operator (equal to) consists of two characters, just like the != operator (not equal to) consists of two characters.

You'll often use comparison operators to compare a variable's value to some other value, like in the `eggCount <= 42` ❶ and `myAge >= 10` ❷ examples. (After all, instead of entering `'dog' != 'cat'` in your code, you could have just entered `True`.) You'll see more examples of this later when you learn about flow control statements.

Boolean Operators

The three Boolean operators (`and`, `or`, and `not`) are used to compare Boolean values. Like comparison operators, they evaluate these expressions down to a Boolean value. Let's explore these operators in detail, starting with the `and` operator.

Binary Boolean Operators

The `and` and `or` operators always take two Boolean values (or expressions), so they're considered *binary* operators. The `and` operator evaluates an expression to `True` if *both* Boolean values are `True`; otherwise, it evaluates to `False`. Enter some expressions using `and` into the interactive shell to see it in action.

```
>>> True and True
True
>>> True and False
False
```

A *truth table* shows every possible result of a Boolean operator. Table 2-2 is the truth table for the `and` operator.

Table 2-2: The `and` Operator's Truth Table

Expression	Evaluates to . . .
`True and True`	`True`
`True and False`	`False`
`False and True`	`False`
`False and False`	`False`

On the other hand, the `or` operator evaluates an expression to `True` if *either* of the two Boolean values is `True`. If both are `False`, it evaluates to `False`.

```
>>> False or True
True
>>> False or False
False
```

You can see every possible outcome of the `or` operator in its truth table, shown in Table 2-3.

Table 2-3: The or Operator's Truth Table

Expression	Evaluates to . . .
`True or True`	`True`
`True or False`	`True`
`False or True`	`True`
`False or False`	`False`

The not Operator

Unlike `and` and `or`, the `not` operator operates on only one Boolean value (or expression). This makes it a *unary* operator. The `not` operator simply evaluates to the opposite Boolean value.

```
>>> not True
False
❶ >>> not not not not True
True
```

Much like using double negatives in speech and writing, you can nest `not` operators ❶, though there's never not no reason to do this in real programs. Table 2-4 shows the truth table for `not`.

Table 2-4: The not Operator's Truth Table

Expression	Evaluates to . . .
`not True`	`False`
`not False`	`True`

Mixing Boolean and Comparison Operators

Since the comparison operators evaluate to Boolean values, you can use them in expressions with the Boolean operators.

Recall that the `and`, `or`, and `not` operators are called Boolean operators because they always operate on the Boolean values `True` and `False`. While expressions like `4 < 5` aren't Boolean values, they are expressions that evaluate down to Boolean values. Try entering some Boolean expressions that use comparison operators into the interactive shell.

```
>>> (4 < 5) and (5 < 6)
True
>>> (4 < 5) and (9 < 6)
False
>>> (1 == 2) or (2 == 2)
True
```

The computer will evaluate the left expression first, and then it will evaluate the right expression. When it knows the Boolean value for each, it will then evaluate the whole expression down to one Boolean value. You can think of the computer's evaluation process for `(4 < 5) and (5 < 6)` as the following:

```
(4 < 5) and (5 < 6)
         ↓
  True and (5 < 6)
         ↓
   True and True
         ↓
       True
```

You can also use multiple Boolean operators in an expression, along with the comparison operators:

```
>>> 2 + 2 == 4 and not 2 + 2 == 5 and 2 * 2 == 2 + 2
True
```

The Boolean operators have an order of operations just like the math operators do. After any math and comparison operators evaluate, Python evaluates the `not` operators first, then the `and` operators, and then the `or` operators.

Elements of Flow Control

Flow control statements often start with a part called the *condition* and are always followed by a block of code called the *clause*. Before you learn about Python's specific flow control statements, I'll cover what a condition and a block are.

Conditions

The Boolean expressions you've seen so far could all be considered conditions, which are the same thing as expressions; *condition* is just a more specific name in the context of flow control statements. Conditions always evaluate down to a Boolean value, `True` or `False`. A flow control statement decides what to do based on whether its condition is `True` or `False`, and almost every flow control statement uses a condition.

Blocks of Code

Lines of Python code can be grouped together in *blocks*. You can tell when a block begins and ends from the indentation of the lines of code. There are three rules for blocks.

- Blocks begin when the indentation increases.
- Blocks can contain other blocks.
- Blocks end when the indentation decreases to zero or to a containing block's indentation.

Blocks are easier to understand by looking at some indented code, so let's find the blocks in part of a small game program, shown here:

```
name = 'Mary'
password = 'swordfish'
if name == 'Mary':
 ❶ print('Hello, Mary')
    if password == 'swordfish':
     ❷ print('Access granted.')
    else:
     ❸ print('Wrong password.')
```

You can view the execution of this program at *https://autbor.com/blocks/*. The first block of code ❶ starts at the line `print('Hello, Mary')` and contains all the lines after it. Inside this block is another block ❷, which has only a single line in it: `print('Access Granted.')`. The third block ❸ is also one line long: `print('Wrong password.')`.

Program Execution

In the previous chapter's *hello.py* program, Python started executing instructions at the top of the program going down, one after another. The *program execution* (or simply, *execution*) is a term for the current instruction being executed. If you print the source code on paper and put your finger on each line as it is executed, you can think of your finger as the program execution.

Not all programs execute by simply going straight down, however. If you use your finger to trace through a program with flow control statements, you'll likely find yourself jumping around the source code based on conditions, and you'll probably skip entire clauses.

Flow Control Statements

Now, let's explore the most important piece of flow control: the statements themselves. The statements represent the diamonds you saw in the flowchart in Figure 2-1, and they are the actual decisions your programs will make.

if Statements

The most common type of flow control statement is the `if` statement. An `if` statement's clause (that is, the block following the `if` statement) will execute if the statement's condition is `True`. The clause is skipped if the condition is `False`.

In plain English, an `if` statement could be read as, "If this condition is true, execute the code in the clause." In Python, an `if` statement consists of the following:

- The `if` keyword
- A condition (that is, an expression that evaluates to `True` or `False`)

- A colon
- Starting on the next line, an indented block of code (called the `if` clause)

For example, let's say you have some code that checks to see whether someone's name is Alice. (Pretend `name` was assigned some value earlier.)

```
if name == 'Alice':
    print('Hi, Alice.')
```

All flow control statements end with a colon and are followed by a new block of code (the clause). This `if` statement's clause is the block with `print('Hi, Alice.')`. Figure 2-2 shows what a flowchart of this code would look like.

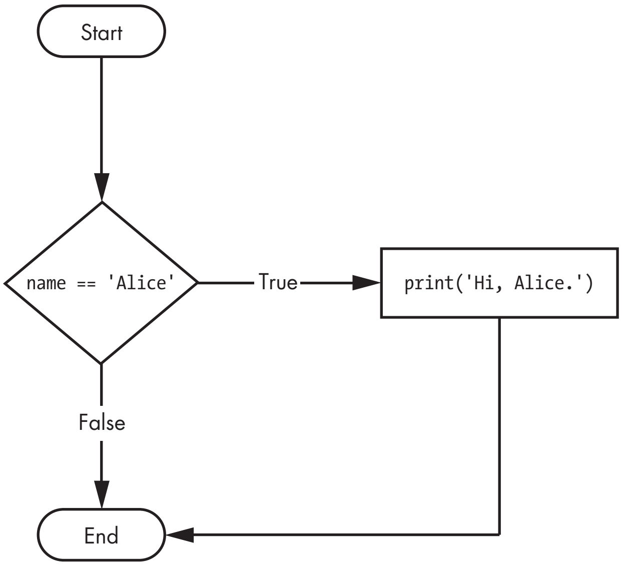


Figure 2-2: The flowchart for an `if` statement

else Statements

An `if` clause can optionally be followed by an `else` statement. The `else` clause is executed only when the `if` statement's condition is `False`. In plain English, an `else` statement could be read as, "If this condition is true, execute this code. Or else, execute that code." An `else` statement doesn't have a condition, and in code, an `else` statement always consists of the following:

- The `else` keyword
- A colon
- Starting on the next line, an indented block of code (called the `else` clause)

Returning to the Alice example, let's look at some code that uses an else statement to offer a different greeting if the person's name isn't Alice.

```
if name == 'Alice':
    print('Hi, Alice.')
else:
    print('Hello, stranger.')
```

Figure 2-3 shows what a flowchart of this code would look like.

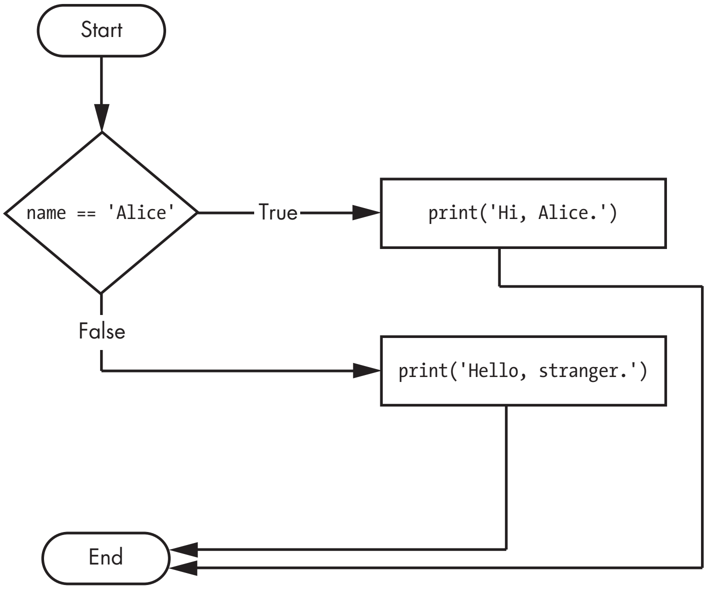


Figure 2-3: The flowchart for an else *statement*

elif Statements

While only one of the if or else clauses will execute, you may have a case where you want one of *many* possible clauses to execute. The elif statement is an "else if" statement that always follows an if or another elif statement. It provides another condition that is checked only if all of the previous conditions were False. In code, an elif statement always consists of the following:

- The elif keyword
- A condition (that is, an expression that evaluates to True or False)
- A colon
- Starting on the next line, an indented block of code (called the elif clause)

Let's add an elif to the name checker to see this statement in action.

```
if name == 'Alice':
    print('Hi, Alice.')
```

```
elif age < 12:
    print('You are not Alice, kiddo.')
```

This time, you check the person's age, and the program will tell them something different if they're younger than 12. You can see the flowchart for this in Figure 2-4.

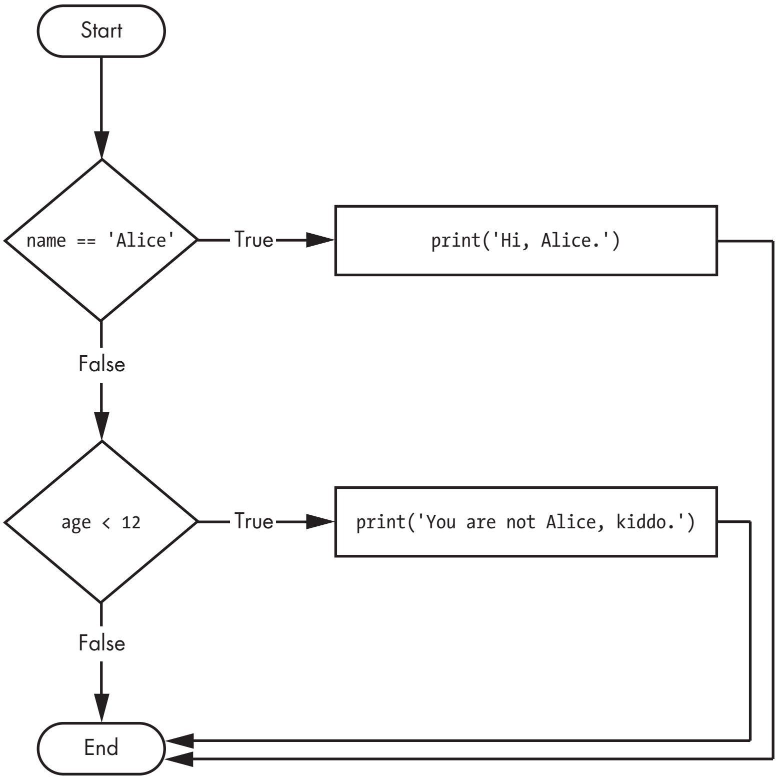
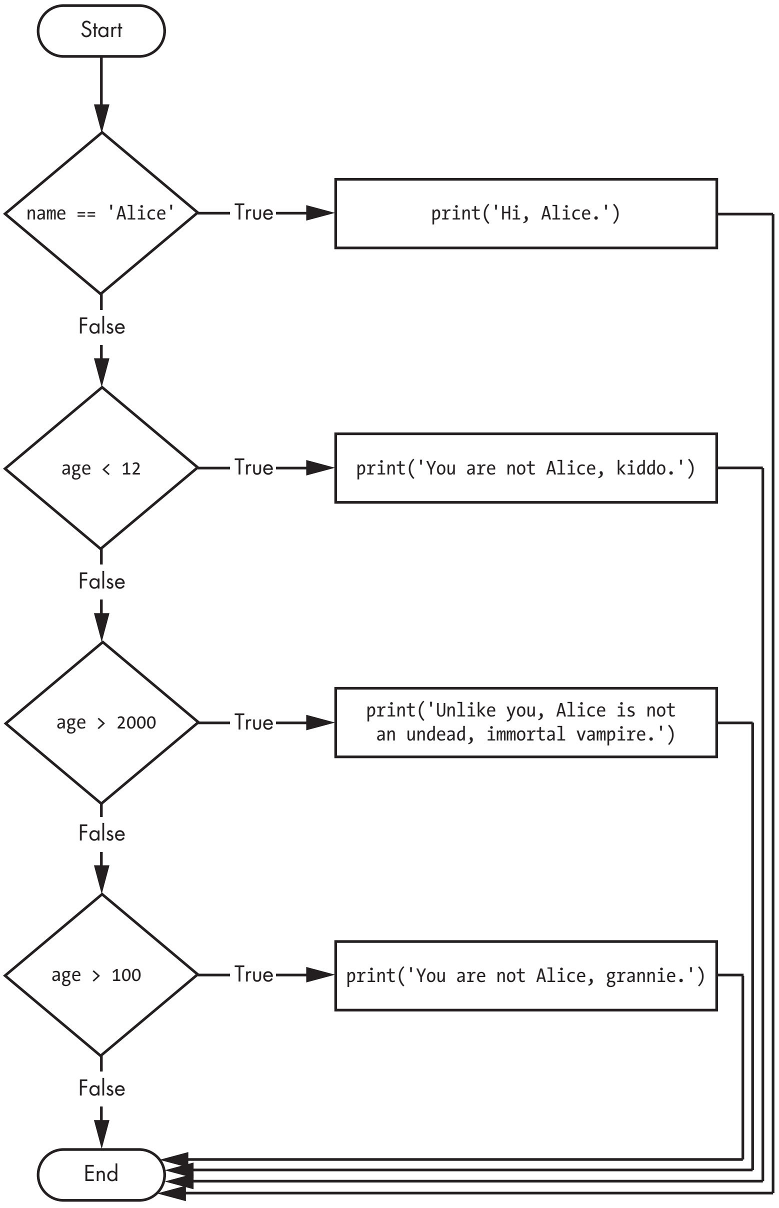


Figure 2-4: The flowchart for an `elif` statement

The `elif` clause executes if `age < 12` is `True` and `name == 'Alice'` is `False`. However, if both of the conditions are `False`, then both of the clauses are skipped. It is *not* guaranteed that at least one of the clauses will be executed. When there is a chain of `elif` statements, only one or none of the clauses will be executed. Once one of the statements' conditions is found to be `True`, the rest of the `elif` clauses are automatically skipped. For example, open a new file editor window and enter the following code, saving it as *vampire.py*:

```
name = 'Carol'
age = 3000
if name == 'Alice':
    print('Hi, Alice.')
elif age < 12:
    print('You are not Alice, kiddo.')
elif age > 2000:
    print('Unlike you, Alice is not an undead, immortal vampire.')
elif age > 100:
    print('You are not Alice, grannie.')
```

You can view the execution of this program at *https://autbor.com/vampire/*. Here, I've added two more `elif` statements to make the name checker greet a person with different answers based on `age`. Figure 2-5 shows the flowchart for this.



Start
name == 'Alice'
True
print('Hi, Alice.')
False
age < 12
True
print('You are not Alice, kiddo.')
False
age > 2000
True
print('Unlike you, Alice is not an undead, immortal vampire.')
False
age > 100
True
print('You are not Alice, grannie.')
False
End

Figure 2-5: The flowchart for multiple `elif` statements in the vampire.py *program*

The order of the `elif` statements does matter, however. Let's rearrange them to introduce a bug. Remember that the rest of the `elif` clauses are automatically skipped once a `True` condition has been found, so if you swap around some of the clauses in *vampire.py*, you run into a problem. Change the code to look like the following, and save it as *vampire2.py*:

```
  name = 'Carol'
  age = 3000
  if name == 'Alice':
      print('Hi, Alice.')
  elif age < 12:
      print('You are not Alice, kiddo.')
❶ elif age > 100:
      print('You are not Alice, grannie.')
  elif age > 2000:
      print('Unlike you, Alice is not an undead, immortal vampire.')
```

You can view the execution of this program at *https://autbor.com/vampire2/*. Say the `age` variable contains the value `3000` before this code is executed. You might expect the code to print the string `'Unlike you, Alice is not an undead, immortal vampire.'`. However, because the `age > 100` condition is `True` (after all, 3,000 *is* greater than 100) ❶, the string `'You are not Alice, grannie.'` is printed, and the rest of the `elif` statements are automatically skipped. Remember that at most only one of the clauses will be executed, and for `elif` statements, the order matters!

Figure 2-6 shows the flowchart for the previous code. Notice how the diamonds for `age > 100` and `age > 2000` are swapped.

Optionally, you can have an `else` statement after the last `elif` statement. In that case, it *is* guaranteed that at least one (and only one) of the clauses will be executed. If the conditions in every `if` and `elif` statement are `False`, then the `else` clause is executed. For example, let's re-create the Alice program to use `if`, `elif`, and `else` clauses.

```
name = 'Carol'
age = 3000
if name == 'Alice':
    print('Hi, Alice.')
elif age < 12:
    print('You are not Alice, kiddo.')
else:
    print('You are neither Alice nor a little kid.')
```

You can view the execution of this program at *https://autbor.com/littlekid/*. Figure 2-7 shows the flowchart for this new code, which we'll save as *littleKid.py*.

In plain English, this type of flow control structure would be "If the first condition is true, do this. Else, if the second condition is true, do that. Otherwise, do something else." When you use `if`, `elif`, and `else` statements together, remember these rules about how to order them to avoid bugs like the one in Figure 2-6. First, there is always exactly one `if` statement. Any elif statements you need should follow the if statement. Second, if you want to be sure that at least one clause is executed, close the structure with an else statement.

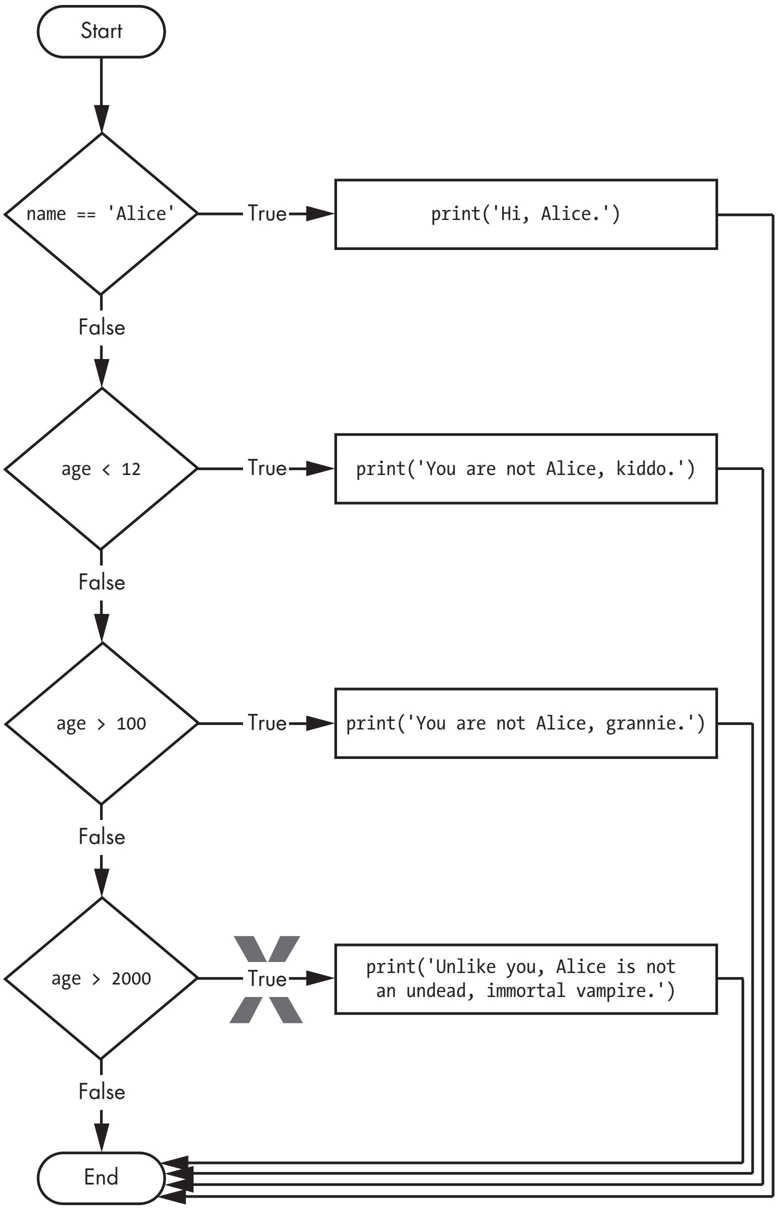

Start
name == 'Alice'
True
print('Hi, Alice.')
False
age < 12
True
print('You are not Alice, kiddo.')
False
age > 100
True
print('You are not Alice, grannie.')
False
age > 2000
True
print('Unlike you, Alice is not an undead, immortal vampire.')
False
End

Figure 2-6: The flowchart for the vampire2.py *program. The X path will logically never happen, because if* age *were greater than* 2000*, it would have already been greater than* 100*.*

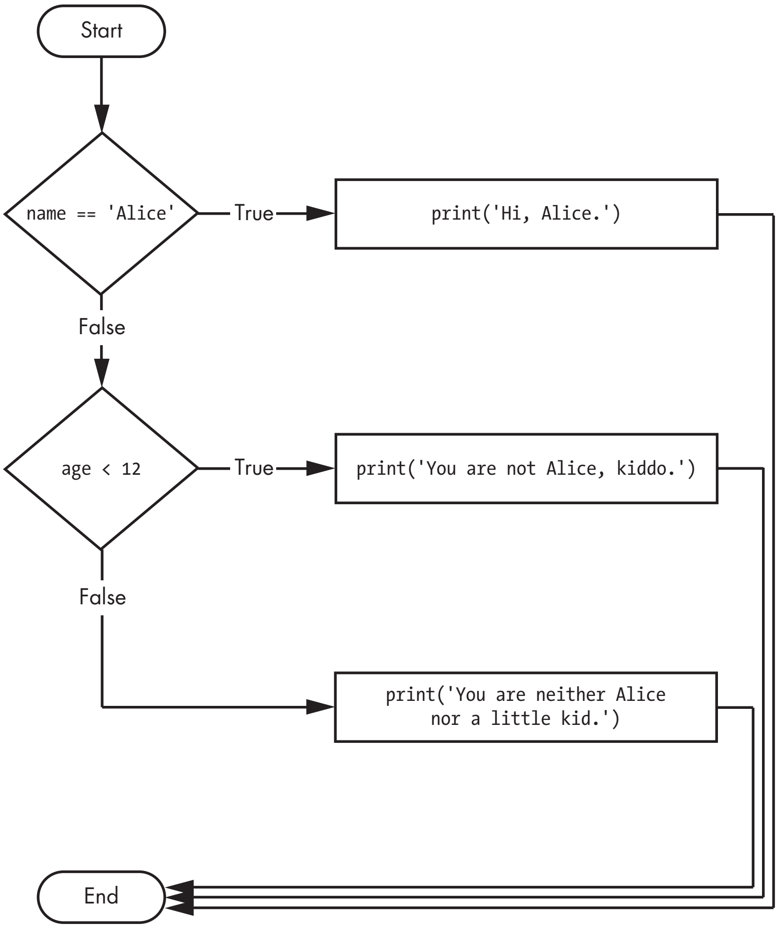

Start
name == 'Alice'
True
print('Hi, Alice.')
False
age < 12
True
print('You are not Alice, kiddo.')
False
print('You are neither Alice nor a little kid.')
End

Figure 2-7: Flowchart for the previous littleKid.py *program*

while Loop Statements

You can make a block of code execute over and over again using a `while` statement. The code in a `while` clause will be executed as long as the `while` statement's condition is `True`. In code, a `while` statement always consists of the following:

- The `while` keyword
- A condition (that is, an expression that evaluates to `True` or `False`)
- A colon
- Starting on the next line, an indented block of code (called the `while` clause)

You can see that a while statement looks similar to an if statement. The difference is in how they behave. At the end of an if clause, the program execution continues after the if statement. But at the end of a while clause, the program execution jumps back to the start of the while statement. The while clause is often called the *while loop* or just the *loop*.

Let's look at an if statement and a while loop that use the same condition and take the same actions based on that condition. Here is the code with an if statement:

```
spam = 0
if spam < 5:
    print('Hello, world.')
    spam = spam + 1
```

Here is the code with a while statement:

```
spam = 0
while spam < 5:
    print('Hello, world.')
    spam = spam + 1
```

These statements are similar—both if and while check the value of spam, and if it's less than 5, they print a message. But when you run these two code snippets, something very different happens for each one. For the if statement, the output is simply "Hello, world.". But for the while statement, it's "Hello, world." repeated five times! Take a look at the flowcharts for these two pieces of code, Figures 2-8 and 2-9, to see why this happens.

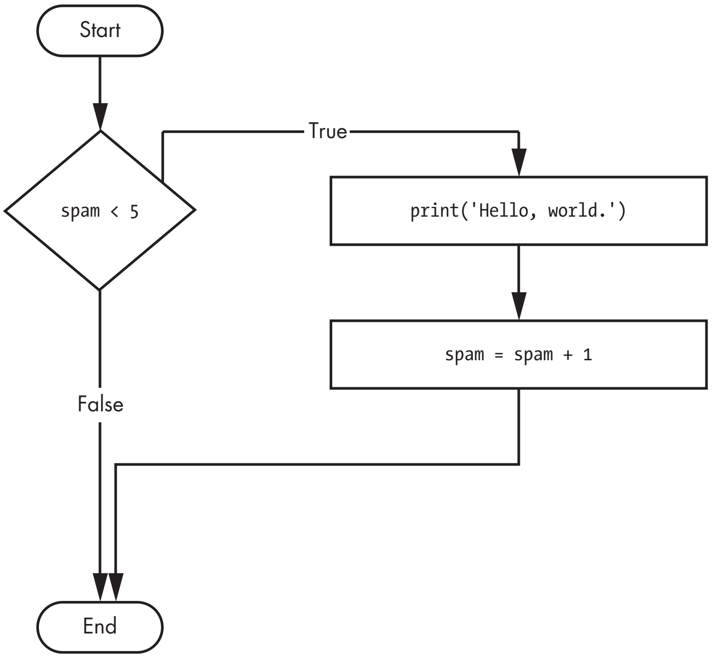


Figure 2-8: The flowchart for the if statement code

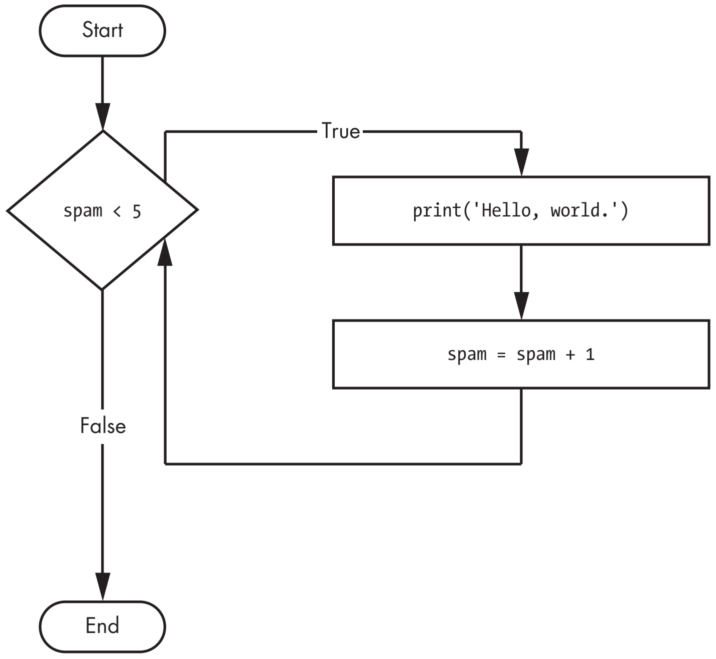


Figure 2-9: The flowchart for the `while` statement code

The code with the `if` statement checks the condition, and it prints `Hello, world.` only once if that condition is true. The code with the `while` loop, on the other hand, will print it five times. The loop stops after five prints because the integer in `spam` increases by one at the end of each loop iteration, which means that the loop will execute five times before `spam < 5` is `False`.

In the `while` loop, the condition is always checked at the start of each *iteration* (that is, each time the loop is executed). If the condition is `True`, then the clause is executed, and afterward, the condition is checked again. The first time the condition is found to be `False`, the `while` clause is skipped.

An Annoying while Loop

Here's a small example program that will keep asking you to type, literally, `your name`. Select **File ▸ New** to open a new file editor window, enter the following code, and save the file as *yourName.py*:

```
❶ name = ''
❷ while name != 'your name':
      print('Please type your name.')
    ❸ name = input()
❹ print('Thank you!')
```

You can view the execution of this program at *https://autbor.com/yourname/*. First, the program sets the `name` variable ❶ to an empty string. This is so that the `name != 'your name'` condition will evaluate to `True` and the program execution will enter the `while` loop's clause ❷.

The code inside this clause asks the user to type their name, which is assigned to the `name` variable ❸. Since this is the last line of the block, the execution moves back to the start of the `while` loop and reevaluates the condition. If the value in `name` is *not equal* to the string `'your name'`, then the condition is `True`, and the execution enters the `while` clause again.

But once the user types `your name`, the condition of the `while` loop will be `'your name' != 'your name'`, which evaluates to `False`. The condition is now `False`, and instead of the program execution reentering the `while` loop's clause, Python skips past it and continues running the rest of the program ❹. Figure 2-10 shows a flowchart for the *yourName.py* program.

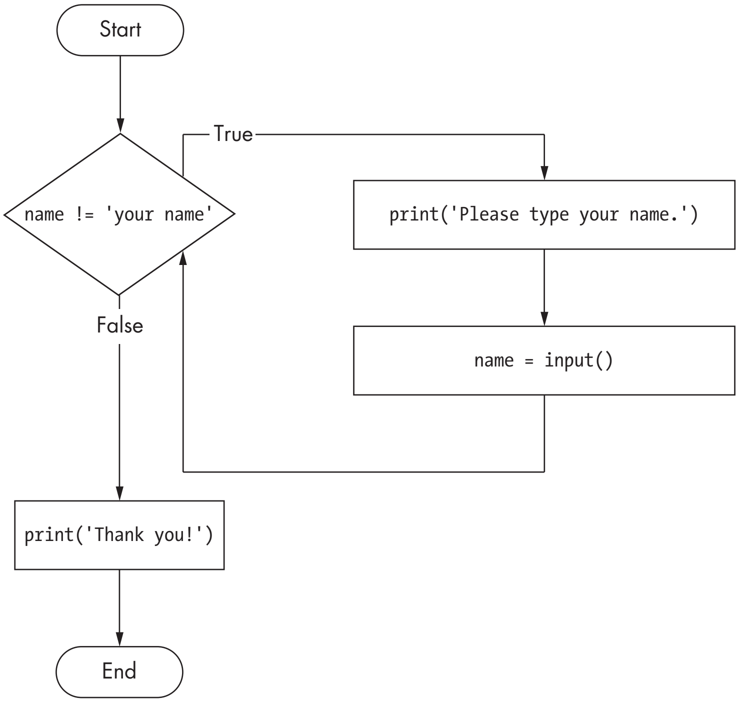


Figure 2-10: A flowchart of the yourName.py *program*

Now, let's see *yourName.py* in action. Press **F5** to run it, and enter something other than `your name` a few times before you give the program what it wants.

```
Please type your name.
Al
Please type your name.
Albert
Please type your name.
%#@#%*(^&!!!
Please type your name.
your name
Thank you!
```

If you never enter `your name`, then the `while` loop's condition will never be `False`, and the program will just keep asking forever. Here, the `input()` call lets the user enter the right string to make the program move on. In other programs, the condition might never actually change, and that can be a problem. Let's look at how you can break out of a `while` loop.

break Statements

There is a shortcut to getting the program execution to break out of a `while` loop's clause early. If the execution reaches a `break` statement, it immediately exits the `while` loop's clause. In code, a `break` statement simply contains the `break` keyword.

Pretty simple, right? Here's a program that does the same thing as the previous program, but it uses a `break` statement to escape the loop. Enter the following code, and save the file as *yourName2.py*:

```
❶ while True:
      print('Please type your name.')
    ❷ name = input()
    ❸ if name == 'your name':
        ❹ break
❺ print('Thank you!')
```

You can view the execution of this program at *https://autbor.com/yourname2/*. The first line ❶ creates an *infinite loop*; it is a `while` loop whose condition is always `True`. (The expression `True`, after all, always evaluates down to the value `True`.) After the program execution enters this loop, it will exit the loop only when a `break` statement is executed. (An infinite loop that *never* exits is a common programming bug.)

Just like before, this program asks the user to enter `your name` ❷. Now, however, while the execution is still inside the `while` loop, an `if` statement checks ❸ whether `name` is equal to `'your name'`. If this condition is `True`, the `break` statement is run ❹, and the execution moves out of the loop to `print('Thank you!')` ❺. Otherwise, the `if` statement's clause that contains the `break` statement is skipped, which puts the execution at the end of the `while` loop. At this point, the program execution jumps back to the start of the `while` statement ❶ to recheck the condition. Since this condition is merely the `True` Boolean value, the execution enters the loop to ask the user to type `your name` again. See Figure 2-11 for this program's flowchart.

Run *yourName2.py*, and enter the same text you entered for *yourName.py*. The rewritten program should respond in the same way as the original.

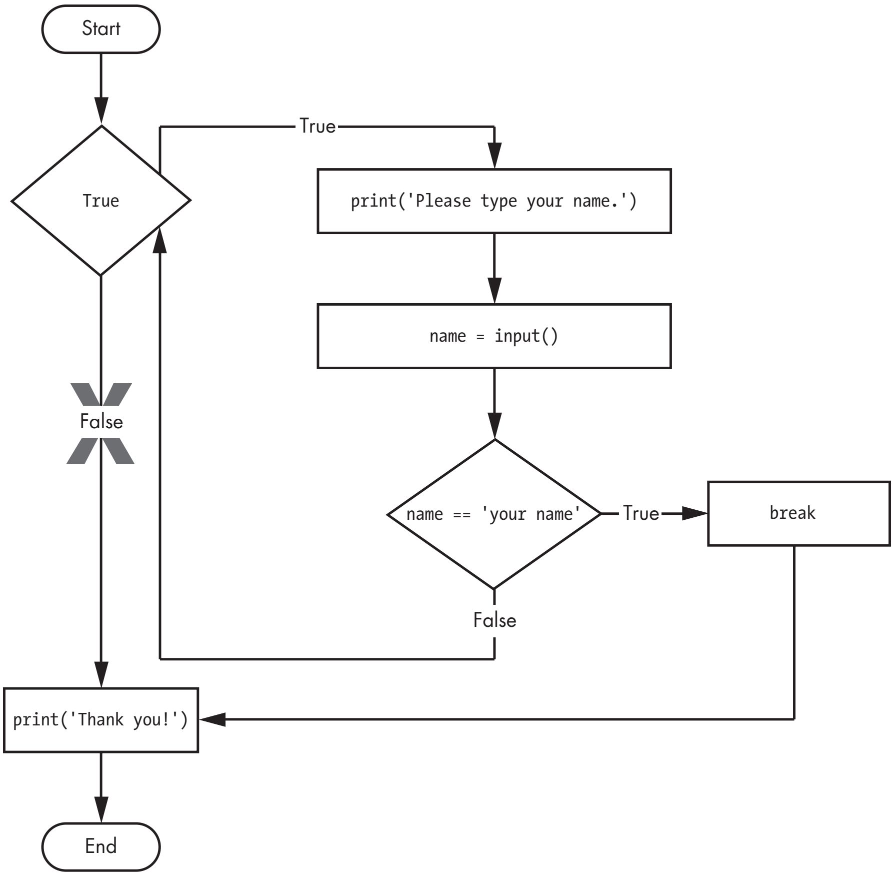


Figure 2-11: The flowchart for the yourName2.py *program with an infinite loop. Note that the X path will logically never happen, because the loop condition is always* `True`*.*

continue Statements

Like `break` statements, `continue` statements are used inside loops. When the program execution reaches a `continue` statement, the program execution immediately jumps back to the start of the loop and reevaluates the loop's condition. (This is also what happens when the execution reaches the end of the loop.)

Let's use `continue` to write a program that asks for a name and password. Enter the following code into a new file editor window and save the program as *swordfish.py*.

TRAPPED IN AN INFINITE LOOP?

If you ever run a program that has a bug causing it to get stuck in an infinite loop, press CTRL-C or select **Shell ▸ Restart Shell** from IDLE's menu. This will send a `KeyboardInterrupt` error to your program and cause it to stop immediately. Try stopping a program by creating a simple infinite loop in the file editor, and save the program as *infiniteLoop.py*.

```
while True:
    print('Hello, world!')
```

When you run this program, it will print `Hello, world!` to the screen forever because the `while` statement's condition is always `True`. CTRL-C is also handy if you want to simply terminate your program immediately, even if it's not stuck in an infinite loop.

```
  while True:
      print('Who are you?')
      name = input()
   ❶ if name != 'Joe':
        ❷ continue
      print('Hello, Joe. What is the password? (It is a fish.)')
   ❸ password = input()
      if password == 'swordfish':
        ❹ break
❺ print('Access granted.')
```

If the user enters any name besides `Joe` ❶, the `continue` statement ❷ causes the program execution to jump back to the start of the loop. When the program reevaluates the condition, the execution will always enter the loop, since the condition is simply the value `True`. Once the user makes it past that `if` statement, they are asked for a password ❸. If the password entered is `swordfish`, then the `break` statement ❹ is run, and the execution jumps out of the `while` loop to print `Access granted` ❺. Otherwise, the execution continues to the end of the `while` loop, where it then jumps back to the start of the loop. See Figure 2-12 for this program's flowchart.

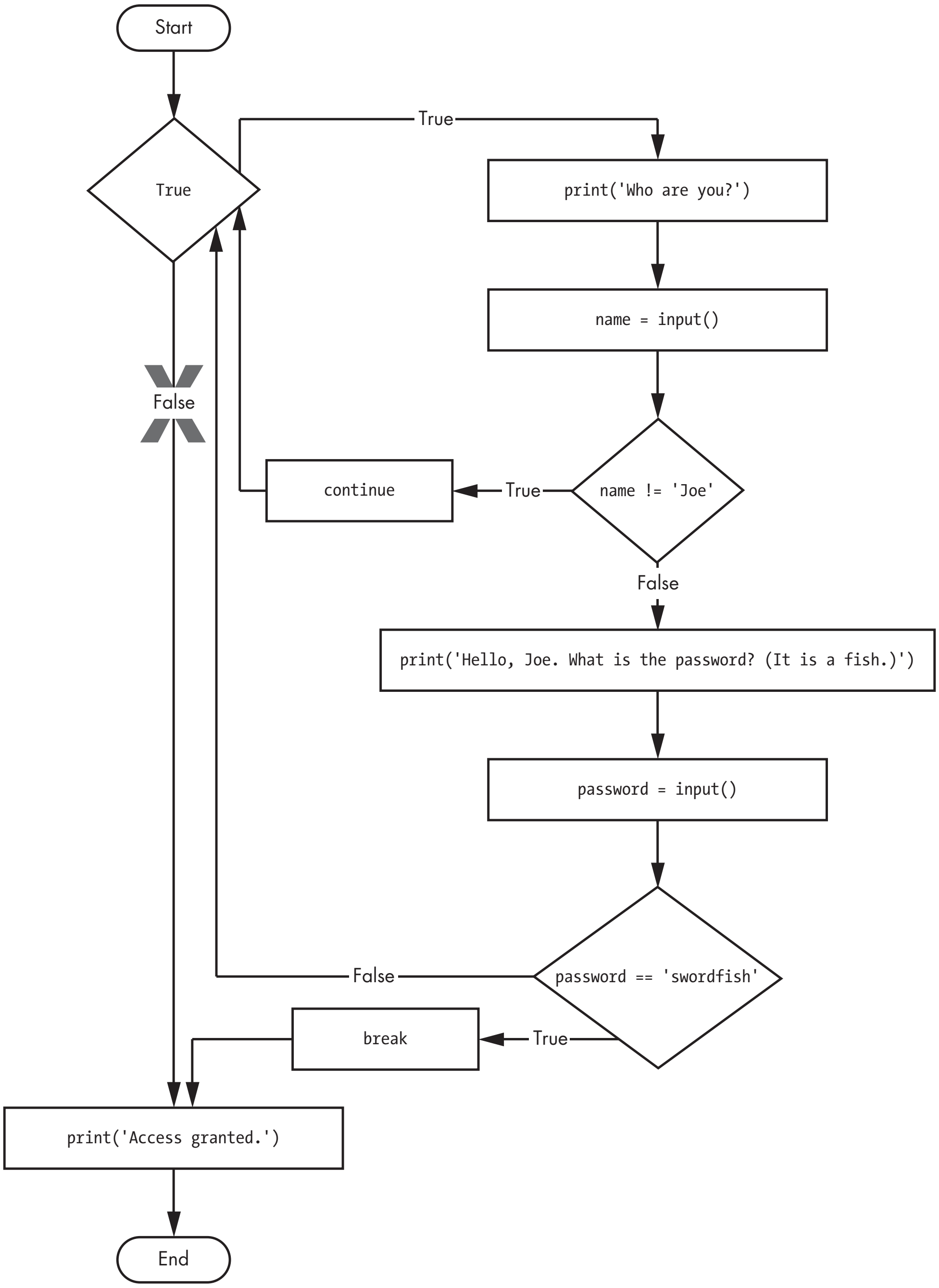


Figure 2-12: A flowchart for swordfish.py*. The X path will logically never happen, because the loop condition is always* `True`*.*

"TRUTHY" AND "FALSEY" VALUES

Conditions will consider some values in other data types equivalent to True and False. When used in conditions, 0, 0.0, and '' (the empty string) are considered False, while all other values are considered True. For example, look at the following program:

```
name = ''
❶ while not name:
    print('Enter your name:')
    name = input()
print('How many guests will you have?')
numOfGuests = int(input())
❷ if numOfGuests:
    ❸ print('Be sure to have enough room for all your guests.')
print('Done')
```

You can view the execution of this program at *https://autbor.com/howmanyguests/*. If the user enters a blank string for name, then the while statement's condition will be True ❶, and the program continues to ask for a name. If the value for numOfGuests is not 0 ❷, then the condition is considered to be True, and the program will print a reminder for the user ❸.

You could have entered not name != '' instead of not name, and numOfGuests != 0 instead of numOfGuests, but using the truthy and falsey values can make your code easier to read.

Run this program and give it some input. Until you claim to be Joe, the program shouldn't ask for a password, and once you enter the correct password, it should exit.

```
Who are you?
I'm fine, thanks. Who are you?
Who are you?
Joe
Hello, Joe. What is the password? (It is a fish.)
Mary
Who are you?
Joe
Hello, Joe. What is the password? (It is a fish.)
swordfish
Access granted.
```

You can view the execution of this program at *https://autbor.com/hellojoe/*.

for Loops and the range() Function

The `while` loop keeps looping while its condition is `True` (which is the reason for its name), but what if you want to execute a block of code only a certain number of times? You can do this with a `for` loop statement and the `range()` function.

In code, a `for` statement looks something like `for i in range(5):` and includes the following:

- The `for` keyword
- A variable name
- The `in` keyword
- A call to the `range()` method with up to three integers passed to it
- A colon
- Starting on the next line, an indented block of code (called the `for` clause)

Let's create a new program called *fiveTimes.py* to help you see a `for` loop in action.

```
print('My name is')
for i in range(5):
    print('Jimmy Five Times (' + str(i) + ')')
```

You can view the execution of this program at *https://autbor.com/fivetimesfor/*. The code in the `for` loop's clause is run five times. The first time it is run, the variable `i` is set to `0`. The `print()` call in the clause will print `Jimmy Five Times (0)`. After Python finishes an iteration through all the code inside the `for` loop's clause, the execution goes back to the top of the loop, and the `for` statement increments `i` by one. This is why `range(5)` results in five iterations through the clause, with `i` being set to `0`, then `1`, then `2`, then `3`, and then `4`. The variable `i` will go up to, but will not include, the integer passed to `range()`. Figure 2-13 shows a flowchart for the *fiveTimes.py* program.

When you run this program, it should print `Jimmy Five Times` followed by the value of `i` five times before leaving the `for` loop.

```
My name is
Jimmy Five Times (0)
Jimmy Five Times (1)
Jimmy Five Times (2)
Jimmy Five Times (3)
Jimmy Five Times (4)
```

NOTE *You can use `break` and `continue` statements inside `for` loops as well. The `continue` statement will continue to the next value of the `for` loop's counter, as if the program execution had reached the end of the loop and returned to the start. In fact, you can use `continue` and `break` statements only inside `while` and `for` loops. If you try to use these statements elsewhere, Python will give you an error.*

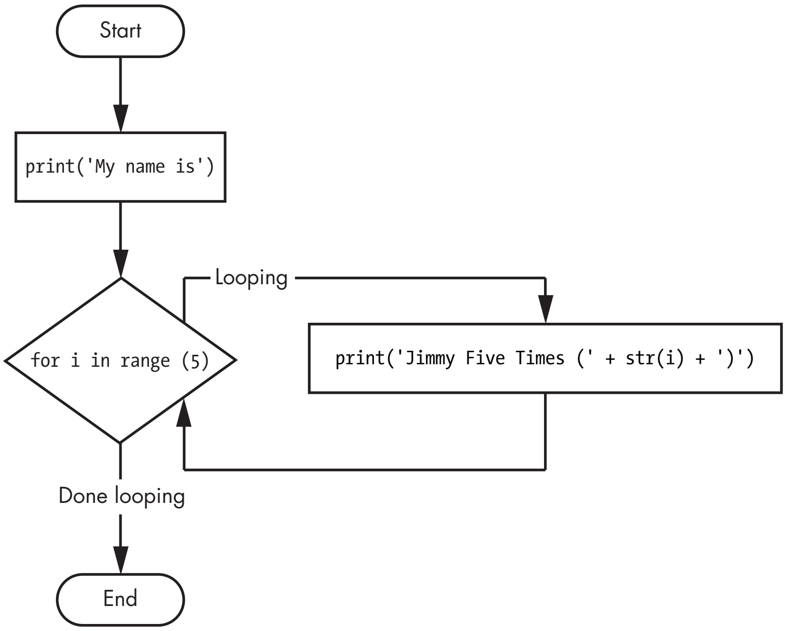


Figure 2-13: The flowchart for fiveTimes.py

As another `for` loop example, consider this story about the mathematician Carl Friedrich Gauss. When Gauss was a boy, a teacher wanted to give the class some busywork. The teacher told them to add up all the numbers from 0 to 100. Young Gauss came up with a clever trick to figure out the answer in a few seconds, but you can write a Python program with a `for` loop to do this calculation for you.

```
❶ total = 0
❷ for num in range(101):
    ❸ total = total + num
❹ print(total)
```

The result should be 5,050. When the program first starts, the `total` variable is set to `0` ❶. The `for` loop ❷ then executes `total = total + num` ❸ 100 times. By the time the loop has finished all of its 100 iterations, every integer from `0` to `100` will have been added to `total`. At this point, `total` is printed to the screen ❹. Even on the slowest computers, this program takes less than a second to complete.

(Young Gauss figured out a way to solve the problem in seconds. There are 50 pairs of numbers that add up to 101: 1 + 100, 2 + 99, 3 + 98, and so on, until 50 + 51. Since 50 × 101 is 5,050, the sum of all the numbers from 0 to 100 is 5,050. Clever kid!)

An Equivalent while Loop

You can actually use a `while` loop to do the same thing as a `for` loop; `for` loops are just more concise. Let's rewrite *fiveTimes.py* to use a `while` loop equivalent of a `for` loop.

```
print('My name is')
i = 0
while i < 5:
    print('Jimmy Five Times (' + str(i) + ')')
    i = i + 1
```

You can view the execution of this program at *https://autbor.com/fivetimeswhile/*. If you run this program, the output should look the same as the *fiveTimes.py* program, which uses a `for` loop.

The Starting, Stopping, and Stepping Arguments to range()

Some functions can be called with multiple arguments separated by a comma, and `range()` is one of them. This lets you change the integer passed to `range()` to follow any sequence of integers, including starting at a number other than zero.

```
for i in range(12, 16):
    print(i)
```

The first argument will be where the `for` loop's variable starts, and the second argument will be up to, but not including, the number to stop at.

```
12
13
14
15
```

The `range()` function can also be called with three arguments. The first two arguments will be the start and stop values, and the third will be the *step argument*. The step is the amount that the variable is increased by after each iteration.

```
for i in range(0, 10, 2):
    print(i)
```

So calling `range(0, 10, 2)` will count from zero to eight by intervals of two.

```
0
2
4
6
8
```

The `range()` function is flexible in the sequence of numbers it produces for `for` loops. *For* example (I never apologize for my puns), you can even use a negative number for the step argument to make the `for` loop count down instead of up.

```
for i in range(5, -1, -1):
    print(i)
```

This `for` loop would have the following output:

```
5
4
3
2
1
0
```

Running a `for` loop to print `i` with `range(5, -1, -1)` should print from five down to zero.

Importing Modules

All Python programs can call a basic set of functions called *built-in functions*, including the `print()`, `input()`, and `len()` functions you've seen before. Python also comes with a set of modules called the *standard library*. Each module is a Python program that contains a related group of functions that can be embedded in your programs. For example, the `math` module has mathematics-related functions, the `random` module has random number-related functions, and so on.

Before you can use the functions in a module, you must import the module with an `import` statement. In code, an `import` statement consists of the following:

- The `import` keyword
- The name of the module
- Optionally, more module names, as long as they are separated by commas

Once you import a module, you can use all the cool functions of that module. Let's give it a try with the `random` module, which will give us access to the `random.randint()` function.

Enter this code into the file editor, and save it as *printRandom.py*:

```
import random
for i in range(5):
    print(random.randint(1, 10))
```

DON'T OVERWRITE MODULE NAMES

When you save your Python scripts, take care not to give them a name that is used by one of Python's modules, such as *random.py*, *sys.py*, *os.py*, or *math.py*. If you accidentally name one of your programs, say, *random.py*, and use an `import random` statement in another program, your program would import your *random.py* file instead of Python's `random` module. This can lead to errors such as `AttributeError: module 'random' has no attribute 'randint'`, since your *random.py* doesn't have the functions that the real `random` module has. Don't use the names of any built-in Python functions either, such as `print()` or `input()`.

Problems like these are uncommon, but can be tricky to solve. As you gain more programming experience, you'll become more aware of the standard names used by Python's modules and functions, and will run into these problems less frequently.

When you run this program, the output will look something like this:

```
4
1
8
4
1
```

You can view the execution of this program at *https://autbor.com/printrandom/*. The `random.randint()` function call evaluates to a random integer value between the two integers that you pass it. Since `randint()` is in the `random` module, you must first type **`random.`** in front of the function name to tell Python to look for this function inside the `random` module.

Here's an example of an `import` statement that imports four different modules:

```
import random, sys, os, math
```

Now we can use any of the functions in these four modules. We'll learn more about them later in the book.

from import Statements

An alternative form of the `import` statement is composed of the `from` keyword, followed by the module name, the `import` keyword, and a star; for example, `from random import *`.

With this form of `import` statement, calls to functions in `random` will not need the `random.` prefix. However, using the full name makes for more readable code, so it is better to use the `import random` form of the statement.

Ending a Program Early with the sys.exit() Function

The last flow control concept to cover is how to terminate the program. Programs always terminate if the program execution reaches the bottom of the instructions. However, you can cause the program to terminate, or exit, before the last instruction by calling the `sys.exit()` function. Since this function is in the `sys` module, you have to import `sys` before your program can use it.

Open a file editor window and enter the following code, saving it as *exitExample.py*:

```
import sys

while True:
    print('Type exit to exit.')
    response = input()
    if response == 'exit':
        sys.exit()
    print('You typed ' + response + '.')
```

Run this program in IDLE. This program has an infinite loop with no `break` statement inside. The only way this program will end is if the execution reaches the `sys.exit()` call. When `response` is equal to `exit`, the line containing the `sys.exit()` call is executed. Since the `response` variable is set by the `input()` function, the user must enter `exit` in order to stop the program.

A Short Program: Guess the Number

The examples I've shown you so far are useful for introducing basic concepts, but now let's see how everything you've learned comes together in a more complete program. In this section, I'll show you a simple "guess the number" game. When you run this program, the output will look something like this:

```
I am thinking of a number between 1 and 20.
Take a guess.
10
Your guess is too low.
Take a guess.
15
Your guess is too low.
Take a guess.
17
Your guess is too high.
Take a guess.
16
Good job! You guessed my number in 4 guesses!
```

Enter the following source code into the file editor, and save the file as *guessTheNumber.py*:

```
# This is a guess the number game.
import random
secretNumber = random.randint(1, 20)
print('I am thinking of a number between 1 and 20.')

# Ask the player to guess 6 times.
for guessesTaken in range(1, 7):
    print('Take a guess.')
    guess = int(input())

    if guess < secretNumber:
        print('Your guess is too low.')
    elif guess > secretNumber:
        print('Your guess is too high.')
    else:
        break    # This condition is the correct guess!

if guess == secretNumber:
    print('Good job! You guessed my number in ' + str(guessesTaken) + '
guesses!')
else:
    print('Nope. The number I was thinking of was ' + str(secretNumber))
```

You can view the execution of this program at *https://autbor.com/guessthenumber/*. Let's look at this code line by line, starting at the top.

```
# This is a guess the number game.
import random
secretNumber = random.randint(1, 20)
```

First, a comment at the top of the code explains what the program does. Then, the program imports the `random` module so that it can use the `random.randint()` function to generate a number for the user to guess. The return value, a random integer between 1 and 20, is stored in the variable `secretNumber`.

```
print('I am thinking of a number between 1 and 20.')

# Ask the player to guess 6 times.
for guessesTaken in range(1, 7):
    print('Take a guess.')
    guess = int(input())
```

The program tells the player that it has come up with a secret number and will give the player six chances to guess it. The code that lets the player enter a guess and checks that guess is in a `for` loop that will loop at most six times. The first thing that happens in the loop is that the player types in a guess. Since `input()` returns a string, its return value is passed straight into int(), which translates the string into an integer value. This gets stored in a variable named guess.

```
    if guess < secretNumber:
        print('Your guess is too low.')
    elif guess > secretNumber:
        print('Your guess is too high.')
```

These few lines of code check to see whether the guess is less than or greater than the secret number. In either case, a hint is printed to the screen.

```
    else:
        break    # This condition is the correct guess!
```

If the guess is neither higher nor lower than the secret number, then it must be equal to the secret number—in which case, you want the program execution to break out of the for loop.

```
if guess == secretNumber:
    print('Good job! You guessed my number in ' + str(guessesTaken) + ' guesses!')
else:
    print('Nope. The number I was thinking of was ' + str(secretNumber))
```

After the for loop, the previous if...else statement checks whether the player has correctly guessed the number and then prints an appropriate message to the screen. In both cases, the program displays a variable that contains an integer value (guessesTaken and secretNumber). Since it must concatenate these integer values to strings, it passes these variables to the str() function, which returns the string value form of these integers. Now these strings can be concatenated with the + operators before finally being passed to the print() function call.

A Short Program: Rock, Paper, Scissors

Let's use the programming concepts we've learned so far to create a simple rock, paper, scissors game. The output will look like this:

```
ROCK, PAPER, SCISSORS
0 Wins, 0 Losses, 0 Ties
Enter your move: (r)ock (p)aper (s)cissors or (q)uit
p
PAPER versus...
PAPER
It is a tie!
0 Wins, 1 Losses, 1 Ties
Enter your move: (r)ock (p)aper (s)cissors or (q)uit
s
SCISSORS versus...
PAPER
You win!
```

```
1 Wins, 1 Losses, 1 Ties
Enter your move: (r)ock (p)aper (s)cissors or (q)uit
q
```

Type the following source code into the file editor, and save the file as *rpsGame.py*:

```
import random, sys

print('ROCK, PAPER, SCISSORS')

# These variables keep track of the number of wins, losses, and ties.
wins = 0
losses = 0
ties = 0

while True: # The main game loop.
    print('%s Wins, %s Losses, %s Ties' % (wins, losses, ties))
    while True: # The player input loop.
        print('Enter your move: (r)ock (p)aper (s)cissors or (q)uit')
        playerMove = input()
        if playerMove == 'q':
            sys.exit() # Quit the program.
        if playerMove == 'r' or playerMove == 'p' or playerMove == 's':
            break # Break out of the player input loop.
        print('Type one of r, p, s, or q.')

    # Display what the player chose:
    if playerMove == 'r':
        print('ROCK versus...')
    elif playerMove == 'p':
        print('PAPER versus...')
    elif playerMove == 's':
        print('SCISSORS versus...')

    # Display what the computer chose:
    randomNumber = random.randint(1, 3)
    if randomNumber == 1:
        computerMove = 'r'
        print('ROCK')
    elif randomNumber == 2:
        computerMove = 'p'
        print('PAPER')
    elif randomNumber == 3:
        computerMove = 's'
        print('SCISSORS')

    # Display and record the win/loss/tie:
    if playerMove == computerMove:
        print('It is a tie!')
        ties = ties + 1
    elif playerMove == 'r' and computerMove == 's':
        print('You win!')
        wins = wins + 1
    elif playerMove == 'p' and computerMove == 'r':
        print('You win!')
        wins = wins + 1
    elif playerMove == 's' and computerMove == 'p':
        print('You win!')
        wins = wins + 1
    elif playerMove == 'r' and computerMove == 'p':
        print('You lose!')
        losses = losses + 1
    elif playerMove == 'p' and computerMove == 's':
        print('You lose!')
        losses = losses + 1
    elif playerMove == 's' and computerMove == 'r':
        print('You lose!')
        losses = losses + 1
```

Let's look at this code line by line, starting at the top.

```
import random, sys

print('ROCK, PAPER, SCISSORS')

# These variables keep track of the number of wins, losses, and ties.
wins = 0
losses = 0
ties = 0
```

First, we import the random and sys module so that our program can call the random.randint() and sys.exit() functions. We also set up three variables to keep track of how many wins, losses, and ties the player has had.

```
while True: # The main game loop.
    print('%s Wins, %s Losses, %s Ties' % (wins, losses, ties))
    while True: # The player input loop.
        print('Enter your move: (r)ock (p)aper (s)cissors or (q)uit')
        playerMove = input()
        if playerMove == 'q':
            sys.exit() # Quit the program.
        if playerMove == 'r' or playerMove == 'p' or playerMove == 's':
            break # Break out of the player input loop.
        print('Type one of r, p, s, or q.')
```

This program uses a while loop inside of another while loop. The first loop is the main game loop, and a single game of rock, paper, scissors is player on each iteration through this loop. The second loop asks for input from the player, and keeps looping until the player has entered an r, p, s, or q for their move. The r, p, and s correspond to rock, paper, and scissors, respectively, while the q means the player intends to quit. In that case, sys.exit() is called and the program exits. If the player has entered r, p, or s, the execution breaks out of the loop. Otherwise, the program reminds the player to enter r, p, s, or q and goes back to the start of the loop.

```
    # Display what the player chose:
    if playerMove == 'r':
        print('ROCK versus...')
    elif playerMove == 'p':
        print('PAPER versus...')
    elif playerMove == 's':
        print('SCISSORS versus...')
```

The player's move is displayed on the screen.

```
    # Display what the computer chose:
    randomNumber = random.randint(1, 3)
    if randomNumber == 1:
        computerMove = 'r'
        print('ROCK')
    elif randomNumber == 2:
        computerMove = 'p'
        print('PAPER')
    elif randomNumber == 3:
        computerMove = 's'
        print('SCISSORS')
```

Next, the computer's move is randomly selected. Since `random.randint()` can only return a random number, the `1`, `2`, or `3` integer value it returns is stored in a variable named `randomNumber`. The program stores a `'r'`, `'p'`, or `'s'` string in `computerMove` based on the integer in `randomNumber`, as well as displays the computer's move.

```
    # Display and record the win/loss/tie:
    if playerMove == computerMove:
        print('It is a tie!')
        ties = ties + 1
    elif playerMove == 'r' and computerMove == 's':
        print('You win!')
        wins = wins + 1
    elif playerMove == 'p' and computerMove == 'r':
        print('You win!')
        wins = wins + 1
    elif playerMove == 's' and computerMove == 'p':
        print('You win!')
        wins = wins + 1
    elif playerMove == 'r' and computerMove == 'p':
        print('You lose!')
        losses = losses + 1
    elif playerMove == 'p' and computerMove == 's':
        print('You lose!')
        losses = losses + 1
    elif playerMove == 's' and computerMove == 'r':
        print('You lose!')
        losses = losses + 1
```

Finally, the program compares the strings in playerMove and computerMove, and displays the results on the screen. It also increments the wins, losses, or ties variable appropriately. Once the execution reaches the end, it jumps back to the start of the main program loop to begin another game.

Summary

By using expressions that evaluate to True or False (also called conditions), you can write programs that make decisions on what code to execute and what code to skip. You can also execute code over and over again in a loop while a certain condition evaluates to True. The break and continue statements are useful if you need to exit a loop or jump back to the loop's start.

These flow control statements will let you write more intelligent programs. You can also use another type of flow control by writing your own functions, which is the topic of the next chapter.

Practice Questions

1. What are the two values of the Boolean data type? How do you write them?
2. What are the three Boolean operators?
3. Write out the truth tables of each Boolean operator (that is, every possible combination of Boolean values for the operator and what they evaluate to).
4. What do the following expressions evaluate to?

```
(5 > 4) and (3 == 5)
not (5 > 4)
(5 > 4) or (3 == 5)
not ((5 > 4) or (3 == 5))
(True and True) and (True == False)
(not False) or (not True)
```

5. What are the six comparison operators?
6. What is the difference between the equal to operator and the assignment operator?
7. Explain what a condition is and where you would use one.
8. Identify the three blocks in this code:

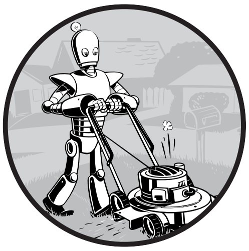
```
spam = 0
if spam == 10:
    print('eggs')
    if spam > 5:
        print('bacon')
    else:
        print('ham')
    print('spam')
print('spam')
```

9. Write code that prints `Hello` if `1` is stored in `spam`, prints `Howdy` if `2` is stored in `spam`, and prints `Greetings!` if anything else is stored in `spam`.
10. What keys can you press if your program is stuck in an infinite loop?
11. What is the difference between `break` and `continue`?
12. What is the difference between `range(10)`, `range(0, 10)`, and `range(0, 10, 1)` in a `for` loop?
13. Write a short program that prints the numbers `1` to `10` using a `for` loop. Then write an equivalent program that prints the numbers `1` to `10` using a `while` loop.
14. If you had a function named `bacon()` inside a module named `spam`, how would you call it after importing `spam`?

Extra credit: Look up the `round()` and `abs()` functions on the internet, and find out what they do. Experiment with them in the interactive shell.

3

FUNCTIONS



You're already familiar with the `print()`, `input()`, and `len()` functions from the previous chapters. Python provides several built-in functions like these, but you can also write your own functions. A *function* is like a miniprogram within a program.

To better understand how functions work, let's create one. Enter this program into the file editor and save it as *helloFunc.py*:

```
❶ def hello():
    ❷ print('Howdy!')
      print('Howdy!!!')
      print('Hello there.')

❸ hello()
  hello()
  hello()
```

You can view the execution of this program at *https://autbor.com/hellofunc/*. The first line is a `def` statement ❶, which defines a function named `hello()`. The code in the block that follows the `def` statement ❷ is the body of the function. This code is executed when the function is called, not when the function is first defined.

The `hello()` lines after the function ❸ are function calls. In code, a function call is just the function's name followed by parentheses, possibly with some number of arguments in between the parentheses. When the program execution reaches these calls, it will jump to the top line in the function and begin executing the code there. When it reaches the end of the function, the execution returns to the line that called the function and continues moving through the code as before.

Since this program calls `hello()` three times, the code in the `hello()` function is executed three times. When you run this program, the output looks like this:

```
Howdy!
Howdy!!!
Hello there.
Howdy!
Howdy!!!
Hello there.
Howdy!
Howdy!!!
Hello there.
```

A major purpose of functions is to group code that gets executed multiple times. Without a function defined, you would have to copy and paste this code each time, and the program would look like this:

```
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
```

In general, you always want to avoid duplicating code because if you ever decide to update the code—if, for example, you find a bug you need to fix—you'll have to remember to change the code everywhere you copied it.

As you get more programming experience, you'll often find yourself *deduplicating* code, which means getting rid of duplicated or copy-and-pasted code. Deduplication makes your programs shorter, easier to read, and easier to update.

def Statements with Parameters

When you call the `print()` or `len()` function, you pass them values, called *arguments*, by typing them between the parentheses. You can also define your own functions that accept arguments. Type this example into the file editor and save it as *helloFunc2.py*:

```
❶ def hello(name):
    ❷ print('Hello, ' + name)

❸ hello('Alice')
  hello('Bob')
```

When you run this program, the output looks like this:

```
Hello, Alice
Hello, Bob
```

You can view the execution of this program at *https://autbor.com/hellofunc2/*. The definition of the `hello()` function in this program has a parameter called `name` ❶. *Parameters* are variables that contain arguments. When a function is called with arguments, the arguments are stored in the parameters. The first time the `hello()` function is called, it is passed the argument `'Alice'` ❸. The program execution enters the function, and the parameter `name` is automatically set to `'Alice'`, which is what gets printed by the `print()` statement ❷.

One special thing to note about parameters is that the value stored in a parameter is forgotten when the function returns. For example, if you added `print(name)` after `hello('Bob')` in the previous program, the program would give you a `NameError` because there is no variable named `name`. This variable is destroyed after the function call `hello('Bob')` returns, so `print(name)` would refer to a `name` variable that does not exist.

This is similar to how a program's variables are forgotten when the program terminates. I'll talk more about why that happens later in the chapter, when I discuss what a function's local scope is.

Define, Call, Pass, Argument, Parameter

The terms *define*, *call*, *pass*, *argument*, and *parameter* can be confusing. Let's look at a code example to review these terms:

```
❶ def sayHello(name):
      print('Hello, ' + name)
❷ sayHello('Al')
```

To *define* a function is to create it, just like an assignment statement like `spam = 42` creates the `spam` variable. The `def` statement defines the `sayHello()` function ❶. The `sayHello('Al')` line ❷ *calls* the now-created function, sending the execution to the top of the function's code. This function call is also known as *passing* the string value `'Al'` to the function. A value being passed to a function in a function call is an *argument*. The argument `'Al'` is assigned to a local variable named `name`. Variables that have arguments assigned to them are *parameters*.

It's easy to mix up these terms, but keeping them straight will ensure that you know precisely what the text in this chapter means.

Return Values and return Statements

When you call the `len()` function and pass it an argument such as `'Hello'`, the function call evaluates to the integer value `5`, which is the length of the string you passed it. In general, the value that a function call evaluates to is called the *return value* of the function.

When creating a function using the `def` statement, you can specify what the return value should be with a `return` statement. A `return` statement consists of the following:

- The `return` keyword
- The value or expression that the function should return

When an expression is used with a `return` statement, the return value is what this expression evaluates to. For example, the following program defines a function that returns a different string depending on what number it is passed as an argument. Enter this code into the file editor and save it as *magic8Ball.py*:

```
❶ import random

❷ def getAnswer(answerNumber):
    ❸ if answerNumber == 1:
          return 'It is certain'
      elif answerNumber == 2:
          return 'It is decidedly so'
      elif answerNumber == 3:
          return 'Yes'
      elif answerNumber == 4:
          return 'Reply hazy try again'
      elif answerNumber == 5:
          return 'Ask again later'
      elif answerNumber == 6:
          return 'Concentrate and ask again'
      elif answerNumber == 7:
          return 'My reply is no'
      elif answerNumber == 8:
          return 'Outlook not so good'
      elif answerNumber == 9:
          return 'Very doubtful'

❹ r = random.randint(1, 9)
❺ fortune = getAnswer(r)
❻ print(fortune)
```

You can view the execution of this program at *https://autbor.com/magic8ball/*. When this program starts, Python first imports the random module ❶. Then the getAnswer() function is defined ❷. Because the function is being defined (and not called), the execution skips over the code in it. Next, the random.randint() function is called with two arguments: 1 and 9 ❹. It evaluates to a random integer between 1 and 9 (including 1 and 9 themselves), and this value is stored in a variable named r.

The getAnswer() function is called with r as the argument ❺. The program execution moves to the top of the getAnswer() function ❸, and the value r is stored in a parameter named answerNumber. Then, depending on the value in answerNumber, the function returns one of many possible string values. The program execution returns to the line at the bottom of the program that originally called getAnswer() ❺. The returned string is assigned to a variable named fortune, which then gets passed to a print() call ❻ and is printed to the screen.

Note that since you can pass return values as an argument to another function call, you could shorten these three lines:

```
r = random.randint(1, 9)
fortune = getAnswer(r)
print(fortune)
```

to this single equivalent line:

```
print(getAnswer(random.randint(1, 9)))
```

Remember, expressions are composed of values and operators. A function call can be used in an expression because the call evaluates to its return value.

The None Value

In Python, there is a value called None, which represents the absence of a value. The None value is the only value of the NoneType data type. (Other programming languages might call this value null, nil, or undefined.) Just like the Boolean True and False values, None must be typed with a capital *N*.

This value-without-a-value can be helpful when you need to store something that won't be confused for a real value in a variable. One place where None is used is as the return value of print(). The print() function displays text on the screen, but it doesn't need to return anything in the same way len() or input() does. But since all function calls need to evaluate to a return value, print() returns None. To see this in action, enter the following into the interactive shell:

```
>>> spam = print('Hello!')
Hello!
>>> None == spam
True
```

Behind the scenes, Python adds `return None` to the end of any function definition with no `return` statement. This is similar to how a `while` or `for` loop implicitly ends with a `continue` statement. Also, if you use a `return` statement without a value (that is, just the `return` keyword by itself), then `None` is returned.

Keyword Arguments and the print() Function

Most arguments are identified by their position in the function call. For example, `random.randint(1, 10)` is different from `random.randint(10, 1)`. The function call `random.randint(1, 10)` will return a random integer between `1` and `10` because the first argument is the low end of the range and the second argument is the high end (while `random.randint(10, 1)` causes an error).

However, rather than through their position, *keyword arguments* are identified by the keyword put before them in the function call. Keyword arguments are often used for *optional parameters*. For example, the `print()` function has the optional parameters `end` and `sep` to specify what should be printed at the end of its arguments and between its arguments (separating them), respectively.

If you ran a program with the following code:

```
print('Hello')
print('World')
```

the output would look like this:

```
Hello
World
```

The two outputted strings appear on separate lines because the `print()` function automatically adds a newline character to the end of the string it is passed. However, you can set the `end` keyword argument to change the newline character to a different string. For example, if the code were this:

```
print('Hello', end='')
print('World')
```

the output would look like this:

```
HelloWorld
```

The output is printed on a single line because there is no longer a newline printed after `'Hello'`. Instead, the blank string is printed. This is useful if you need to disable the newline that gets added to the end of every `print()` function call.

Similarly, when you pass multiple string values to `print()`, the function will automatically separate them with a single space. Enter the following into the interactive shell:

```
>>> print('cats', 'dogs', 'mice')
cats dogs mice
```

But you could replace the default separating string by passing the `sep` keyword argument a different string. Enter the following into the interactive shell:

```
>>> print('cats', 'dogs', 'mice', sep=',')
cats,dogs,mice
```

You can add keyword arguments to the functions you write as well, but first you'll have to learn about the list and dictionary data types in the next two chapters. For now, just know that some functions have optional keyword arguments that can be specified when the function is called.

The Call Stack

Imagine that you have a meandering conversation with someone. You talk about your friend Alice, which then reminds you of a story about your coworker Bob, but first you have to explain something about your cousin Carol. You finish you story about Carol and go back to talking about Bob, and when you finish your story about Bob, you go back to talking about Alice. But then you are reminded about your brother David, so you tell a story about him, and then get back to finishing your original story about Alice. Your conversation followed a *stack*-like structure, like in Figure 3-1. The conversation is stack-like because the current topic is always at the top of the stack.

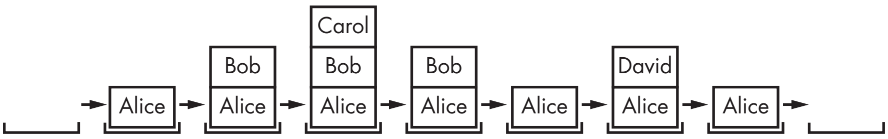


Figure 3-1: Your meandering conversation stack

Similar to our meandering conversation, calling a function doesn't send the execution on a one-way trip to the top of a function. Python will remember which line of code called the function so that the execution can return there when it encounters a `return` statement. If that original function called other functions, the execution would return to *those* function calls first, before returning from the original function call.

Open a file editor window and enter the following code, saving it as *abcdCallStack.py*:

```
def a():
    print('a() starts')
 ❶ b()
 ❷ d()
    print('a() returns')

def b():
    print('b() starts')
 ❸ c()
    print('b() returns')

def c():
 ❹ print('c() starts')
    print('c() returns')

def d():
    print('d() starts')
    print('d() returns')

❺ a()
```

If you run this program, the output will look like this:

```
a() starts
b() starts
c() starts
c() returns
b() returns
d() starts
d() returns
a() returns
```

You can view the execution of this program at *https://autbor.com/abcdcallstack/*. When `a()` is called ❺, it calls `b()` ❶, which in turn calls `c()` ❸. The `c()` function doesn't call anything; it just displays `c() starts` ❹ and `c() returns` before returning to the line in `b()` that called it ❸. Once execution returns to the code in `b()` that called `c()`, it returns to the line in `a()` that called `b()` ❶. The execution continues to the next line in the `b()` function ❷, which is a call to `d()`. Like the `c()` function, the `d()` function also doesn't call anything. It just displays `d() starts` and `d() returns` before returning to the line in `b()` that called it. Since `b()` contains no other code, the execution returns to the line in `a()` that called `b()` ❷. The last line in `a()` displays `a() returns` before returning to the original `a()` call at the end of the program ❺.

The *call stack* is how Python remembers where to return the execution after each function call. The call stack isn't stored in a variable in your program; rather, Python handles it behind the scenes. When your program calls a function, Python creates a *frame object* on the top of the call stack. Frame objects store the line number of the original function call so that Python can remember where to return. If another function call is made, Python puts another frame object on the call stack above the other one.

When a function call returns, Python removes a frame object from the top of the stack and moves the execution to the line number stored in it. Note that frame objects are always added and removed from the top of the stack and not from any other place. Figure 3-2 illustrates the state of the call stack in *abcdCallStack.py* as each function is called and returns.

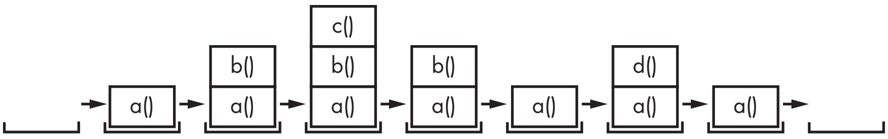


Figure 3-2: The frame objects of the call stack as abcdCallStack.py *calls and returns from functions*

The top of the call stack is which function the execution is currently in. When the call stack is empty, the execution is on a line outside of all functions.

The call stack is a technical detail that you don't strictly need to know about to write programs. It's enough to understand that function calls return to the line number they were called from. However, understanding call stacks makes it easier to understand local and global scopes, described in the next section.

Local and Global Scope

Parameters and variables that are assigned in a called function are said to exist in that function's *local scope*. Variables that are assigned outside all functions are said to exist in the *global scope*. A variable that exists in a local scope is called a *local variable*, while a variable that exists in the global scope is called a *global variable*. A variable must be one or the other; it cannot be both local and global.

Think of a *scope* as a container for variables. When a scope is destroyed, all the values stored in the scope's variables are forgotten. There is only one global scope, and it is created when your program begins. When your program terminates, the global scope is destroyed, and all its variables are forgotten. Otherwise, the next time you ran a program, the variables would remember their values from the last time you ran it.

A local scope is created whenever a function is called. Any variables assigned in the function exist within the function's local scope. When the function returns, the local scope is destroyed, and these variables are forgotten. The next time you call the function, the local variables will not remember the values stored in them from the last time the function was called. Local variables are also stored in frame objects on the call stack.

Scopes matter for several reasons:

- Code in the global scope, outside of all functions, cannot use any local variables.
- However, code in a local scope can access global variables.
- Code in a function's local scope cannot use variables in any other local scope.
- You can use the same name for different variables if they are in different scopes. That is, there can be a local variable named spam and a global variable also named spam.

The reason Python has different scopes instead of just making everything a global variable is so that when variables are modified by the code in a particular call to a function, the function interacts with the rest of the program only through its parameters and the return value. This narrows down the number of lines of code that may be causing a bug. If your program contained nothing but global variables and had a bug because of a variable being set to a bad value, then it would be hard to track down where this bad value was set. It could have been set from anywhere in the program, and your program could be hundreds or thousands of lines long! But if the bug is caused by a local variable with a bad value, you know that only the code in that one function could have set it incorrectly.

While using global variables in small programs is fine, it is a bad habit to rely on global variables as your programs get larger and larger.

Local Variables Cannot Be Used in the Global Scope

Consider this program, which will cause an error when you run it:

```
def spam():
❶ eggs = 31337
spam()
print(eggs)
```

If you run this program, the output will look like this:

```
Traceback (most recent call last):
  File "C:/test1.py", line 4, in <module>
    print(eggs)
NameError: name 'eggs' is not defined
```

The error happens because the eggs variable exists only in the local scope created when spam() is called ❶. Once the program execution returns from spam, that local scope is destroyed, and there is no longer a variable named eggs. So when your program tries to run print(eggs), Python gives you an error saying that eggs is not defined. This makes sense if you think about it; when the program execution is in the global scope, no local scopes exist, so there can't be any local variables. This is why only global variables can be used in the global scope.

Local Scopes Cannot Use Variables in Other Local Scopes

A new local scope is created whenever a function is called, including when a function is called from another function. Consider this program:

```
  def spam():
    ❶ eggs = 99
    ❷ bacon()
    ❸ print(eggs)

  def bacon():
      ham = 101
    ❹ eggs = 0

❺ spam()
```

You can view the execution of this program at *https://autbor.com/otherlocalscopes/*. When the program starts, the `spam()` function is called ❺, and a local scope is created. The local variable `eggs` ❶ is set to `99`. Then the `bacon()` function is called ❷, and a second local scope is created. Multiple local scopes can exist at the same time. In this new local scope, the local variable `ham` is set to `101`, and a local variable `eggs`—which is different from the one in `spam()`'s local scope—is also created ❹ and set to `0`.

When `bacon()` returns, the local scope for that call is destroyed, including its `eggs` variable. The program execution continues in the `spam()` function to print the value of `eggs` ❸. Since the local scope for the call to `spam()` still exists, the only `eggs` variable is the `spam()` function's `eggs` variable, which was set to `99`. This is what the program prints.

The upshot is that local variables in one function are completely separate from the local variables in another function.

Global Variables Can Be Read from a Local Scope

Consider the following program:

```
def spam():
    print(eggs)
eggs = 42
spam()
print(eggs)
```

You can view the execution of this program at *https://autbor.com/readglobal/*. Since there is no parameter named `eggs` or any code that assigns `eggs` a value in the `spam()` function, when `eggs` is used in `spam()`, Python considers it a reference to the global variable `eggs`. This is why `42` is printed when the previous program is run.

Local and Global Variables with the Same Name

Technically, it's perfectly acceptable to use the same variable name for a global variable and local variables in different scopes in Python. But, to simplify your life, avoid doing this. To see what happens, enter the following code into the file editor and save it as *localGlobalSameName.py*:

```
def spam():
 ❶ eggs = 'spam local'
    print(eggs)    # prints 'spam local'

def bacon():
 ❷ eggs = 'bacon local'
    print(eggs)    # prints 'bacon local'
    spam()
    print(eggs)    # prints 'bacon local'

❸ eggs = 'global'
bacon()
print(eggs)        # prints 'global'
```

When you run this program, it outputs the following:

```
bacon local
spam local
bacon local
global
```

You can view the execution of this program at *https://autbor.com/localglobalsamename/*. There are actually three different variables in this program, but confusingly they are all named `eggs`. The variables are as follows:

❶ A variable named `eggs` that exists in a local scope when `spam()` is called.
❷ A variable named `eggs` that exists in a local scope when `bacon()` is called.
❸ A variable named `eggs` that exists in the global scope.

Since these three separate variables all have the same name, it can be confusing to keep track of which one is being used at any given time. This is why you should avoid using the same variable name in different scopes.

The global Statement

If you need to modify a global variable from within a function, use the `global` statement. If you have a line such as `global eggs` at the top of a function, it tells Python, "In this function, `eggs` refers to the global variable, so don't create a local variable with this name." For example, enter the following code into the file editor and save it as *globalStatement.py*:

```
def spam():
 ❶ global eggs
 ❷ eggs = 'spam'
```

```
eggs = 'global'
spam()
print(eggs)
```

When you run this program, the final `print()` call will output this:

```
spam
```

You can view the execution of this program at *https://autbor.com/globalstatement/*. Because `eggs` is declared `global` at the top of `spam()` ❶, when `eggs` is set to `'spam'` ❷, this assignment is done to the globally scoped `eggs`. No local `eggs` variable is created.

There are four rules to tell whether a variable is in a local scope or global scope:

- If a variable is being used in the global scope (that is, outside of all functions), then it is always a global variable.
- If there is a `global` statement for that variable in a function, it is a global variable.
- Otherwise, if the variable is used in an assignment statement in the function, it is a local variable.
- But if the variable is not used in an assignment statement, it is a global variable.

To get a better feel for these rules, here's an example program. Enter the following code into the file editor and save it as *sameNameLocalGlobal.py*:

```
def spam():
 ❶ global eggs
    eggs = 'spam' # this is the global

def bacon():
 ❷ eggs = 'bacon' # this is a local

def ham():
 ❸ print(eggs) # this is the global

eggs = 42 # this is the global
spam()
print(eggs)
```

In the `spam()` function, `eggs` is the global `eggs` variable because there's a `global` statement for `eggs` at the beginning of the function ❶. In `bacon()`, `eggs` is a local variable because there's an assignment statement for it in that function ❷. In `ham()` ❸, `eggs` is the global variable because there is no assignment statement or `global` statement for it in that function. If you run *sameNameLocalGlobal.py*, the output will look like this:

```
spam
```

You can view the execution of this program at *https://autbor.com/sameNameLocalGlobal/*. In a function, a variable will either always be global or always be local. The code in a function can't use a local variable named eggs and then use the global eggs variable later in that same function.

NOTE *If you ever want to modify the value stored in a global variable from in a function, you must use a* `global` *statement on that variable.*

If you try to use a local variable in a function before you assign a value to it, as in the following program, Python will give you an error. To see this, enter the following into the file editor and save it as *sameNameError.py*:

```
def spam():
    print(eggs) # ERROR!
 ❶ eggs = 'spam local'

❷ eggs = 'global'
spam()
```

If you run the previous program, it produces an error message.

```
Traceback (most recent call last):
  File "C:/sameNameError.py", line 6, in <module>
    spam()
  File "C:/sameNameError.py", line 2, in spam
    print(eggs) # ERROR!
UnboundLocalError: local variable 'eggs' referenced before assignment
```

You can view the execution of this program at *https://autbor.com/sameNameError/*. This error happens because Python sees that there is an assignment statement for eggs in the spam() function ❶ and, therefore, considers eggs to be local. But because print(eggs) is executed before eggs is assigned anything, the local variable eggs doesn't exist. Python will *not* fall back to using the global eggs variable ❷.

FUNCTIONS AS "BLACK BOXES"

Often, all you need to know about a function are its inputs (the parameters) and output value; you don't always have to burden yourself with how the function's code actually works. When you think about functions in this high-level way, it's common to say that you're treating a function as a "black box."

This idea is fundamental to modern programming. Later chapters in this book will show you several modules with functions that were written by other people. While you can take a peek at the source code if you're curious, you don't need to know how these functions work in order to use them. And because writing functions without global variables is encouraged, you usually don't have to worry about the function's code interacting with the rest of your program.

Exception Handling

Right now, getting an error, or *exception*, in your Python program means the entire program will crash. You don't want this to happen in real-world programs. Instead, you want the program to detect errors, handle them, and then continue to run.

For example, consider the following program, which has a divide-by-zero error. Open a file editor window and enter the following code, saving it as *zeroDivide.py*:

```
def spam(divideBy):
    return 42 / divideBy

print(spam(2))
print(spam(12))
print(spam(0))
print(spam(1))
```

We've defined a function called `spam`, given it a parameter, and then printed the value of that function with various parameters to see what happens. This is the output you get when you run the previous code:

```
21.0
3.5
Traceback (most recent call last):
  File "C:/zeroDivide.py", line 6, in <module>
    print(spam(0))
  File "C:/zeroDivide.py", line 2, in spam
    return 42 / divideBy
ZeroDivisionError: division by zero
```

You can view the execution of this program at *https://autbor.com/zerodivide/*. A `ZeroDivisionError` happens whenever you try to divide a number by zero. From the line number given in the error message, you know that the `return` statement in `spam()` is causing an error.

Errors can be handled with `try` and `except` statements. The code that could potentially have an error is put in a `try` clause. The program execution moves to the start of a following `except` clause if an error happens.

You can put the previous divide-by-zero code in a `try` clause and have an `except` clause contain code to handle what happens when this error occurs.

```
def spam(divideBy):
    try:
        return 42 / divideBy
    except ZeroDivisionError:
        print('Error: Invalid argument.')

print(spam(2))
print(spam(12))
print(spam(0))
print(spam(1))
```

When code in a `try` clause causes an error, the program execution immediately moves to the code in the `except` clause. After running that code, the execution continues as normal. The output of the previous program is as follows:

```
21.0
3.5
Error: Invalid argument.
None
42.0
```

You can view the execution of this program at *https://autbor.com/tryexceptzerodivide/*. Note that any errors that occur in function calls in a `try` block will also be caught. Consider the following program, which instead has the `spam()` calls in the `try` block:

```
def spam(divideBy):
    return 42 / divideBy

try:
    print(spam(2))
    print(spam(12))
    print(spam(0))
    print(spam(1))
except ZeroDivisionError:
    print('Error: Invalid argument.')
```

When this program is run, the output looks like this:

```
21.0
3.5
Error: Invalid argument.
```

You can view the execution of this program at *https://autbor.com/spamintry/*. The reason `print(spam(1))` is never executed is because once the execution jumps to the code in the `except` clause, it does not return to the `try` clause. Instead, it just continues moving down the program as normal.

A Short Program: Zigzag

Let's use the programming concepts you've learned so far to create a small animation program. This program will create a back-and-forth, zigzag pattern until the user stops it by pressing the Mu editor's Stop button or by pressing CTRL-C. When you run this program, the output will look something like this:

```
    ********
   ********
  ********
```

```
 ********
********
 ********
  ********
   ********
    ********
```

Type the following source code into the file editor, and save the file as *zigzag.py*:

```
import time, sys
indent = 0 # How many spaces to indent.
indentIncreasing = True # Whether the indentation is increasing or not.

try:
    while True: # The main program loop.
        print(' ' * indent, end='')
        print('********')
        time.sleep(0.1) # Pause for 1/10 of a second.

        if indentIncreasing:
            # Increase the number of spaces:
            indent = indent + 1
            if indent == 20:
                # Change direction:
                indentIncreasing = False
        else:
            # Decrease the number of spaces:
            indent = indent - 1
            if indent == 0:
                # Change direction:
                indentIncreasing = True
except KeyboardInterrupt:
    sys.exit()
```

Let's look at this code line by line, starting at the top.

```
import time, sys
indent = 0 # How many spaces to indent.
indentIncreasing = True # Whether the indentation is increasing or not.
```

First, we'll import the `time` and `sys` modules. Our program uses two variables: the `indent` variable keeps track of how many spaces of indentation are before the band of eight asterisks and `indentIncreasing` contains a Boolean value to determine if the amount of indentation is increasing or decreasing.

```
try:
    while True: # The main program loop.
        print(' ' * indent, end='')
        print('********')
        time.sleep(0.1) # Pause for 1/10 of a second.
```

Next, we place the rest of the program inside a try statement. When the user presses CTRL-C while a Python program is running, Python raises the KeyboardInterrupt exception. If there is no try-except statement to catch this exception, the program crashes with an ugly error message. However, for our program, we want it to cleanly handle the KeyboardInterrupt exception by calling sys.exit(). (The code for this is in the except statement at the end of the program.)

The while True: infinite loop will repeat the instructions in our program forever. This involves using ' ' * indent to print the correct amount of spaces of indentation. We don't want to automatically print a newline after these spaces, so we also pass end='' to the first print() call. A second print() call prints the band of asterisks. The time.sleep() function hasn't been covered yet, but suffice it to say that it introduces a one-tenth-second pause in our program at this point.

```
        if indentIncreasing:
            # Increase the number of spaces:
            indent = indent + 1
            if indent == 20:
                indentIncreasing = False # Change direction.
```

Next, we want to adjust the amount of indentation for the next time we print asterisks. If indentIncreasing is True, then we want to add one to indent. But once indent reaches 20, we want the indentation to decrease.

```
        else:
            # Decrease the number of spaces:
            indent = indent - 1
            if indent == 0:
                indentIncreasing = True # Change direction.
```

Meanwhile, if indentIncreasing was False, we want to subtract one from indent. Once indent reaches 0, we want the indentation to increase once again. Either way, the program execution will jump back to the start of the main program loop to print the asterisks again.

```
except KeyboardInterrupt:
    sys.exit()
```

If the user presses CTRL-C at any point that the program execution is in the try block, the KeyboardInterrrupt exception is raised and handled by this except statement. The program execution moves inside the except block, which runs sys.exit() and quits the program. This way, even though the main program loop is an infinite loop, the user has a way to shut down the program.

Summary

Functions are the primary way to compartmentalize your code into logical groups. Since the variables in functions exist in their own local scopes, the code in one function cannot directly affect the values of variables in other functions. This limits what code could be changing the values of your variables, which can be helpful when it comes to debugging your code.

Functions are a great tool to help you organize your code. You can think of them as black boxes: they have inputs in the form of parameters and outputs in the form of return values, and the code in them doesn't affect variables in other functions.

In previous chapters, a single error could cause your programs to crash. In this chapter, you learned about `try` and `except` statements, which can run code when an error has been detected. This can make your programs more resilient to common error cases.

Practice Questions

1. Why are functions advantageous to have in your programs?
2. When does the code in a function execute: when the function is defined or when the function is called?
3. What statement creates a function?
4. What is the difference between a function and a function call?
5. How many global scopes are there in a Python program? How many local scopes?
6. What happens to variables in a local scope when the function call returns?
7. What is a return value? Can a return value be part of an expression?
8. If a function does not have a return statement, what is the return value of a call to that function?
9. How can you force a variable in a function to refer to the global variable?
10. What is the data type of `None`?
11. What does the `import areallyourpetsnamederic` statement do?
12. If you had a function named `bacon()` in a module named `spam`, how would you call it after importing `spam`?
13. How can you prevent a program from crashing when it gets an error?
14. What goes in the `try` clause? What goes in the `except` clause?

Practice Projects

For practice, write programs to do the following tasks.

The Collatz Sequence

Write a function named `collatz()` that has one parameter named `number`. If `number` is even, then `collatz()` should print `number // 2` and return this value. If `number` is odd, then `collatz()` should print and return `3 * number + 1`.

Then write a program that lets the user type in an integer and that keeps calling `collatz()` on that number until the function returns the value `1`. (Amazingly enough, this sequence actually works for any integer—sooner or later, using this sequence, you'll arrive at 1! Even mathematicians aren't sure why. Your program is exploring what's called the *Collatz sequence*, sometimes called "the simplest impossible math problem.")

Remember to convert the return value from `input()` to an integer with the `int()` function; otherwise, it will be a string value.

Hint: An integer `number` is even if `number % 2 == 0`, and it's odd if `number % 2 == 1`.

The output of this program could look something like this:

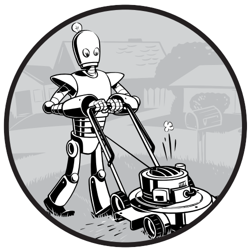
```
Enter number:
3
10
5
16
8
4
2
1
```

Input Validation

Add `try` and `except` statements to the previous project to detect whether the user types in a noninteger string. Normally, the `int()` function will raise a `ValueError` error if it is passed a noninteger string, as in `int('puppy')`. In the `except` clause, print a message to the user saying they must enter an integer.

4

LISTS



One more topic you'll need to understand before you can begin writing programs in earnest is the list data type and its cousin, the tuple. Lists and tuples can contain multiple values, which makes writing programs that handle large amounts of data easier. And since lists themselves can contain other lists, you can use them to arrange data into hierarchical structures.

In this chapter, I'll discuss the basics of lists. I'll also teach you about methods, which are functions that are tied to values of a certain data type. Then I'll briefly cover the sequence data types (lists, tuples, and strings) and show how they compare with each other. In the next chapter, I'll introduce you to the dictionary data type.

The List Data Type

A *list* is a value that contains multiple values in an ordered sequence. The term *list value* refers to the list itself (which is a value that can be stored in a variable or passed to a function like any other value), not the values inside the list value. A list value looks like this: `['cat', 'bat', 'rat', 'elephant']`. Just as string values are typed with quote characters to mark where the string begins and ends, a list begins with an opening square bracket and ends with a closing square bracket, `[]`. Values inside the list are also called *items*. Items are separated with commas (that is, they are *comma-delimited*). For example, enter the following into the interactive shell:

```
>>> [1, 2, 3]
[1, 2, 3]
>>> ['cat', 'bat', 'rat', 'elephant']
['cat', 'bat', 'rat', 'elephant']
>>> ['hello', 3.1415, True, None, 42]
['hello', 3.1415, True, None, 42]
❶ >>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam
['cat', 'bat', 'rat', 'elephant']
```

The `spam` variable ❶ is still assigned only one value: the list value. But the list value itself contains other values. The value `[]` is an empty list that contains no values, similar to `''`, the empty string.

Getting Individual Values in a List with Indexes

Say you have the list `['cat', 'bat', 'rat', 'elephant']` stored in a variable named `spam`. The Python code `spam[0]` would evaluate to `'cat'`, and `spam[1]` would evaluate to `'bat'`, and so on. The integer inside the square brackets that follows the list is called an *index*. The first value in the list is at index `0`, the second value is at index `1`, the third value is at index `2`, and so on. Figure 4-1 shows a list value assigned to `spam`, along with what the index expressions would evaluate to. Note that because the first index is `0`, the last index is one less than the size of the list; a list of four items has `3` as its last index.

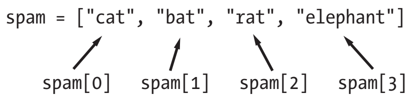


Figure 4-1: A list value stored in the variable spam, showing which value each index refers to

For example, enter the following expressions into the interactive shell. Start by assigning a list to the variable `spam`.

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[0]
'cat'
```

```
>>> spam[1]
'bat'
>>> spam[2]
'rat'
>>> spam[3]
'elephant'
>>> ['cat', 'bat', 'rat', 'elephant'][3]
'elephant'
❶ >>> 'Hello, ' + spam[0]
❷ 'Hello, cat'
>>> 'The ' + spam[1] + ' ate the ' + spam[0] + '.'
'The bat ate the cat.'
```

Notice that the expression `'Hello, ' + spam[0]` ❶ evaluates to `'Hello, ' + 'cat'` because `spam[0]` evaluates to the string `'cat'`. This expression in turn evaluates to the string value `'Hello, cat'` ❷.

Python will give you an `IndexError` error message if you use an index that exceeds the number of values in your list value.

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[10000]
Traceback (most recent call last):
  File "<pyshell#9>", line 1, in <module>
    spam[10000]
IndexError: list index out of range
```

Indexes can be only integer values, not floats. The following example will cause a `TypeError` error:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[1]
'bat'
>>> spam[1.0]
Traceback (most recent call last):
  File "<pyshell#13>", line 1, in <module>
    spam[1.0]
TypeError: list indices must be integers or slices, not float
>>> spam[int(1.0)]
'bat'
```

Lists can also contain other list values. The values in these lists of lists can be accessed using multiple indexes, like so:

```
>>> spam = [['cat', 'bat'], [10, 20, 30, 40, 50]]
>>> spam[0]
['cat', 'bat']
>>> spam[0][1]
'bat'
>>> spam[1][4]
50
```

The first index dictates which list value to use, and the second indicates the value within the list value. For example, spam[0][1] prints 'bat', the second value in the first list. If you only use one index, the program will print the full list value at that index.

Negative Indexes

While indexes start at 0 and go up, you can also use negative integers for the index. The integer value -1 refers to the last index in a list, the value -2 refers to the second-to-last index in a list, and so on. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[-1]
'elephant'
>>> spam[-3]
'bat'
>>> 'The ' + spam[-1] + ' is afraid of the ' + spam[-3] + '.'
'The elephant is afraid of the bat.'
```

Getting a List from Another List with Slices

Just as an index can get a single value from a list, a *slice* can get several values from a list, in the form of a new list. A slice is typed between square brackets, like an index, but it has two integers separated by a colon. Notice the difference between indexes and slices.

- spam[2] is a list with an index (one integer).
- spam[1:4] is a list with a slice (two integers).

In a slice, the first integer is the index where the slice starts. The second integer is the index where the slice ends. A slice goes up to, but will not include, the value at the second index. A slice evaluates to a new list value. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[0:4]
['cat', 'bat', 'rat', 'elephant']
>>> spam[1:3]
['bat', 'rat']
>>> spam[0:-1]
['cat', 'bat', 'rat']
```

As a shortcut, you can leave out one or both of the indexes on either side of the colon in the slice. Leaving out the first index is the same as using 0, or the beginning of the list. Leaving out the second index is the same as using the length of the list, which will slice to the end of the list. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[:2]
```

```
['cat', 'bat']
>>> spam[1:]
['bat', 'rat', 'elephant']
>>> spam[:]
['cat', 'bat', 'rat', 'elephant']
```

Getting a List's Length with the len() Function

The `len()` function will return the number of values that are in a list value passed to it, just like it can count the number of characters in a string value. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'dog', 'moose']
>>> len(spam)
3
```

Changing Values in a List with Indexes

Normally, a variable name goes on the left side of an assignment statement, like `spam = 42`. However, you can also use an index of a list to change the value at that index. For example, `spam[1] = 'aardvark'` means "Assign the value at index `1` in the list `spam` to the string `'aardvark'`." Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam[1] = 'aardvark'
>>> spam
['cat', 'aardvark', 'rat', 'elephant']
>>> spam[2] = spam[1]
>>> spam
['cat', 'aardvark', 'aardvark', 'elephant']
>>> spam[-1] = 12345
>>> spam
['cat', 'aardvark', 'aardvark', 12345]
```

List Concatenation and List Replication

Lists can be concatenated and replicated just like strings. The `+` operator combines two lists to create a new list value and the `*` operator can be used with a list and an integer value to replicate the list. Enter the following into the interactive shell:

```
>>> [1, 2, 3] + ['A', 'B', 'C']
[1, 2, 3, 'A', 'B', 'C']
>>> ['X', 'Y', 'Z'] * 3
['X', 'Y', 'Z', 'X', 'Y', 'Z', 'X', 'Y', 'Z']
>>> spam = [1, 2, 3]
>>> spam = spam + ['A', 'B', 'C']
>>> spam
[1, 2, 3, 'A', 'B', 'C']
```

Removing Values from Lists with del Statements

The `del` statement will delete values at an index in a list. All of the values in the list after the deleted value will be moved up one index. For example, enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> del spam[2]
>>> spam
['cat', 'bat', 'elephant']
>>> del spam[2]
>>> spam
['cat', 'bat']
```

The `del` statement can also be used on a simple variable to delete it, as if it were an "unassignment" statement. If you try to use the variable after deleting it, you will get a `NameError` error because the variable no longer exists. In practice, you almost never need to delete simple variables. The `del` statement is mostly used to delete values from lists.

Working with Lists

When you first begin writing programs, it's tempting to create many individual variables to store a group of similar values. For example, if I wanted to store the names of my cats, I might be tempted to write code like this:

```
catName1 = 'Zophie'
catName2 = 'Pooka'
catName3 = 'Simon'
catName4 = 'Lady Macbeth'
catName5 = 'Fat-tail'
catName6 = 'Miss Cleo'
```

It turns out that this is a bad way to write code. (Also, I don't actually own this many cats, I swear.) For one thing, if the number of cats changes, your program will never be able to store more cats than you have variables. These types of programs also have a lot of duplicate or nearly identical code in them. Consider how much duplicate code is in the following program, which you should enter into the file editor and save as *allMyCats1.py*:

```
print('Enter the name of cat 1:')
catName1 = input()
print('Enter the name of cat 2:')
catName2 = input()
print('Enter the name of cat 3:')
catName3 = input()
print('Enter the name of cat 4:')
catName4 = input()
print('Enter the name of cat 5:')
catName5 = input()
print('Enter the name of cat 6:')
```

```
catName6 = input()
print('The cat names are:')
print(catName1 + ' ' + catName2 + ' ' + catName3 + ' ' + catName4 + ' ' +
catName5 + ' ' + catName6)
```

Instead of using multiple, repetitive variables, you can use a single variable that contains a list value. For example, here's a new and improved version of the *allMyCats1.py* program. This new version uses a single list and can store any number of cats that the user types in. In a new file editor window, enter the following source code and save it as *allMyCats2.py*:

```
catNames = []
while True:
    print('Enter the name of cat ' + str(len(catNames) + 1) +
      ' (Or enter nothing to stop.):')
    name = input()
    if name == '':
        break
    catNames = catNames + [name]  # list concatenation
print('The cat names are:')
for name in catNames:
    print('  ' + name)
```

When you run this program, the output will look something like this:

```
Enter the name of cat 1 (Or enter nothing to stop.):
Zophie
Enter the name of cat 2 (Or enter nothing to stop.):
Pooka
Enter the name of cat 3 (Or enter nothing to stop.):
Simon
Enter the name of cat 4 (Or enter nothing to stop.):
Lady Macbeth
Enter the name of cat 5 (Or enter nothing to stop.):
Fat-tail
Enter the name of cat 6 (Or enter nothing to stop.):
Miss Cleo
Enter the name of cat 7 (Or enter nothing to stop.):

The cat names are:
  Zophie
  Pooka
  Simon
  Lady Macbeth
  Fat-tail
  Miss Cleo
```

You can view the execution of these programs at *https://autbor.com/allmycats1/* and *https://autbor.com/allmycats2/*. The benefit of using a list is that your data is now in a structure, so your program is much more flexible in processing the data than it would be with several repetitive variables.

Using for Loops with Lists

In Chapter 2, you learned about using for loops to execute a block of code a certain number of times. Technically, a for loop repeats the code block once for each item in a list value. For example, if you ran this code:

```
for i in range(4):
    print(i)
```

the output of this program would be as follows:

```
0
1
2
3
```

This is because the return value from range(4) is a sequence value that Python considers similar to [0, 1, 2, 3]. (Sequences are described in "Sequence Data Types" on page 93.) The following program has the same output as the previous one:

```
for i in [0, 1, 2, 3]:
    print(i)
```

The previous for loop actually loops through its clause with the variable i set to a successive value in the [0, 1, 2, 3] list in each iteration.

A common Python technique is to use range(len(*someList*)) with a for loop to iterate over the indexes of a list. For example, enter the following into the interactive shell:

```
>>> supplies = ['pens', 'staplers', 'flamethrowers', 'binders']
>>> for i in range(len(supplies)):
...     print('Index ' + str(i) + ' in supplies is: ' + supplies[i])

Index 0 in supplies is: pens
Index 1 in supplies is: staplers
Index 2 in supplies is: flamethrowers
Index 3 in supplies is: binders
```

Using range(len(supplies)) in the previously shown for loop is handy because the code in the loop can access the index (as the variable i) and the value at that index (as supplies[i]). Best of all, range(len(supplies)) will iterate through all the indexes of supplies, no matter how many items it contains.

The in and not in Operators

You can determine whether a value is or isn't in a list with the in and not in operators. Like other operators, in and not in are used in expressions and connect two values: a value to look for in a list and the list where it may be found. These expressions will evaluate to a Boolean value. Enter the following into the interactive shell:

```
>>> 'howdy' in ['hello', 'hi', 'howdy', 'heyas']
True
>>> spam = ['hello', 'hi', 'howdy', 'heyas']
>>> 'cat' in spam
False
>>> 'howdy' not in spam
False
>>> 'cat' not in spam
True
```

For example, the following program lets the user type in a pet name and then checks to see whether the name is in a list of pets. Open a new file editor window, enter the following code, and save it as *myPets.py*:

```
myPets = ['Zophie', 'Pooka', 'Fat-tail']
print('Enter a pet name:')
name = input()
if name not in myPets:
    print('I do not have a pet named ' + name)
else:
    print(name + ' is my pet.')
```

The output may look something like this:

```
Enter a pet name:
Footfoot
I do not have a pet named Footfoot
```

You can view the execution of this program at *https://autbor.com/mypets/*.

The Multiple Assignment Trick

The *multiple assignment trick* (technically called *tuple unpacking*) is a shortcut that lets you assign multiple variables with the values in a list in one line of code. So instead of doing this:

```
>>> cat = ['fat', 'gray', 'loud']
>>> size = cat[0]
>>> color = cat[1]
>>> disposition = cat[2]
```

you could type this line of code:

```
>>> cat = ['fat', 'gray', 'loud']
>>> size, color, disposition = cat
```

The number of variables and the length of the list must be exactly equal, or Python will give you a `ValueError`:

```
>>> cat = ['fat', 'gray', 'loud']
>>> size, color, disposition, name = cat
Traceback (most recent call last):
  File "<pyshell#84>", line 1, in <module>
    size, color, disposition, name = cat
ValueError: not enough values to unpack (expected 4, got 3)
```

Using the enumerate() Function with Lists

Instead of using the `range(len(`*`someList`*`))` technique with a `for` loop to obtain the integer index of the items in the list, you can call the `enumerate()` function instead. On each iteration of the loop, `enumerate()` will return two values: the index of the item in the list, and the item in the list itself. For example, this code is equivalent to the code in the "Using for Loops with Lists" on page 84:

```
>>> supplies = ['pens', 'staplers', 'flamethrowers', 'binders']
>>> for index, item in enumerate(supplies):
...     print('Index ' + str(index) + ' in supplies is: ' + item)

Index 0 in supplies is: pens
Index 1 in supplies is: staplers
Index 2 in supplies is: flamethrowers
Index 3 in supplies is: binders
```

The `enumerate()` function is useful if you need both the item and the item's index in the loop's block.

Using the random.choice() and random.shuffle() Functions with Lists

The `random` module has a couple functions that accept lists for arguments. The `random.choice()` function will return a randomly selected item from the list. Enter the following into the interactive shell:

```
>>> import random
>>> pets = ['Dog', 'Cat', 'Moose']
>>> random.choice(pets)
'Dog'
>>> random.choice(pets)
'Cat'
>>> random.choice(pets)
'Cat'
```

You can consider `random.choice(someList)` to be a shorter form of `someList[random.randint(0, len(someList) - 1]`.

The random.shuffle() function will reorder the items in a list. This function modifies the list in place, rather than returning a new list. Enter the following into the interactive shell:

```
>>> import random
>>> people = ['Alice', 'Bob', 'Carol', 'David']
>>> random.shuffle(people)
>>> people
['Carol', 'David', 'Alice', 'Bob']
>>> random.shuffle(people)
>>> people
['Alice', 'David', 'Bob', 'Carol']
```

Augmented Assignment Operators

When assigning a value to a variable, you will frequently use the variable itself. For example, after assigning 42 to the variable spam, you would increase the value in spam by 1 with the following code:

```
>>> spam = 42
>>> spam = spam + 1
>>> spam
43
```

As a shortcut, you can use the augmented assignment operator += to do the same thing:

```
>>> spam = 42
>>> spam += 1
>>> spam
43
```

There are augmented assignment operators for the +, -, *, /, and % operators, described in Table 4-1.

Table 4-1: The Augmented Assignment Operators

Augmented assignment statement	Equivalent assignment statement
spam += 1	spam = spam + 1
spam -= 1	spam = spam - 1
spam *= 1	spam = spam * 1
spam /= 1	spam = spam / 1
spam %= 1	spam = spam % 1

The += operator can also do string and list concatenation, and the *= operator can do string and list replication. Enter the following into the interactive shell:

```
>>> spam = 'Hello,'
>>> spam += ' world!'
>>> spam
'Hello world!'
>>> bacon = ['Zophie']
>>> bacon *= 3
>>> bacon
['Zophie', 'Zophie', 'Zophie']
```

Methods

A *method* is the same thing as a function, except it is "called on" a value. For example, if a list value were stored in spam, you would call the index() list method (which I'll explain shortly) on that list like so: spam.index('hello'). The method part comes after the value, separated by a period.

Each data type has its own set of methods. The list data type, for example, has several useful methods for finding, adding, removing, and otherwise manipulating values in a list.

Finding a Value in a List with the index() Method

List values have an index() method that can be passed a value, and if that value exists in the list, the index of the value is returned. If the value isn't in the list, then Python produces a ValueError error. Enter the following into the interactive shell:

```
>>> spam = ['hello', 'hi', 'howdy', 'heyas']
>>> spam.index('hello')
0
>>> spam.index('heyas')
3
>>> spam.index('howdy howdy howdy')
Traceback (most recent call last):
  File "<pyshell#31>", line 1, in <module>
    spam.index('howdy howdy howdy')
ValueError: 'howdy howdy howdy' is not in list
```

When there are duplicates of the value in the list, the index of its first appearance is returned. Enter the following into the interactive shell, and notice that index() returns 1, not 3:

```
>>> spam = ['Zophie', 'Pooka', 'Fat-tail', 'Pooka']
>>> spam.index('Pooka')
1
```

Adding Values to Lists with the append() and insert() Methods

To add new values to a list, use the `append()` and `insert()` methods. Enter the following into the interactive shell to call the `append()` method on a list value stored in the variable `spam`:

```
>>> spam = ['cat', 'dog', 'bat']
>>> spam.append('moose')
>>> spam
['cat', 'dog', 'bat', 'moose']
```

The previous `append()` method call adds the argument to the end of the list. The `insert()` method can insert a value at any index in the list. The first argument to `insert()` is the index for the new value, and the second argument is the new value to be inserted. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'dog', 'bat']
>>> spam.insert(1, 'chicken')
>>> spam
['cat', 'chicken', 'dog', 'bat']
```

Notice that the code is `spam.append('moose')` and `spam.insert(1, 'chicken')`, not `spam = spam.append('moose')` and `spam = spam.insert(1, 'chicken')`. Neither `append()` nor `insert()` gives the new value of `spam` as its return value. (In fact, the return value of `append()` and `insert()` is `None`, so you definitely wouldn't want to store this as the new variable value.) Rather, the list is modified *in place*. Modifying a list in place is covered in more detail later in "Mutable and Immutable Data Types" on page 94.

Methods belong to a single data type. The `append()` and `insert()` methods are list methods and can be called only on list values, not on other values such as strings or integers. Enter the following into the interactive shell, and note the `AttributeError` error messages that show up:

```
>>> eggs = 'hello'
>>> eggs.append('world')
Traceback (most recent call last):
  File "<pyshell#19>", line 1, in <module>
    eggs.append('world')
AttributeError: 'str' object has no attribute 'append'
>>> bacon = 42
>>> bacon.insert(1, 'world')
Traceback (most recent call last):
  File "<pyshell#22>", line 1, in <module>
    bacon.insert(1, 'world')
AttributeError: 'int' object has no attribute 'insert'
```

Removing Values from Lists with the remove() Method

The `remove()` method is passed the value to be removed from the list it is called on. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam.remove('bat')
>>> spam
['cat', 'rat', 'elephant']
```

Attempting to delete a value that does not exist in the list will result in a `ValueError` error. For example, enter the following into the interactive shell and notice the error that is displayed:

```
>>> spam = ['cat', 'bat', 'rat', 'elephant']
>>> spam.remove('chicken')
Traceback (most recent call last):
  File "<pyshell#11>", line 1, in <module>
    spam.remove('chicken')
ValueError: list.remove(x): x not in list
```

If the value appears multiple times in the list, only the first instance of the value will be removed. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'bat', 'rat', 'cat', 'hat', 'cat']
>>> spam.remove('cat')
>>> spam
['bat', 'rat', 'cat', 'hat', 'cat']
```

The `del` statement is good to use when you know the index of the value you want to remove from the list. The `remove()` method is useful when you know the value you want to remove from the list.

Sorting the Values in a List with the sort() Method

Lists of number values or lists of strings can be sorted with the `sort()` method. For example, enter the following into the interactive shell:

```
>>> spam = [2, 5, 3.14, 1, -7]
>>> spam.sort()
>>> spam
[-7, 1, 2, 3.14, 5]
>>> spam = ['ants', 'cats', 'dogs', 'badgers', 'elephants']
>>> spam.sort()
>>> spam
['ants', 'badgers', 'cats', 'dogs', 'elephants']
```

You can also pass True for the reverse keyword argument to have sort() sort the values in reverse order. Enter the following into the interactive shell:

```
>>> spam.sort(reverse=True)
>>> spam
['elephants', 'dogs', 'cats', 'badgers', 'ants']
```

There are three things you should note about the sort() method. First, the sort() method sorts the list in place; don't try to capture the return value by writing code like spam = spam.sort().

Second, you cannot sort lists that have both number values *and* string values in them, since Python doesn't know how to compare these values. Enter the following into the interactive shell and notice the TypeError error:

```
>>> spam = [1, 3, 2, 4, 'Alice', 'Bob']
>>> spam.sort()
Traceback (most recent call last):
  File "<pyshell#70>", line 1, in <module>
    spam.sort()
TypeError: '<' not supported between instances of 'str' and 'int'
```

Third, sort() uses "ASCIIbetical order" rather than actual alphabetical order for sorting strings. This means uppercase letters come before lowercase letters. Therefore, the lowercase *a* is sorted so that it comes *after* the uppercase *Z*. For an example, enter the following into the interactive shell:

```
>>> spam = ['Alice', 'ants', 'Bob', 'badgers', 'Carol', 'cats']
>>> spam.sort()
>>> spam
['Alice', 'Bob', 'Carol', 'ants', 'badgers', 'cats']
```

If you need to sort the values in regular alphabetical order, pass str.lower for the key keyword argument in the sort() method call.

```
>>> spam = ['a', 'z', 'A', 'Z']
>>> spam.sort(key=str.lower)
>>> spam
['a', 'A', 'z', 'Z']
```

This causes the sort() function to treat all the items in the list as if they were lowercase without actually changing the values in the list.

Reversing the Values in a List with the reverse() Method

If you need to quickly reverse the order of the items in a list, you can call the reverse() list method. Enter the following into the interactive shell:

```
>>> spam = ['cat', 'dog', 'moose']
>>> spam.reverse()
>>> spam
['moose', 'dog', 'cat']
```

EXCEPTIONS TO INDENTATION RULES IN PYTHON

In most cases, the amount of indentation for a line of code tells Python what block it is in. There are some exceptions to this rule, however. For example, lists can actually span several lines in the source code file. The indentation of these lines does not matter; Python knows that the list is not finished until it sees the ending square bracket. For example, you can have code that looks like this:

```
spam = ['apples',
    'oranges',
                    'bananas',
'cats']
print(spam)
```

Of course, practically speaking, most people use Python's behavior to make their lists look pretty and readable, like the messages list in the Magic 8 Ball program.

You can also split up a single instruction across multiple lines using the \ *line continuation character* at the end. Think of \ as saying, "This instruction continues on the next line." The indentation on the line after a \ line continuation is not significant. For example, the following is valid Python code:

```
print('Four score and seven ' + \
      'years ago...')
```

These tricks are useful when you want to rearrange long lines of Python code to be a bit more readable.

Like the `sort()` list method, `reverse()` doesn't return a list. This is why you write `spam.reverse()`, instead of `spam = spam.reverse()`.

Example Program: Magic 8 Ball with a List

Using lists, you can write a much more elegant version of the previous chapter's Magic 8 Ball program. Instead of several lines of nearly identical `elif` statements, you can create a single list that the code works with. Open a new file editor window and enter the following code. Save it as *magic8Ball2.py*.

```
import random

messages = ['It is certain',
    'It is decidedly so',
    'Yes definitely',
    'Reply hazy try again',
    'Ask again later',
    'Concentrate and ask again',
    'My reply is no',
    'Outlook not so good',
    'Very doubtful']

print(messages[random.randint(0, len(messages) - 1)])
```

You can view the execution of this program at *https://autbor.com/magic8ball2/*.

When you run this program, you'll see that it works the same as the previous *magic8Ball.py* program.

Notice the expression you use as the index for `messages`: `random.randint(0, len(messages) - 1)`. This produces a random number to use for the index, regardless of the size of `messages`. That is, you'll get a random number between `0` and the value of `len(messages) - 1`. The benefit of this approach is that you can easily add and remove strings to the `messages` list without changing other lines of code. If you later update your code, there will be fewer lines you have to change and fewer chances for you to introduce bugs.

Sequence Data Types

Lists aren't the only data types that represent ordered sequences of values. For example, strings and lists are actually similar if you consider a string to be a "list" of single text characters. The Python sequence data types include lists, strings, range objects returned by `range()`, and tuples (explained in the "The Tuple Data Type" on page 96). Many of the things you can do with lists can also be done with strings and other values of sequence types: indexing; slicing; and using them with `for` loops, with `len()`, and with the `in` and `not in` operators. To see this, enter the following into the interactive shell:

```
>>> name = 'Zophie'
>>> name[0]
'Z'
>>> name[-2]
'i'
>>> name[0:4]
'Zoph'
>>> 'Zo' in name
True
>>> 'z' in name
False
>>> 'p' not in name
False
>>> for i in name:
...     print('* * * ' + i + ' * * *')


* * * Z * * *
* * * o * * *
* * * p * * *
* * * h * * *
* * * i * * *
* * * e * * *
```

Mutable and Immutable Data Types

But lists and strings are different in an important way. A list value is a *mutable* data type: it can have values added, removed, or changed. However, a string is *immutable*: it cannot be changed. Trying to reassign a single character in a string results in a TypeError error, as you can see by entering the following into the interactive shell:

```
>>> name = 'Zophie a cat'
>>> name[7] = 'the'
Traceback (most recent call last):
  File "<pyshell#50>", line 1, in <module>
    name[7] = 'the'
TypeError: 'str' object does not support item assignment
```

The proper way to "mutate" a string is to use slicing and concatenation to build a *new* string by copying from parts of the old string. Enter the following into the interactive shell:

```
>>> name = 'Zophie a cat'
>>> newName = name[0:7] + 'the' + name[8:12]
>>> name
'Zophie a cat'
>>> newName
'Zophie the cat'
```

We used [0:7] and [8:12] to refer to the characters that we don't wish to replace. Notice that the original 'Zophie a cat' string is not modified, because strings are immutable.

Although a list value *is* mutable, the second line in the following code does not modify the list eggs:

```
>>> eggs = [1, 2, 3]
>>> eggs = [4, 5, 6]
>>> eggs
[4, 5, 6]
```

The list value in eggs isn't being changed here; rather, an entirely new and different list value ([4, 5, 6]) is overwriting the old list value ([1, 2, 3]). This is depicted in Figure 4-2.

If you wanted to actually modify the original list in eggs to contain [4, 5, 6], you would have to do something like this:

```
>>> eggs = [1, 2, 3]
>>> del eggs[2]
>>> del eggs[1]
>>> del eggs[0]
>>> eggs.append(4)
>>> eggs.append(5)
>>> eggs.append(6)
>>> eggs
[4, 5, 6]
```

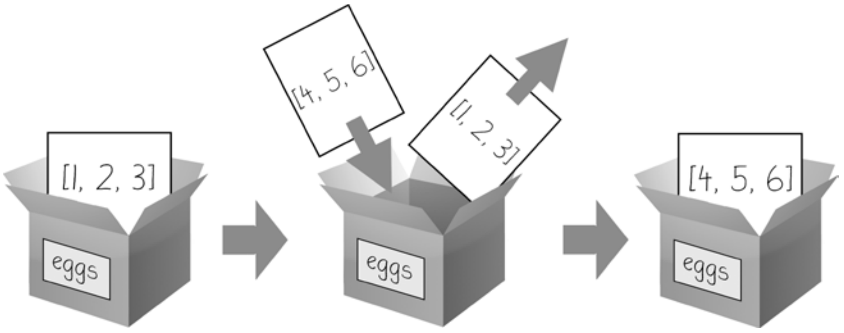


Figure 4-2: When `eggs = [4, 5, 6]` *is executed, the contents of* `eggs` *are replaced with a new list value.*

In the first example, the list value that `eggs` ends up with is the same list value it started with. It's just that this list has been changed, rather than overwritten. Figure 4-3 depicts the seven changes made by the first seven lines in the previous interactive shell example.

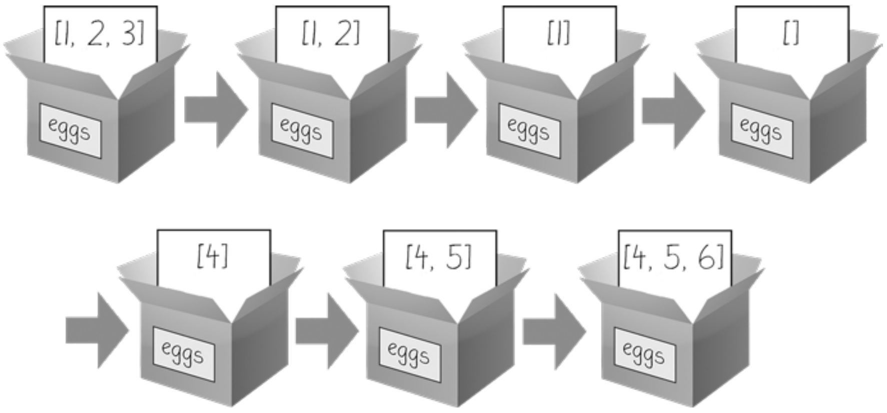


Figure 4-3: The `del` *statement and the* `append()` *method modify the same list value in place.*

Changing a value of a mutable data type (like what the `del` statement and `append()` method do in the previous example) changes the value in place, since the variable's value is not replaced with a new list value.

Mutable versus immutable types may seem like a meaningless distinction, but "Passing References" on page 100 will explain the different behavior when calling functions with mutable arguments versus immutable arguments. But first, let's find out about the tuple data type, which is an immutable form of the list data type.

The Tuple Data Type

The *tuple* data type is almost identical to the list data type, except in two ways. First, tuples are typed with parentheses, (and), instead of square brackets, [and]. For example, enter the following into the interactive shell:

```
>>> eggs = ('hello', 42, 0.5)
>>> eggs[0]
'hello'
>>> eggs[1:3]
(42, 0.5)
>>> len(eggs)
3
```

But the main way that tuples are different from lists is that tuples, like strings, are immutable. Tuples cannot have their values modified, appended, or removed. Enter the following into the interactive shell, and look at the `TypeError` error message:

```
>>> eggs = ('hello', 42, 0.5)
>>> eggs[1] = 99
Traceback (most recent call last):
  File "<pyshell#5>", line 1, in <module>
    eggs[1] = 99
TypeError: 'tuple' object does not support item assignment
```

If you have only one value in your tuple, you can indicate this by placing a trailing comma after the value inside the parentheses. Otherwise, Python will think you've just typed a value inside regular parentheses. The comma is what lets Python know this is a tuple value. (Unlike some other programming languages, it's fine to have a trailing comma after the last item in a list or tuple in Python.) Enter the following `type()` function calls into the interactive shell to see the distinction:

```
>>> type(('hello',))
<class 'tuple'>
>>> type(('hello'))
<class 'str'>
```

You can use tuples to convey to anyone reading your code that you don't intend for that sequence of values to change. If you need an ordered sequence of values that never changes, use a tuple. A second benefit of using tuples instead of lists is that, because they are immutable and their contents don't change, Python can implement some optimizations that make code using tuples slightly faster than code using lists.

Converting Types with the list() and tuple() Functions

Just like how `str(42)` will return `'42'`, the string representation of the integer `42`, the functions `list()` and `tuple()` will return list and tuple versions of the values passed to them. Enter the following into the interactive shell, and notice that the return value is of a different data type than the value passed:

```
>>> tuple(['cat', 'dog', 5])
('cat', 'dog', 5)
>>> list(('cat', 'dog', 5))
['cat', 'dog', 5]
>>> list('hello')
['h', 'e', 'l', 'l', 'o']
```

Converting a tuple to a list is handy if you need a mutable version of a tuple value.

References

As you've seen, variables "store" strings and integer values. However, this explanation is a simplification of what Python is actually doing. Technically, variables are storing references to the computer memory locations where the values are stored. Enter the following into the interactive shell:

```
>>> spam = 42
>>> cheese = spam
>>> spam = 100
>>> spam
100
>>> cheese
42
```

When you assign `42` to the `spam` variable, you are actually creating the `42` value in the computer's memory and storing a *reference* to it in the spam variable. When you copy the value in `spam` and assign it to the variable `cheese`, you are actually copying the reference. Both the `spam` and `cheese` variables refer to the `42` value in the computer's memory. When you later change the value in `spam` to `100`, you're creating a new `100` value and storing a reference to it in `spam`. This doesn't affect the value in `cheese`. Integers are *immutable* values that don't change; changing the *spam* variable is actually making it refer to a completely different value in memory.

But lists don't work this way, because list values can change; that is, lists are *mutable*. Here is some code that will make this distinction easier to understand. Enter this into the interactive shell:

```
❶ >>> spam = [0, 1, 2, 3, 4, 5]
❷ >>> cheese = spam # The reference is being copied, not the list.
❸ >>> cheese[1] = 'Hello!' # This changes the list value.
  >>> spam
```

```
[0, 'Hello!', 2, 3, 4, 5]
>>> cheese # The cheese variable refers to the same list.
[0, 'Hello!', 2, 3, 4, 5]
```

This might look odd to you. The code touched only the `cheese` list, but it seems that both the `cheese` and `spam` lists have changed.

When you create the list ❶, you assign a reference to it in the `spam` variable. But the next line ❷ copies only the list reference in `spam` to `cheese`, not the list value itself. This means the values stored in `spam` and `cheese` now both refer to the same list. There is only one underlying list because the list itself was never actually copied. So when you modify the first element of `cheese` ❸, you are modifying the same list that `spam` refers to.

Remember that variables are like boxes that contain values. The previous figures in this chapter show that lists in boxes aren't exactly accurate, because list variables don't actually contain lists—they contain *references* to lists. (These references will have ID numbers that Python uses internally, but you can ignore them.) Using boxes as a metaphor for variables, Figure 4-4 shows what happens when a list is assigned to the `spam` variable.

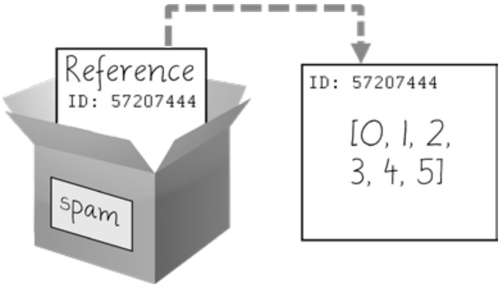


Figure 4-4: `spam = [0, 1, 2, 3, 4, 5]` stores a reference to a list, not the actual list.

Then, in Figure 4-5, the reference in `spam` is copied to `cheese`. Only a new reference was created and stored in `cheese`, not a new list. Note how both references refer to the same list.

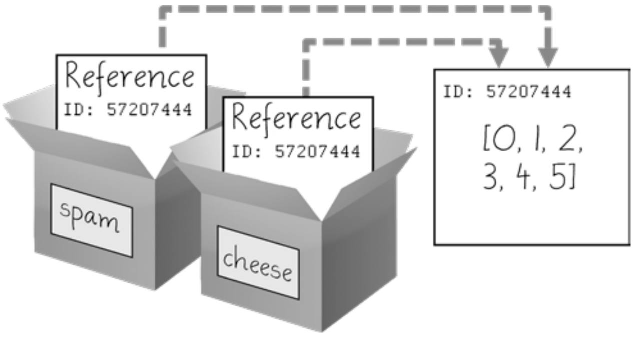


Figure 4-5: `spam = cheese` copies the reference, not the list.

When you alter the list that cheese refers to, the list that spam refers to is also changed, because both cheese and spam refer to the same list. You can see this in Figure 4-6.

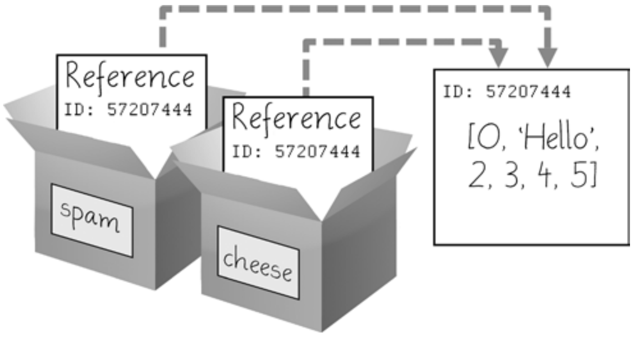


Figure 4-6: cheese[1] = 'Hello!' modifies the list that both variables refer to.

Although Python variables technically contain references to values, people often casually say that the variable contains the value.

Identity and the id() Function

You may be wondering why the weird behavior with mutable lists in the previous section doesn't happen with immutable values like integers or strings. We can use Python's id() function to understand this. All values in Python have a unique identity that can be obtained with the id() function. Enter the following into the interactive shell:

```
>>> id('Howdy') # The returned number will be different on your machine.
44491136
```

When Python runs id('Howdy'), it creates the 'Howdy' string in the computer's memory. The numeric memory address where the string is stored is returned by the id() function. Python picks this address based on which memory bytes happen to be free on your computer at the time, so it'll be different each time you run this code.

Like all strings, 'Howdy' is immutable and cannot be changed. If you "change" the string in a variable, a new string object is being made at a different place in memory, and the variable refers to this new string. For example, enter the following into the interactive shell and see how the identity of the string referred to by bacon changes:

```
>>> bacon = 'Hello'
>>> id(bacon)
44491136
>>> bacon += ' world!' # A new string is made from 'Hello' and ' world!'.
>>> id(bacon) # bacon now refers to a completely different string.
44609712
```

However, lists can be modified because they are mutable objects. The `append()` method doesn't create a new list object; it changes the existing list object. We call this "modifying the object *in-place*."

```
>>> eggs = ['cat', 'dog'] # This creates a new list.
>>> id(eggs)
35152584
>>> eggs.append('moose') # append() modifies the list "in place".
>>> id(eggs) # eggs still refers to the same list as before.
35152584
>>> eggs = ['bat', 'rat', 'cow'] # This creates a new list, which has a new
identity.
>>> id(eggs) # eggs now refers to a completely different list.
44409800
```

If two variables refer to the same list (like `spam` and `cheese` in the previous section) and the list value itself changes, both variables are affected because they both refer to the same list. The `append()`, `extend()`, `remove()`, `sort()`, `reverse()`, and other list methods modify their lists in place.

Python's *automatic garbage collector* deletes any values not being referred to by any variables to free up memory. You don't need to worry about how the garbage collector works, which is a good thing: manual memory management in other programming languages is a common source of bugs.

Passing References

References are particularly important for understanding how arguments get passed to functions. When a function is called, the values of the arguments are copied to the parameter variables. For lists (and dictionaries, which I'll describe in the next chapter), this means a copy of the reference is used for the parameter. To see the consequences of this, open a new file editor window, enter the following code, and save it as *passingReference.py*:

```
def eggs(someParameter):
    someParameter.append('Hello')

spam = [1, 2, 3]
eggs(spam)
print(spam)
```

Notice that when `eggs()` is called, a return value is not used to assign a new value to `spam`. Instead, it modifies the list in place, directly. When run, this program produces the following output:

```
[1, 2, 3, 'Hello']
```

Even though `spam` and `someParameter` contain separate references, they both refer to the same list. This is why the `append('Hello')` method call inside the function affects the list even after the function call has returned.

Keep this behavior in mind: forgetting that Python handles list and dictionary variables this way can lead to confusing bugs.

The copy Module's copy() and deepcopy() Functions

Although passing around references is often the handiest way to deal with lists and dictionaries, if the function modifies the list or dictionary that is passed, you may not want these changes in the original list or dictionary value. For this, Python provides a module named `copy` that provides both the `copy()` and `deepcopy()` functions. The first of these, `copy.copy()`, can be used to make a duplicate copy of a mutable value like a list or dictionary, not just a copy of a reference. Enter the following into the interactive shell:

```
>>> import copy
>>> spam = ['A', 'B', 'C', 'D']
>>> id(spam)
44684232
>>> cheese = copy.copy(spam)
>>> id(cheese) # cheese is a different list with different identity.
44685832
>>> cheese[1] = 42
>>> spam
['A', 'B', 'C', 'D']
>>> cheese
['A', 42, 'C', 'D']
```

Now the `spam` and `cheese` variables refer to separate lists, which is why only the list in `cheese` is modified when you assign `42` at index `1`. As you can see in Figure 4-7, the reference ID numbers are no longer the same for both variables because the variables refer to independent lists.

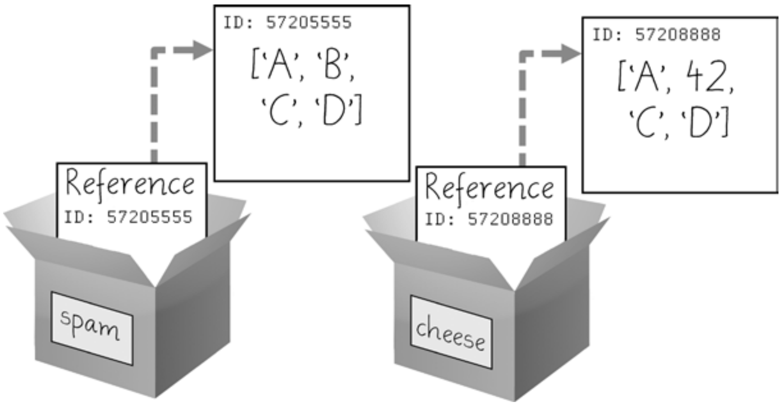


Figure 4-7: `cheese = copy.copy(spam)` *creates a second list that can be modified independently of the first.*

If the list you need to copy contains lists, then use the `copy.deepcopy()` function instead of `copy.copy()`. The `deepcopy()` function will copy these inner lists as well.

A Short Program: Conway's Game of Life

Conway's Game of Life is an example of *cellular automata*: a set of rules governing the behavior of a field made up of discrete cells. In practice, it creates a pretty animation to look at. You can draw out each step on graph paper, using the squares as cells. A filled-in square will be "alive" and an empty square will be "dead." If a living square has two or three living neighbors, it continues to live on the next step. If a dead square has exactly three living neighbors, it comes alive on the next step. Every other square dies or remains dead on the next step. You can see an example of the progression of steps in Figure 4-8.

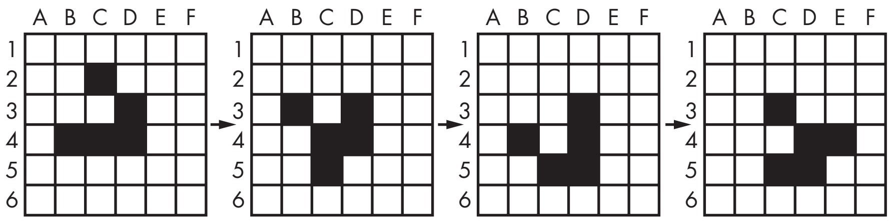


Figure 4-8: Four steps in a Conway's Game of Life simulation

Even though the rules are simple, there are many surprising behaviors that emerge. Patterns in Conway's Game of Life can move, self-replicate, or even mimic CPUs. But at the foundation of all of this complex, advanced behavior is a rather simple program.

We can use a list of lists to represent the two-dimensional field. The inner list represents each column of squares and stores a `'#'` hash string for living squares and a `' '` space string for dead squares. Type the following source code into the file editor, and save the file as *conway.py*. It's fine if you don't quite understand how all of the code works; just enter it and follow along with comments and explanations provided here as close as you can:

```
# Conway's Game of Life
import random, time, copy
WIDTH = 60
HEIGHT = 20

# Create a list of list for the cells:
nextCells = []
for x in range(WIDTH):
    column = [] # Create a new column.
    for y in range(HEIGHT):
        if random.randint(0, 1) == 0:
            column.append('#') # Add a living cell.
        else:
            column.append(' ') # Add a dead cell.
    nextCells.append(column) # nextCells is a list of column lists.

while True: # Main program loop.
    print('\n\n\n\n\n') # Separate each step with newlines.
    currentCells = copy.deepcopy(nextCells)
    # Print currentCells on the screen:
    for y in range(HEIGHT):
        for x in range(WIDTH):
            print(currentCells[x][y], end='') # Print the # or space.
        print() # Print a newline at the end of the row.

    # Calculate the next step's cells based on current step's cells:
    for x in range(WIDTH):
        for y in range(HEIGHT):
            # Get neighboring coordinates:
            # `% WIDTH` ensures leftCoord is always between 0 and WIDTH - 1
            leftCoord  = (x - 1) % WIDTH
            rightCoord = (x + 1) % WIDTH
            aboveCoord = (y - 1) % HEIGHT
            belowCoord = (y + 1) % HEIGHT

            # Count number of living neighbors:
            numNeighbors = 0
            if currentCells[leftCoord][aboveCoord] == '#':
                numNeighbors += 1 # Top-left neighbor is alive.
            if currentCells[x][aboveCoord] == '#':
                numNeighbors += 1 # Top neighbor is alive.
            if currentCells[rightCoord][aboveCoord] == '#':
                numNeighbors += 1 # Top-right neighbor is alive.
            if currentCells[leftCoord][y] == '#':
                numNeighbors += 1 # Left neighbor is alive.
            if currentCells[rightCoord][y] == '#':
                numNeighbors += 1 # Right neighbor is alive.
            if currentCells[leftCoord][belowCoord] == '#':
                numNeighbors += 1 # Bottom-left neighbor is alive.
            if currentCells[x][belowCoord] == '#':
                numNeighbors += 1 # Bottom neighbor is alive.
            if currentCells[rightCoord][belowCoord] == '#':
                numNeighbors += 1 # Bottom-right neighbor is alive.

            # Set cell based on Conway's Game of Life rules:
            if currentCells[x][y] == '#' and (numNeighbors == 2 or
numNeighbors == 3):
                # Living cells with 2 or 3 neighbors stay alive:
                nextCells[x][y] = '#'
            elif currentCells[x][y] == ' ' and numNeighbors == 3:
                # Dead cells with 3 neighbors become alive:
                nextCells[x][y] = '#'
            else:
                # Everything else dies or stays dead:
                nextCells[x][y] = ' '
    time.sleep(1) # Add a 1-second pause to reduce flickering.
```

Let's look at this code line by line, starting at the top.

```
# Conway's Game of Life
import random, time, copy
WIDTH = 60
HEIGHT = 20
```

First we import modules that contain functions we'll need, namely the random.randint(), time.sleep(), and copy.deepcopy() functions.

```
# Create a list of list for the cells:
nextCells = []
for x in range(WIDTH):
    column = [] # Create a new column.
    for y in range(HEIGHT):
        if random.randint(0, 1) == 0:
            column.append('#') # Add a living cell.
        else:
            column.append(' ') # Add a dead cell.
    nextCells.append(column) # nextCells is a list of column lists.
```

The very first step of our cellular automata will be completely random. We need to create a list of lists data structure to store the '#' and ' ' strings that represent a living or dead cell, and their place in the list of lists reflects their position on the screen. The inner lists each represent a column of cells. The random.randint(0, 1) call gives an even 50/50 chance between the cell starting off alive or dead.

We put this list of lists in a variable called nextCells, because the first step in our main program loop will be to copy nextCells into currentCells. For our list of lists data structure, the x-coordinates start at 0 on the left and increase going right, while the y-coordinates start at 0 at the top and increase going down. So nextCells[0][0] will represent the cell at the top left of the screen, while nextCells[1][0] represents the cell to the right of that cell and nextCells[0][1] represents the cell beneath it.

```
while True: # Main program loop.
    print('\n\n\n\n\n') # Separate each step with newlines.
    currentCells = copy.deepcopy(nextCells)
```

Each iteration of our main program loop will be a single step of our cellular automata. On each step, we'll copy nextCells to currentCells, print currentCells on the screen, and then use the cells in currentCells to calculate the cells in nextCells.

```
    # Print currentCells on the screen:
    for y in range(HEIGHT):
        for x in range(WIDTH):
            print(currentCells[x][y], end='') # Print the # or space.
        print() # Print a newline at the end of the row.
```

These nested for loops ensure that we print a full row of cells to the screen, followed by a newline character at the end of the row. We repeat this for each row in nextCells.

```
    # Calculate the next step's cells based on current step's cells:
    for x in range(WIDTH):
        for y in range(HEIGHT):
            # Get neighboring coordinates:
```

```
            # `% WIDTH` ensures leftCoord is always between 0 and WIDTH - 1
            leftCoord  = (x - 1) % WIDTH
            rightCoord = (x + 1) % WIDTH
            aboveCoord = (y - 1) % HEIGHT
            belowCoord = (y + 1) % HEIGHT
```

Next, we need to use two nested `for` loops to calculate each cell for the next step. The living or dead state of the cell depends on the neighbors, so let's first calculate the index of the cells to the left, right, above, and below the current x- and y-coordinates.

The `%` mod operator performs a "wraparound." The left neighbor of a cell in the leftmost column `0` would be `0 - 1` or `-1`. To wrap this around to the rightmost column's index, `59`, we calculate `(0 - 1) % WIDTH`. Since `WIDTH` is `60`, this expression evaluates to `59`. This mod-wraparound technique works for the right, above, and below neighbors as well.

```
            # Count number of living neighbors:
            numNeighbors = 0
            if currentCells[leftCoord][aboveCoord] == '#':
                numNeighbors += 1 # Top-left neighbor is alive.
            if currentCells[x][aboveCoord] == '#':
                numNeighbors += 1 # Top neighbor is alive.
            if currentCells[rightCoord][aboveCoord] == '#':
                numNeighbors += 1 # Top-right neighbor is alive.
            if currentCells[leftCoord][y] == '#':
                numNeighbors += 1 # Left neighbor is alive.
            if currentCells[rightCoord][y] == '#':
                numNeighbors += 1 # Right neighbor is alive.
            if currentCells[leftCoord][belowCoord] == '#':
                numNeighbors += 1 # Bottom-left neighbor is alive.
            if currentCells[x][belowCoord] == '#':
                numNeighbors += 1 # Bottom neighbor is alive.
            if currentCells[rightCoord][belowCoord] == '#':
                numNeighbors += 1 # Bottom-right neighbor is alive.
```

To decide if the cell at `nextCells[x][y]` should be living or dead, we need to count the number of living neighbors `currentCells[x][y]` has. This series of `if` statements checks each of the eight neighbors of this cell, and adds `1` to `numNeighbors` for each living one.

```
            # Set cell based on Conway's Game of Life rules:
            if currentCells[x][y] == '#' and (numNeighbors == 2 or
numNeighbors == 3):
                # Living cells with 2 or 3 neighbors stay alive:
                nextCells[x][y] = '#'
            elif currentCells[x][y] == ' ' and numNeighbors == 3:
                # Dead cells with 3 neighbors become alive:
                nextCells[x][y] = '#'
            else:
                # Everything else dies or stays dead:
                nextCells[x][y] = ' '
    time.sleep(1) # Add a 1-second pause to reduce flickering.
```

Now that we know the number of living neighbors for the cell at currentCells[x][y], we can set nextCells[x][y] to either '#' or ' '. After we loop over every possible x- and y-coordinate, the program takes a 1-second pause by calling time.sleep(1). Then the program execution goes back to the start of the main program loop to continue with the next step.

Several patterns have been discovered with names such as "glider," "propeller," or "heavyweight spaceship." The glider pattern, pictured in Figure 4-8, results in a pattern that "moves" diagonally every four steps. You can create a single glider by replacing this line in our *conway.py* program:

```
        if random.randint(0, 1) == 0:
```

with this line:

```
        if (x, y) in ((1, 0), (2, 1), (0, 2), (1, 2), (2, 2)):
```

You can find out more about the intriguing devices made using Conway's Game of Life by searching the web. And you can find other short, text-based Python programs like this one at *https://github.com/asweigart/pythonstdiogames*.

Summary

Lists are useful data types since they allow you to write code that works on a modifiable number of values in a single variable. Later in this book, you will see programs using lists to do things that would be difficult or impossible to do without them.

Lists are a sequence data type that is mutable, meaning that their contents can change. Tuples and strings, though also sequence data types, are immutable and cannot be changed. A variable that contains a tuple or string value can be overwritten with a new tuple or string value, but this is not the same thing as modifying the existing value in place—like, say, the append() or remove() methods do on lists.

Variables do not store list values directly; they store *references* to lists. This is an important distinction when you are copying variables or passing lists as arguments in function calls. Because the value that is being copied is the list reference, be aware that any changes you make to the list might impact another variable in your program. You can use copy() or deepcopy() if you want to make changes to a list in one variable without modifying the original list.

Practice Questions

1. What is []?
2. How would you assign the value 'hello' as the third value in a list stored in a variable named spam? (Assume spam contains [2, 4, 6, 8, 10].)

For the following three questions, let's say spam contains the list ['a', 'b', 'c', 'd'].

3. What does spam[int(int('3' * 2) // 11)] evaluate to?
4. What does spam[-1] evaluate to?
5. What does spam[:2] evaluate to?

For the following three questions, let's say bacon contains the list [3.14, 'cat', 11, 'cat', True].

6. What does bacon.index('cat') evaluate to?
7. What does bacon.append(99) make the list value in bacon look like?
8. What does bacon.remove('cat') make the list value in bacon look like?
9. What are the operators for list concatenation and list replication?
10. What is the difference between the append() and insert() list methods?
11. What are two ways to remove values from a list?
12. Name a few ways that list values are similar to string values.
13. What is the difference between lists and tuples?
14. How do you type the tuple value that has just the integer value 42 in it?
15. How can you get the tuple form of a list value? How can you get the list form of a tuple value?
16. Variables that "contain" list values don't actually contain lists directly. What do they contain instead?
17. What is the difference between copy.copy() and copy.deepcopy()?

Practice Projects

For practice, write programs to do the following tasks.

Comma Code

Say you have a list value like this:

```
spam = ['apples', 'bananas', 'tofu', 'cats']
```

Write a function that takes a list value as an argument and returns a string with all the items separated by a comma and a space, with *and* inserted before the last item. For example, passing the previous spam list to the function would return 'apples, bananas, tofu, and cats'. But your function should be able to work with any list value passed to it. Be sure to test the case where an empty list [] is passed to your function.

Coin Flip Streaks

For this exercise, we'll try doing an experiment. If you flip a coin 100 times and write down an "H" for each heads and "T" for each tails, you'll create a list that looks like "T T T T H H H H T T." If you ask a human to make up 100 random coin flips, you'll probably end up with alternating head-tail results like "H T H T H H T H T T," which looks random (to humans), but isn't mathematically random. A human will almost never write down a streak of six heads or six tails in a row, even though it is highly likely to happen in truly random coin flips. Humans are predictably bad at being random.

Write a program to find out how often a streak of six heads or a streak of six tails comes up in a randomly generated list of heads and tails. Your program breaks up the experiment into two parts: the first part generates a list of randomly selected `'heads'` and `'tails'` values, and the second part checks if there is a streak in it. Put all of this code in a loop that repeats the experiment 10,000 times so we can find out what percentage of the coin flips contains a streak of six heads or tails in a row. As a hint, the function call `random.randint(0, 1)` will return a `0` value 50% of the time and a `1` value the other 50% of the time.

You can start with the following template:

```
import random
numberOfStreaks = 0
for experimentNumber in range(10000):
    # Code that creates a list of 100 'heads' or 'tails' values.

    # Code that checks if there is a streak of 6 heads or tails in a row.
print('Chance of streak: %s%%' % (numberOfStreaks / 100))
```

Of course, this is only an estimate, but 10,000 is a decent sample size. Some knowledge of mathematics could give you the exact answer and save you the trouble of writing a program, but programmers are notoriously bad at math.

Character Picture Grid

Say you have a list of lists where each value in the inner lists is a one-character string, like this:

```
grid = [['.', '.', '.', '.', '.', '.'],
        ['.', 'O', 'O', '.', '.', '.'],
        ['O', 'O', 'O', 'O', '.', '.'],
        ['O', 'O', 'O', 'O', 'O', '.'],
        ['.', 'O', 'O', 'O', 'O', 'O'],
        ['O', 'O', 'O', 'O', 'O', '.'],
        ['O', 'O', 'O', 'O', '.', '.'],
        ['.', 'O', 'O', '.', '.', '.'],
        ['.', '.', '.', '.', '.', '.']]
```

Think of `grid[x][y]` as being the character at the x- and y-coordinates of a "picture" drawn with text characters. The `(0, 0)` origin is in the upper-left corner, the x-coordinates increase going right, and the y-coordinates increase going down.

Copy the previous grid value, and write code that uses it to print the image.

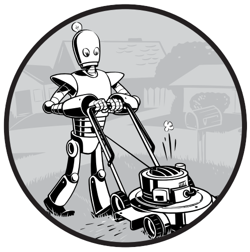
```
..OO.OO..
.OOOOOOO.
.OOOOOOO.
..OOOOO..
...OOO...
....O....
```

Hint: You will need to use a loop in a loop in order to print `grid[0][0]`, then `grid[1][0]`, then `grid[2][0]`, and so on, up to `grid[8][0]`. This will finish the first row, so then print a newline. Then your program should print `grid[0][1]`, then `grid[1][1]`, then `grid[2][1]`, and so on. The last thing your program will print is `grid[8][5]`.

Also, remember to pass the `end` keyword argument to `print()` if you don't want a newline printed automatically after each `print()` call.

5

DICTIONARIES AND STRUCTURING DATA



In this chapter, I will cover the dictionary data type, which provides a flexible way to access and organize data. Then, combining dictionaries with your knowledge of lists from the previous chapter, you'll learn how to create a data structure to model a tic-tac-toe board.

The Dictionary Data Type

Like a list, a *dictionary* is a mutable collection of many values. But unlike indexes for lists, indexes for dictionaries can use many different data types, not just integers. Indexes for dictionaries are called *keys*, and a key with its associated value is called a *key-value pair*.

In code, a dictionary is typed with braces, {}. Enter the following into the interactive shell:

```
>>> myCat = {'size': 'fat', 'color': 'gray', 'disposition': 'loud'}
```

This assigns a dictionary to the myCat variable. This dictionary's keys are 'size', 'color', and 'disposition'. The values for these keys are 'fat', 'gray', and 'loud', respectively. You can access these values through their keys:

```
>>> myCat['size']
'fat'
>>> 'My cat has ' + myCat['color'] + ' fur.'
'My cat has gray fur.'
```

Dictionaries can still use integer values as keys, just like lists use integers for indexes, but they do not have to start at 0 and can be any number.

```
>>> spam = {12345: 'Luggage Combination', 42: 'The Answer'}
```

Dictionaries vs. Lists

Unlike lists, items in dictionaries are unordered. The first item in a list named spam would be spam[0]. But there is no "first" item in a dictionary. While the order of items matters for determining whether two lists are the same, it does not matter in what order the key-value pairs are typed in a dictionary. Enter the following into the interactive shell:

```
>>> spam = ['cats', 'dogs', 'moose']
>>> bacon = ['dogs', 'moose', 'cats']
>>> spam == bacon
False
>>> eggs = {'name': 'Zophie', 'species': 'cat', 'age': '8'}
>>> ham = {'species': 'cat', 'age': '8', 'name': 'Zophie'}
>>> eggs == ham
True
```

Because dictionaries are not ordered, they can't be sliced like lists.

Trying to access a key that does not exist in a dictionary will result in a KeyError error message, much like a list's "out-of-range" IndexError error message. Enter the following into the interactive shell, and notice the error message that shows up because there is no 'color' key:

```
>>> spam = {'name': 'Zophie', 'age': 7}
>>> spam['color']
Traceback (most recent call last):
  File "<pyshell#1>", line 1, in <module>
    spam['color']
KeyError: 'color'
```

Though dictionaries are not ordered, the fact that you can have arbitrary values for the keys allows you to organize your data in powerful ways. Say you wanted your program to store data about your friends' birthdays. You can use a dictionary with the names as keys and the birthdays as values. Open a new file editor window and enter the following code. Save it as *birthdays.py*.

```
❶ birthdays = {'Alice': 'Apr 1', 'Bob': 'Dec 12', 'Carol': 'Mar 4'}

  while True:
      print('Enter a name: (blank to quit)')
      name = input()
      if name == '':
          break

    ❷ if name in birthdays:
        ❸ print(birthdays[name] + ' is the birthday of ' + name)
      else:
          print('I do not have birthday information for ' + name)
          print('What is their birthday?')
          bday = input()
        ❹ birthdays[name] = bday
          print('Birthday database updated.')
```

You can view the execution of this program at *https://autbor.com/bdaydb*. You create an initial dictionary and store it in `birthdays` ❶. You can see if the entered name exists as a key in the dictionary with the `in` keyword ❷, just as you did for lists. If the name is in the dictionary, you access the associated value using square brackets ❸; if not, you can add it using the same square bracket syntax combined with the assignment operator ❹.

When you run this program, it will look like this:

```
Enter a name: (blank to quit)
Alice
Apr 1 is the birthday of Alice
Enter a name: (blank to quit)
Eve
I do not have birthday information for Eve
What is their birthday?
Dec 5
Birthday database updated.
Enter a name: (blank to quit)
Eve
Dec 5 is the birthday of Eve
Enter a name: (blank to quit)
```

Of course, all the data you enter in this program is forgotten when the program terminates. You'll learn how to save data to files on the hard drive in Chapter 9.

ORDERED DICTIONARIES IN PYTHON 3.7

While they're still not ordered and have no "first" key-value pair, dictionaries in Python 3.7 and later will remember the insertion order of their key-value pairs if you create a sequence value from them. For example, notice the order of items in the lists made from the eggs and ham dictionaries matches the order in which they were entered:

```
>>> eggs = {'name': 'Zophie', 'species': 'cat', 'age': '8'}
>>> list(eggs)
['name', 'species', 'age']
>>> ham = {'species': 'cat', 'age': '8', 'name': 'Zophie'}
>>> list(ham)
['species', 'age', 'name']
```

The dictionaries are still unordered, as you can't access items in them using integer indexes like eggs[0] or ham[2]. You shouldn't rely on this behavior, as dictionaries in older versions of Python don't remember the insertion order of key-value pairs. For example, notice how the list doesn't match the insertion order of the dictionary's key-value pairs when I run this code in Python 3.5:

```
>>> spam = {}
>>> spam['first key'] = 'value'
>>> spam['second key'] = 'value'
>>> spam['third key'] = 'value'
>>> list(spam)
['first key', 'third key', 'second key']
```

The keys(), values(), and items() Methods

There are three dictionary methods that will return list-like values of the dictionary's keys, values, or both keys and values: keys(), values(), and items(). The values returned by these methods are not true lists: they cannot be modified and do not have an append() method. But these data types (dict_keys, dict_values, and dict_items, respectively) *can* be used in for loops. To see how these methods work, enter the following into the interactive shell:

```
>>> spam = {'color': 'red', 'age': 42}
>>> for v in spam.values():
...     print(v)

red
42
```

Here, a for loop iterates over each of the values in the spam dictionary. A for loop can also iterate over the keys or both keys and values:

```
>>> for k in spam.keys():
...     print(k)

color
age
>>> for i in spam.items():
...     print(i)

('color', 'red')
('age', 42)
```

When you use the keys(), values(), and items() methods, a for loop can iterate over the keys, values, or key-value pairs in a dictionary, respectively. Notice that the values in the dict_items value returned by the items() method are tuples of the key and value.

If you want a true list from one of these methods, pass its list-like return value to the list() function. Enter the following into the interactive shell:

```
>>> spam = {'color': 'red', 'age': 42}
>>> spam.keys()
dict_keys(['color', 'age'])
>>> list(spam.keys())
['color', 'age']
```

The list(spam.keys()) line takes the dict_keys value returned from keys() and passes it to list(), which then returns a list value of ['color', 'age'].

You can also use the multiple assignment trick in a for loop to assign the key and value to separate variables. Enter the following into the interactive shell:

```
>>> spam = {'color': 'red', 'age': 42}
>>> for k, v in spam.items():
...     print('Key: ' + k + ' Value: ' + str(v))

Key: age Value: 42
Key: color Value: red
```

Checking Whether a Key or Value Exists in a Dictionary

Recall from the previous chapter that the in and not in operators can check whether a value exists in a list. You can also use these operators to see whether a certain key or value exists in a dictionary. Enter the following into the interactive shell:

```
>>> spam = {'name': 'Zophie', 'age': 7}
>>> 'name' in spam.keys()
True
```

```
>>> 'Zophie' in spam.values()
True
>>> 'color' in spam.keys()
False
>>> 'color' not in spam.keys()
True
>>> 'color' in spam
False
```

In the previous example, notice that `'color' in spam` is essentially a shorter version of writing `'color' in spam.keys()`. This is always the case: if you ever want to check whether a value is (or isn't) a key in the dictionary, you can simply use the `in` (or `not in`) keyword with the dictionary value itself.

The get() Method

It's tedious to check whether a key exists in a dictionary before accessing that key's value. Fortunately, dictionaries have a `get()` method that takes two arguments: the key of the value to retrieve and a fallback value to return if that key does not exist.

Enter the following into the interactive shell:

```
>>> picnicItems = {'apples': 5, 'cups': 2}
>>> 'I am bringing ' + str(picnicItems.get('cups', 0)) + ' cups.'
'I am bringing 2 cups.'
>>> 'I am bringing ' + str(picnicItems.get('eggs', 0)) + ' eggs.'
'I am bringing 0 eggs.'
```

Because there is no `'eggs'` key in the `picnicItems` dictionary, the default value `0` is returned by the `get()` method. Without using `get()`, the code would have caused an error message, such as in the following example:

```
>>> picnicItems = {'apples': 5, 'cups': 2}
>>> 'I am bringing ' + str(picnicItems['eggs']) + ' eggs.'
Traceback (most recent call last):
  File "<pyshell#34>", line 1, in <module>
    'I am bringing ' + str(picnicItems['eggs']) + ' eggs.'
KeyError: 'eggs'
```

The setdefault() Method

You'll often have to set a value in a dictionary for a certain key only if that key does not already have a value. The code looks something like this:

```
spam = {'name': 'Pooka', 'age': 5}
if 'color' not in spam:
    spam['color'] = 'black'
```

The `setdefault()` method offers a way to do this in one line of code. The first argument passed to the method is the key to check for, and the second argument is the value to set at that key if the key does not exist. If the key does exist, the `setdefault()` method returns the key's value. Enter the following into the interactive shell:

```
>>> spam = {'name': 'Pooka', 'age': 5}
>>> spam.setdefault('color', 'black')
'black'
>>> spam
{'color': 'black', 'age': 5, 'name': 'Pooka'}
>>> spam.setdefault('color', 'white')
'black'
>>> spam
{'color': 'black', 'age': 5, 'name': 'Pooka'}
```

The first time `setdefault()` is called, the dictionary in `spam` changes to `{'color': 'black', 'age': 5, 'name': 'Pooka'}`. The method returns the value `'black'` because this is now the value set for the key `'color'`. When `spam.setdefault('color', 'white')` is called next, the value for that key is *not* changed to `'white'`, because `spam` already has a key named `'color'`.

The `setdefault()` method is a nice shortcut to ensure that a key exists. Here is a short program that counts the number of occurrences of each letter in a string. Open the file editor window and enter the following code, saving it as *characterCount.py*:

```
message = 'It was a bright cold day in April, and the clocks were striking
thirteen.'
count = {}

for character in message:
❶ count.setdefault(character, 0)
❷ count[character] = count[character] + 1

print(count)
```

You can view the execution of this program at *https://autbor.com/setdefault*. The program loops over each character in the `message` variable's string, counting how often each character appears. The `setdefault()` method call ❶ ensures that the key is in the `count` dictionary (with a default value of `0`) so the program doesn't throw a `KeyError` error when `count[character] = count[character] + 1` is executed ❷. When you run this program, the output will look like this:

```
{' ': 13, ',': 1, '.': 1, 'A': 1, 'I': 1, 'a': 4, 'c': 3, 'b': 1, 'e': 5, 'd': 3, 'g': 2,
'i': 6, 'h': 3, 'k': 2, 'l': 3, 'o': 2, 'n': 4, 'p': 1, 's': 3, 'r': 5, 't': 6, 'w': 2, 'y': 1}
```

From the output, you can see that the lowercase letter *c* appears 3 times, the space character appears 13 times, and the uppercase letter *A* appears 1 time. This program will work no matter what string is inside the `message` variable, even if the string is millions of characters long!

Pretty Printing

If you import the `pprint` module into your programs, you'll have access to the `pprint()` and `pformat()` functions that will "pretty print" a dictionary's values. This is helpful when you want a cleaner display of the items in a dictionary than what `print()` provides. Modify the previous *characterCount.py* program and save it as *prettyCharacterCount.py*.

```
import pprint
message = 'It was a bright cold day in April, and the clocks were striking
thirteen.'
count = {}

for character in message:
    count.setdefault(character, 0)
    count[character] = count[character] + 1

pprint.pprint(count)
```

You can view the execution of this program at *https://autbor.com/pprint/*. This time, when the program is run, the output looks much cleaner, with the keys sorted.

```
{' ': 13,
 ',': 1,
 '.': 1,
 'A': 1,
 'I': 1,
 --snip--
 't': 6,
 'w': 2,
 'y': 1}
```

The `pprint.pprint()` function is especially helpful when the dictionary itself contains nested lists or dictionaries.

If you want to obtain the prettified text as a string value instead of displaying it on the screen, call `pprint.pformat()` instead. These two lines are equivalent to each other:

```
pprint.pprint(someDictionaryValue)
print(pprint.pformat(someDictionaryValue))
```

Using Data Structures to Model Real-World Things

Even before the internet, it was possible to play a game of chess with someone on the other side of the world. Each player would set up a chessboard at their home and then take turns mailing a postcard to each other describing each move. To do this, the players needed a way to unambiguously describe the state of the board and their moves.

In *algebraic chess notation*, the spaces on the chessboard are identified by a number and letter coordinate, as in Figure 5-1.

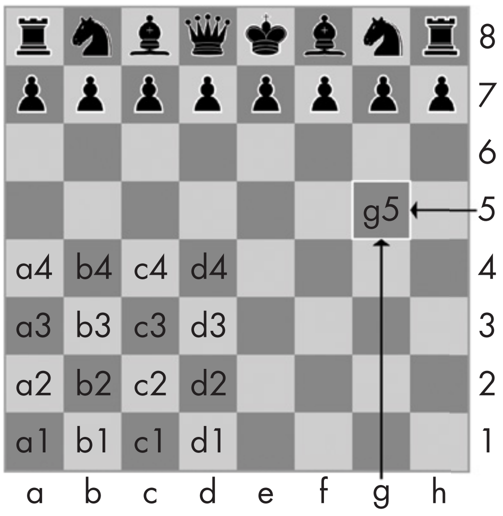


Figure 5-1: The coordinates of a chessboard in algebraic chess notation

The chess pieces are identified by letters: *K* for king, *Q* for queen, *R* for rook, *B* for bishop, and *N* for knight. Describing a move uses the letter of the piece and the coordinates of its destination. A pair of these moves describes what happens in a single turn (with white going first); for instance, the notation *2. Nf3 Nc6* indicates that white moved a knight to f3 and black moved a knight to c6 on the second turn of the game.

There's a bit more to algebraic notation than this, but the point is that you can unambiguously describe a game of chess without needing to be in front of a chessboard. Your opponent can even be on the other side of the world! In fact, you don't even need a physical chess set if you have a good memory: you can just read the mailed chess moves and update boards you have in your imagination.

Computers have good memories. A program on a modern computer can easily store billions of strings like `'2. Nf3 Nc6'`. This is how computers can play chess without having a physical chessboard. They model data to represent a chessboard, and you can write code to work with this model.

This is where lists and dictionaries can come in. For example, the dictionary `{'1h': 'bking', '6c': 'wqueen', '2g': 'bbishop', '5h': 'bqueen', '3e': 'wking'}` could represent the chess board in Figure 5-2.

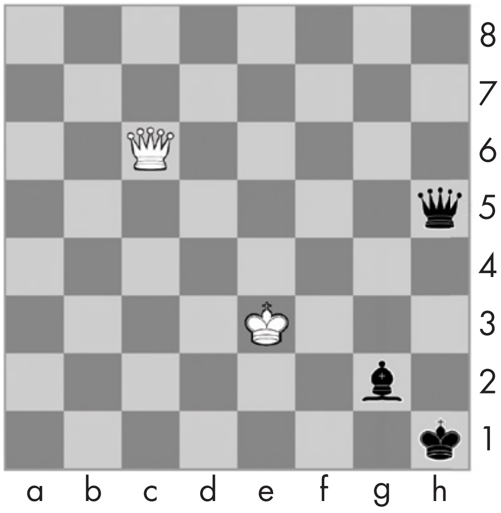


Figure 5-2: A chess board modeled by the dictionary
{'1h': 'bking', '6c': 'wqueen', '2g': 'bbishop', '5h': 'bqueen', '3e': 'wking'}

But for another example, you'll use a game that's a little simpler than chess: tic-tac-toe.

A Tic-Tac-Toe Board

A tic-tac-toe board looks like a large hash symbol (#) with nine slots that can each contain an *X*, an *O*, or a blank. To represent the board with a dictionary, you can assign each slot a string-value key, as shown in Figure 5-3.

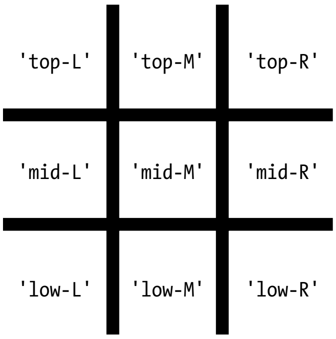


Figure 5-3: The slots of a tic-tac-toe board with their corresponding keys

You can use string values to represent what's in each slot on the board: `'X'`, `'O'`, or `' '` (a space). Thus, you'll need to store nine strings. You can use a dictionary of values for this. The string value with the key `'top-R'` can represent the top-right corner, the string value with the key `'low-L'` can represent the bottom-left corner, the string value with the key `'mid-M'` can represent the middle, and so on.

This dictionary is a data structure that represents a tic-tac-toe board. Store this board-as-a-dictionary in a variable named `theBoard`. Open a new file editor window, and enter the following source code, saving it as *ticTacToe.py*:

```
theBoard = {'top-L': ' ', 'top-M': ' ', 'top-R': ' ',
            'mid-L': ' ', 'mid-M': ' ', 'mid-R': ' ',
            'low-L': ' ', 'low-M': ' ', 'low-R': ' '}
```

The data structure stored in the `theBoard` variable represents the tic-tac-toe board in Figure 5-4.

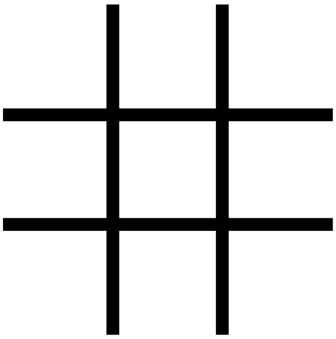


Figure 5-4: An empty tic-tac-toe board

Since the value for every key in `theBoard` is a single-space string, this dictionary represents a completely clear board. If player X went first and chose the middle space, you could represent that board with this dictionary:

```
theBoard = {'top-L': ' ', 'top-M': ' ', 'top-R': ' ',
            'mid-L': ' ', 'mid-M': 'X', 'mid-R': ' ',
            'low-L': ' ', 'low-M': ' ', 'low-R': ' '}
```

The data structure in `theBoard` now represents the tic-tac-toe board in Figure 5-5.

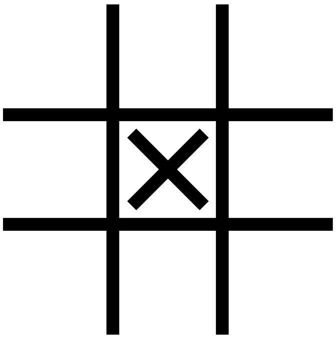


Figure 5-5: The first move

A board where player O has won by placing *O*s across the top might look like this:

```
theBoard = {'top-L': 'O', 'top-M': 'O', 'top-R': 'O',
            'mid-L': 'X', 'mid-M': 'X', 'mid-R': ' ',
            'low-L': ' ', 'low-M': ' ', 'low-R': 'X'}
```

The data structure in theBoard now represents the tic-tac-toe board in Figure 5-6.

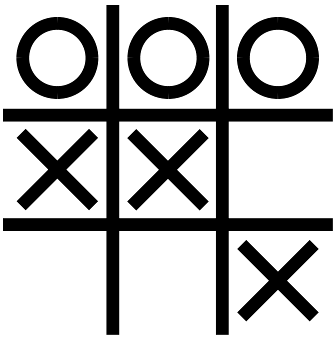


Figure 5-6: Player O wins.

Of course, the player sees only what is printed to the screen, not the contents of variables. Let's create a function to print the board dictionary onto the screen. Make the following addition to *ticTacToe.py* (new code is in bold):

```
theBoard = {'top-L': ' ', 'top-M': ' ', 'top-R': ' ',
            'mid-L': ' ', 'mid-M': ' ', 'mid-R': ' ',
            'low-L': ' ', 'low-M': ' ', 'low-R': ' '}
def printBoard(board):
    print(board['top-L'] + '|' + board['top-M'] + '|' + board['top-R'])
    print('-+-+-')
    print(board['mid-L'] + '|' + board['mid-M'] + '|' + board['mid-R'])
    print('-+-+-')
    print(board['low-L'] + '|' + board['low-M'] + '|' + board['low-R'])
printBoard(theBoard)
```

You can view the execution of this program at *https://autbor.com/tictactoe1/*. When you run this program, printBoard() will print out a blank tic-tac-toe board.

```
 | |
-+-+-
 | |
-+-+-
 | |
```

The printBoard() function can handle any tic-tac-toe data structure you pass it. Try changing the code to the following:

```
theBoard = {'top-L': 'O', 'top-M': 'O', 'top-R': 'O', 'mid-L': 'X', 'mid-M':
'X', 'mid-R': ' ', 'low-L': ' ', 'low-M': ' ', 'low-R': 'X'}

def printBoard(board):
    print(board['top-L'] + '|' + board['top-M'] + '|' + board['top-R'])
    print('-+-+-')
    print(board['mid-L'] + '|' + board['mid-M'] + '|' + board['mid-R'])
    print('-+-+-')
    print(board['low-L'] + '|' + board['low-M'] + '|' + board['low-R'])
printBoard(theBoard)
```

You can view the execution of this program at *https://autbor.com/tictactoe2/*. Now when you run this program, the new board will be printed to the screen.

```
O|O|O
-+-+-
X|X|
-+-+-
 | |X
```

Because you created a data structure to represent a tic-tac-toe board and wrote code in printBoard() to interpret that data structure, you now have a program that "models" the tic-tac-toe board. You could have organized your data structure differently (for example, using keys like 'TOP-LEFT' instead of 'top-L'), but as long as the code works with your data structures, you will have a correctly working program.

For example, the printBoard() function expects the tic-tac-toe data structure to be a dictionary with keys for all nine slots. If the dictionary you passed was missing, say, the 'mid-L' key, your program would no longer work.

```
O|O|O
-+-+-
Traceback (most recent call last):
  File "ticTacToe.py", line 10, in <module>
    printBoard(theBoard)
  File "ticTacToe.py", line 6, in printBoard
    print(board['mid-L'] + '|' + board['mid-M'] + '|' + board['mid-R'])
KeyError: 'mid-L'
```

Now let's add code that allows the players to enter their moves. Modify the *ticTacToe.py* program to look like this:

```
theBoard = {'top-L': ' ', 'top-M': ' ', 'top-R': ' ', 'mid-L': ' ', 'mid-M': '
', 'mid-R': ' ', 'low-L': ' ', 'low-M': ' ', 'low-R': ' '}

def printBoard(board):
    print(board['top-L'] + '|' + board['top-M'] + '|' + board['top-R'])
    print('-+-+-')
    print(board['mid-L'] + '|' + board['mid-M'] + '|' + board['mid-R'])
    print('-+-+-')
    print(board['low-L'] + '|' + board['low-M'] + '|' + board['low-R'])
turn = 'X'
for i in range(9):
 ❶ printBoard(theBoard)
    print('Turn for ' + turn + '. Move on which space?')
 ❷ move = input()
 ❸ theBoard[move] = turn
 ❹ if turn == 'X':
        turn = 'O'
    else:
        turn = 'X'
printBoard(theBoard)
```

You can view the execution of this program at *https://autbor.com/tictactoe3/*. The new code prints out the board at the start of each new turn ❶, gets the active player's move ❷, updates the game board accordingly ❸, and then swaps the active player ❹ before moving on to the next turn.

When you run this program, it will look something like this:

```
 | |
-+-+-
 | |
-+-+-
 | |
Turn for X. Move on which space?
mid-M
 | |
-+-+-
 |X|
-+-+-
 | |

--snip--

O|O|X
-+-+-
X|X|O
-+-+-
O| |X
Turn for X. Move on which space?
low-M
O|O|X
-+-+-
X|X|O
-+-+-
O|X|X
```

This isn't a complete tic-tac-toe game—for instance, it doesn't ever check whether a player has won—but it's enough to see how data structures can be used in programs.

NOTE *If you are curious, the source code for a complete tic-tac-toe program is described in the resources available from* https://nostarch.com/automatestuff2/.

Nested Dictionaries and Lists

Modeling a tic-tac-toe board was fairly simple: the board needed only a single dictionary value with nine key-value pairs. As you model more complicated things, you may find you need dictionaries and lists that contain other dictionaries and lists. Lists are useful to contain an ordered series of values, and dictionaries are useful for associating keys with values. For example, here's a program that uses a dictionary that contains other dictionaries of what items guests are bringing to a picnic. The `totalBrought()` function can read this data structure and calculate the total number of an item being brought by all the guests.

```
allGuests = {'Alice': {'apples': 5, 'pretzels': 12},
             'Bob': {'ham sandwiches': 3, 'apples': 2},
             'Carol': {'cups': 3, 'apple pies': 1}}

def totalBrought(guests, item):
    numBrought = 0
 ❶ for k, v in guests.items():
     ❷ numBrought = numBrought + v.get(item, 0)
    return numBrought

print('Number of things being brought:')
print(' - Apples         ' + str(totalBrought(allGuests, 'apples')))
print(' - Cups           ' + str(totalBrought(allGuests, 'cups')))
print(' - Cakes          ' + str(totalBrought(allGuests, 'cakes')))
print(' - Ham Sandwiches ' + str(totalBrought(allGuests, 'ham sandwiches')))
print(' - Apple Pies     ' + str(totalBrought(allGuests, 'apple pies')))
```

You can view the execution of this program at *https://autbor.com/guestpicnic/*. Inside the `totalBrought()` function, the `for` loop iterates over the key-value pairs in `guests` ❶. Inside the loop, the string of the guest's name is assigned to `k`, and the dictionary of picnic items they're bringing is assigned to `v`. If the item parameter exists as a key in this dictionary, its value (the quantity) is added to `numBrought` ❷. If it does not exist as a key, the `get()` method returns `0` to be added to `numBrought`.

The output of this program looks like this:

```
Number of things being brought:
- Apples 7
- Cups 3
- Cakes 0
- Ham Sandwiches 3
- Apple Pies 1
```

This may seem like such a simple thing to model that you wouldn't need to bother with writing a program to do it. But realize that this same `totalBrought()` function could easily handle a dictionary that contains thousands of guests, each bringing *thousands* of different picnic items. Then having this information in a data structure along with the `totalBrought()` function would save you a lot of time!

You can model things with data structures in whatever way you like, as long as the rest of the code in your program can work with the data model correctly. When you first begin programming, don't worry so much about the "right" way to model data. As you gain more experience, you may come up with more efficient models, but the important thing is that the data model works for your program's needs.

Summary

You learned all about dictionaries in this chapter. Lists and dictionaries are values that can contain multiple values, including other lists and dictionaries. Dictionaries are useful because you can map one item (the key) to another (the value), as opposed to lists, which simply contain a series of values in order. Values inside a dictionary are accessed using square brackets just as with lists. Instead of an integer index, dictionaries can have keys of a variety of data types: integers, floats, strings, or tuples. By organizing a program's values into data structures, you can create representations of real-world objects. You saw an example of this with a tic-tac-toe board.

Practice Questions

1. What does the code for an empty dictionary look like?
2. What does a dictionary value with a key `'foo'` and a value `42` look like?
3. What is the main difference between a dictionary and a list?
4. What happens if you try to access `spam['foo']` if `spam` is `{'bar': 100}`?
5. If a dictionary is stored in `spam`, what is the difference between the expressions `'cat' in spam` and `'cat' in spam.keys()`?
6. If a dictionary is stored in `spam`, what is the difference between the expressions `'cat' in spam` and `'cat' in spam.values()`?
7. What is a shortcut for the following code?

```
if 'color' not in spam:
    spam['color'] = 'black'
```

8. What module and function can be used to "pretty print" dictionary values?

Practice Projects

For practice, write programs to do the following tasks.

Chess Dictionary Validator

In this chapter, we used the dictionary value `{'1h': 'bking', '6c': 'wqueen', '2g': 'bbishop', '5h': 'bqueen', '3e': 'wking'}` to represent a chess board. Write a function named `isValidChessBoard()` that takes a dictionary argument and returns `True` or `False` depending on if the board is valid.

A valid board will have exactly one black king and exactly one white king. Each player can only have at most 16 pieces, at most 8 pawns, and all pieces must be on a valid space from `'1a'` to `'8h'`; that is, a piece can't be on space `'9z'`. The piece names begin with either a `'w'` or `'b'` to represent white or black, followed by `'pawn'`, `'knight'`, `'bishop'`, `'rook'`, `'queen'`, or `'king'`. This function should detect when a bug has resulted in an improper chess board.

Fantasy Game Inventory

You are creating a fantasy video game. The data structure to model the player's inventory will be a dictionary where the keys are string values describing the item in the inventory and the value is an integer value detailing how many of that item the player has. For example, the dictionary value `{'rope': 1, 'torch': 6, 'gold coin': 42, 'dagger': 1, 'arrow': 12}` means the player has 1 rope, 6 torches, 42 gold coins, and so on.

Write a function named `displayInventory()` that would take any possible "inventory" and display it like the following:

```
Inventory:
12 arrow
42 gold coin
1 rope
6 torch
1 dagger
Total number of items: 62
```

Hint: You can use a `for` loop to loop through all the keys in a dictionary.

```
# inventory.py
stuff = {'rope': 1, 'torch': 6, 'gold coin': 42, 'dagger': 1, 'arrow': 12}

def displayInventory(inventory):
    print("Inventory:")
    item_total = 0
    for k, v in inventory.items():
        # FILL THIS PART IN
    print("Total number of items: " + str(item_total))

displayInventory(stuff)
```

List to Dictionary Function for Fantasy Game Inventory

Imagine that a vanquished dragon's loot is represented as a list of strings like this:

```
dragonLoot = ['gold coin', 'dagger', 'gold coin', 'gold coin', 'ruby']
```

Write a function named `addToInventory(inventory, addedItems)`, where the `inventory` parameter is a dictionary representing the player's inventory (like in the previous project) and the `addedItems` parameter is a list like `dragonLoot`. The `addToInventory()` function should return a dictionary that represents the updated inventory. Note that the `addedItems` list can contain multiples of the same item. Your code could look something like this:

```
def addToInventory(inventory, addedItems):
    # your code goes here

inv = {'gold coin': 42, 'rope': 1}
dragonLoot = ['gold coin', 'dagger', 'gold coin', 'gold coin', 'ruby']
inv = addToInventory(inv, dragonLoot)
displayInventory(inv)
```

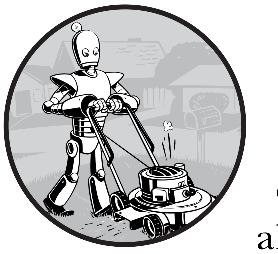
The previous program (with your `displayInventory()` function from the previous project) would output the following:

```
Inventory:
45 gold coin
1 rope
1 ruby
1 dagger

Total number of items: 48
```

6

MANIPULATING STRINGS



Text is one of the most common forms of data your programs will handle. You already know how to concatenate two string values together with the + operator, but you can do much more than that. You can extract partial strings from string values, add or remove spacing, convert letters to lowercase or uppercase, and check that strings are formatted correctly. You can even write Python code to access the clipboard for copying and pasting text.

In this chapter, you'll learn all this and more. Then you'll work through two different programming projects: a simple clipboard that stores multiple strings of text and a program to automate the boring chore of formatting pieces of text.

Working with Strings

Let's look at some of the ways Python lets you write, print, and access strings in your code.

String Literals

Typing string values in Python code is fairly straightforward: they begin and end with a single quote. But then how can you use a quote inside a string? Typing **`'That is Alice's cat.'`** won't work, because Python thinks the string ends after `Alice`, and the rest (`s cat.'`) is invalid Python code. Fortunately, there are multiple ways to type strings.

Double Quotes

Strings can begin and end with double quotes, just as they do with single quotes. One benefit of using double quotes is that the string can have a single quote character in it. Enter the following into the interactive shell:

```
>>> spam = "That is Alice's cat."
```

Since the string begins with a double quote, Python knows that the single quote is part of the string and not marking the end of the string. However, if you need to use both single quotes and double quotes in the string, you'll need to use escape characters.

Escape Characters

An *escape character* lets you use characters that are otherwise impossible to put into a string. An escape character consists of a backslash (`\`) followed by the character you want to add to the string. (Despite consisting of two characters, it is commonly referred to as a singular escape character.) For example, the escape character for a single quote is `\'`. You can use this inside a string that begins and ends with single quotes. To see how escape characters work, enter the following into the interactive shell:

```
>>> spam = 'Say hi to Bob\'s mother.'
```

Python knows that since the single quote in `Bob\'s` has a backslash, it is not a single quote meant to end the string value. The escape characters `\'` and `\"` let you put single quotes and double quotes inside your strings, respectively.

Table 6-1 lists the escape characters you can use.

Table 6-1: Escape Characters

Escape character	Prints as
`\'`	Single quote
`\"`	Double quote
`\t`	Tab
`\n`	Newline (line break)
`\\`	Backslash

Enter the following into the interactive shell:

```
>>> print("Hello there!\nHow are you?\nI\'m doing fine.")
Hello there!
How are you?
I'm doing fine.
```

Raw Strings

You can place an `r` before the beginning quotation mark of a string to make it a raw string. A *raw string* completely ignores all escape characters and prints any backslash that appears in the string. For example, enter the following into the interactive shell:

```
>>> print(r'That is Carol\'s cat.')
That is Carol\'s cat.
```

Because this is a raw string, Python considers the backslash as part of the string and not as the start of an escape character. Raw strings are helpful if you are typing string values that contain many backslashes, such as the strings used for Windows file paths like `r'C:\Users\Al\Desktop'` or regular expressions described in the next chapter.

Multiline Strings with Triple Quotes

While you can use the `\n` escape character to put a newline into a string, it is often easier to use multiline strings. A multiline string in Python begins and ends with either three single quotes or three double quotes. Any quotes, tabs, or newlines in between the "triple quotes" are considered part of the string. Python's indentation rules for blocks do not apply to lines inside a multiline string.

Open the file editor and write the following:

```
print('''Dear Alice,

Eve's cat has been arrested for catnapping, cat burglary, and extortion.

Sincerely,
Bob''')
```

Save this program as *catnapping.py* and run it. The output will look like this:

```
Dear Alice,

Eve's cat has been arrested for catnapping, cat burglary, and extortion.

Sincerely,
Bob
```

Notice that the single quote character in `Eve's` does not need to be escaped. Escaping single and double quotes is optional in multiline strings. The following `print()` call would print identical text but doesn't use a multiline string:

```
print('Dear Alice,\n\nEve\'s cat has been arrested for catnapping, cat
burglary, and extortion.\n\nSincerely,\nBob')
```

Multiline Comments

While the hash character (`#`) marks the beginning of a comment for the rest of the line, a multiline string is often used for comments that span multiple lines. The following is perfectly valid Python code:

```
"""This is a test Python program.
Written by Al Sweigart al@inventwithpython.com

This program was designed for Python 3, not Python 2.
"""

def spam():
    """This is a multiline comment to help
    explain what the spam() function does."""
    print('Hello!')
```

Indexing and Slicing Strings

Strings use indexes and slices the same way lists do. You can think of the string `'Hello, world!'` as a list and each character in the string as an item with a corresponding index.

```
'  H  e  l  l  o  ,     w  o  r  l  d  !  '
   0  1  2  3  4  5  6  7  8  9  10 11 12
```

The space and exclamation point are included in the character count, so `'Hello, world!'` is 13 characters long, from `H` at index 0 to `!` at index 12.

Enter the following into the interactive shell:

```
>>> spam = 'Hello, world!'
>>> spam[0]
'H'
>>> spam[4]
'o'
>>> spam[-1]
'!'
>>> spam[0:5]
'Hello'
>>> spam[:5]
'Hello'
>>> spam[7:]
'world!'
```

If you specify an index, you'll get the character at that position in the string. If you specify a range from one index to another, the starting index is included and the ending index is not. That's why, if `spam` is `'Hello, world!'`, `spam[0:5]` is `'Hello'`. The substring you get from `spam[0:5]` will include everything from `spam[0]` to `spam[4]`, leaving out the comma at index 5 and the space at index 6. This is similar to how `range(5)` will cause a `for` loop to iterate up to, but not including, `5`.

Note that slicing a string does not modify the original string. You can capture a slice from one variable in a separate variable. Try entering the following into the interactive shell:

```
>>> spam = 'Hello, world!'
>>> fizz = spam[0:5]
>>> fizz
'Hello'
```

By slicing and storing the resulting substring in another variable, you can have both the whole string and the substring handy for quick, easy access.

The in and not in Operators with Strings

The `in` and `not in` operators can be used with strings just like with list values. An expression with two strings joined using `in` or `not in` will evaluate to a Boolean `True` or `False`. Enter the following into the interactive shell:

```
>>> 'Hello' in 'Hello, World'
True
>>> 'Hello' in 'Hello'
True
>>> 'HELLO' in 'Hello, World'
False
>>> '' in 'spam'
True
>>> 'cats' not in 'cats and dogs'
False
```

These expressions test whether the first string (the exact string, case-sensitive) can be found within the second string.

Putting Strings Inside Other Strings

Putting strings inside other strings is a common operation in programming. So far, we've been using the + operator and string concatenation to do this:

```
>>> name = 'Al'
>>> age = 4000
>>> 'Hello, my name is ' + name + '. I am ' + str(age) + ' years old.'
'Hello, my name is Al. I am 4000 years old.'
```

However, this requires a lot of tedious typing. A simpler approach is to use *string interpolation*, in which the `%s` operator inside the string acts as a marker to be replaced by values following the string. One benefit of string interpolation is that `str()` doesn't have to be called to convert values to strings. Enter the following into the interactive shell:

```
>>> name = 'Al'
>>> age = 4000
>>> 'My name is %s. I am %s years old.' % (name, age)
'My name is Al. I am 4000 years old.'
```

Python 3.6 introduced *f-strings*, which is similar to string interpolation except that braces are used instead of `%s`, with the expressions placed directly inside the braces. Like raw strings, f-strings have an `f` prefix before the starting quotation mark. Enter the following into the interactive shell:

```
>>> name = 'Al'
>>> age = 4000
>>> f'My name is {name}. Next year I will be {age + 1}.'
'My name is Al. Next year I will be 4001.'
```

Remember to include the `f` prefix; otherwise, the braces and their contents will be a part of the string value:

```
>>> 'My name is {name}. Next year I will be {age + 1}.'
'My name is {name}. Next year I will be {age + 1}.'
```

Useful String Methods

Several string methods analyze strings or create transformed string values. This section describes the methods you'll be using most often.

The upper(), lower(), isupper(), and islower() Methods

The `upper()` and `lower()` string methods return a new string where all the letters in the original string have been converted to uppercase or lowercase, respectively. Nonletter characters in the string remain unchanged. Enter the following into the interactive shell:

```
>>> spam = 'Hello, world!'
>>> spam = spam.upper()
>>> spam
'HELLO, WORLD!'
>>> spam = spam.lower()
>>> spam
'hello, world!'
```

Note that these methods do not change the string itself but return new string values. If you want to change the original string, you have to call `upper()` or `lower()` on the string and then assign the new string to the variable where the original was stored. This is why you must use `spam = spam.upper()` to change the string in `spam` instead of simply `spam.upper()`. (This is just like if a variable `eggs` contains the value `10`. Writing `eggs + 3` does not change the value of `eggs`, but `eggs = eggs + 3` does.)

The `upper()` and `lower()` methods are helpful if you need to make a case-insensitive comparison. For example, the strings `'great'` and `'GREat'` are not equal to each other. But in the following small program, it does not matter whether the user types `Great`, `GREAT`, or `grEAT`, because the string is first converted to lowercase.

```
print('How are you?')
feeling = input()
if feeling.lower() == 'great':
    print('I feel great too.')
else:
    print('I hope the rest of your day is good.')
```

When you run this program, the question is displayed, and entering a variation on `great`, such as `GREat`, will still give the output `I feel great too`. Adding code to your program to handle variations or mistakes in user input, such as inconsistent capitalization, will make your programs easier to use and less likely to fail.

```
How are you?
GREat
I feel great too.
```

You can view the execution of this program at *https://autbor.com/convertlowercase/*. The `isupper()` and `islower()` methods will return a Boolean `True` value if the string has at least one letter and all the letters are uppercase or lowercase, respectively. Otherwise, the method returns False. Enter the following into the interactive shell, and notice what each method call returns:

```
>>> spam = 'Hello, world!'
>>> spam.islower()
False
>>> spam.isupper()
False
>>> 'HELLO'.isupper()
True
>>> 'abc12345'.islower()
True
>>> '12345'.islower()
False
>>> '12345'.isupper()
False
```

Since the upper() and lower() string methods themselves return strings, you can call string methods on *those* returned string values as well. Expressions that do this will look like a chain of method calls. Enter the following into the interactive shell:

```
>>> 'Hello'.upper()
'HELLO'
>>> 'Hello'.upper().lower()
'hello'
>>> 'Hello'.upper().lower().upper()
'HELLO'
>>> 'HELLO'.lower()
'hello'
>>> 'HELLO'.lower().islower()
True
```

The isX() Methods

Along with islower() and isupper(), there are several other string methods that have names beginning with the word *is*. These methods return a Boolean value that describes the nature of the string. Here are some common is*X* string methods:

isalpha() Returns True if the string consists only of letters and isn't blank

isalnum() Returns True if the string consists only of letters and numbers and is not blank

isdecimal() Returns True if the string consists only of numeric characters and is not blank

isspace() Returns True if the string consists only of spaces, tabs, and newlines and is not blank

istitle() Returns True if the string consists only of words that begin with an uppercase letter followed by only lowercase letters

Enter the following into the interactive shell:

```
>>> 'hello'.isalpha()
True
>>> 'hello123'.isalpha()
False
>>> 'hello123'.isalnum()
True
>>> 'hello'.isalnum()
True
>>> '123'.isdecimal()
True
>>> '    '.isspace()
True
>>> 'This Is Title Case'.istitle()
True
>>> 'This Is Title Case 123'.istitle()
True
>>> 'This Is not Title Case'.istitle()
False
>>> 'This Is NOT Title Case Either'.istitle()
False
```

The is*X()* string methods are helpful when you need to validate user input. For example, the following program repeatedly asks users for their age and a password until they provide valid input. Open a new file editor window and enter this program, saving it as *validateInput.py*:

```
while True:
    print('Enter your age:')
    age = input()
    if age.isdecimal():
        break
    print('Please enter a number for your age.')

while True:
    print('Select a new password (letters and numbers only):')
    password = input()
    if password.isalnum():
        break
    print('Passwords can only have letters and numbers.')
```

In the first while loop, we ask the user for their age and store their input in age. If age is a valid (decimal) value, we break out of this first while loop and move on to the second, which asks for a password. Otherwise, we inform the user that they need to enter a number and again ask them to enter their age. In the second while loop, we ask for a password, store the user's input in password, and break out of the loop if the input was alphanumeric. If it wasn't, we're not satisfied, so we tell the user the password needs to be alphanumeric and again ask them to enter a password.

When run, the program's output looks like this:

```
Enter your age:
forty two
Please enter a number for your age.
Enter your age:
42
Select a new password (letters and numbers only):
secr3t!
Passwords can only have letters and numbers.
Select a new password (letters and numbers only):
secr3t
```

You can view the execution of this program at *https://autbor.com/validateinput/*. Calling `isdecimal()` and `isalnum()` on variables, we're able to test whether the values stored in those variables are decimal or not, alphanumeric or not. Here, these tests help us reject the input `forty two` but accept `42`, and reject `secr3t!` but accept `secr3t`.

The startswith() and endswith() Methods

The `startswith()` and `endswith()` methods return `True` if the string value they are called on begins or ends (respectively) with the string passed to the method; otherwise, they return `False`. Enter the following into the interactive shell:

```
>>> 'Hello, world!'.startswith('Hello')
True
>>> 'Hello, world!'.endswith('world!')
True
>>> 'abc123'.startswith('abcdef')
False
>>> 'abc123'.endswith('12')
False
>>> 'Hello, world!'.startswith('Hello, world!')
True
>>> 'Hello, world!'.endswith('Hello, world!')
True
```

These methods are useful alternatives to the `==` equals operator if you need to check only whether the first or last part of the string, rather than the whole thing, is equal to another string.

The join() and split() Methods

The `join()` method is useful when you have a list of strings that need to be joined together into a single string value. The `join()` method is called on a string, gets passed a list of strings, and returns a string. The returned string is the concatenation of each string in the passed-in list. For example, enter the following into the interactive shell:

```
>>> ', '.join(['cats', 'rats', 'bats'])
'cats, rats, bats'
>>> ' '.join(['My', 'name', 'is', 'Simon'])
'My name is Simon'
>>> 'ABC'.join(['My', 'name', 'is', 'Simon'])
'MyABCnameABCisABCSimon'
```

Notice that the string `join()` calls on is inserted between each string of the list argument. For example, when `join(['cats', 'rats', 'bats'])` is called on the `', '` string, the returned string is `'cats, rats, bats'`.

Remember that `join()` is called on a string value and is passed a list value. (It's easy to accidentally call it the other way around.) The `split()` method does the opposite: It's called on a string value and returns a list of strings. Enter the following into the interactive shell:

```
>>> 'My name is Simon'.split()
['My', 'name', 'is', 'Simon']
```

By default, the string `'My name is Simon'` is split wherever whitespace characters such as the space, tab, or newline characters are found. These whitespace characters are not included in the strings in the returned list. You can pass a delimiter string to the `split()` method to specify a different string to split upon. For example, enter the following into the interactive shell:

```
>>> 'MyABCnameABCisABCSimon'.split('ABC')
['My', 'name', 'is', 'Simon']
>>> 'My name is Simon'.split('m')
['My na', 'e is Si', 'on']
```

A common use of `split()` is to split a multiline string along the newline characters. Enter the following into the interactive shell:

```
>>> spam = '''Dear Alice,
How have you been? I am fine.
There is a container in the fridge
that is labeled "Milk Experiment."

Please do not drink it.
Sincerely,
Bob'''
>>> spam.split('\n')
['Dear Alice,', 'How have you been? I am fine.', 'There is a container in the
fridge', 'that is labeled "Milk Experiment."', '', 'Please do not drink it.',
'Sincerely,', 'Bob']
```

Passing `split()` the argument `'\n'` lets us split the multiline string stored in `spam` along the newlines and return a list in which each item corresponds to one line of the string.

Splitting Strings with the partition() Method

The `partition()` string method can split a string into the text before and after a separator string. This method searches the string it is called on for the separator string it is passed, and returns a tuple of three substrings for the "before," "separator," and "after" substrings. Enter the following into the interactive shell:

```
>>> 'Hello, world!'.partition('w')
('Hello, ', 'w', 'orld!')
>>> 'Hello, world!'.partition('world')
('Hello, ', 'world', '!')
```

If the separator string you pass to `partition()` occurs multiple times in the string that `partition()` calls on, the method splits the string only on the first occurrence:

```
>>> 'Hello, world!'.partition('o')
('Hell', 'o', ', world!')
```

If the separator string can't be found, the first string returned in the tuple will be the entire string, and the other two strings will be empty:

```
>>> 'Hello, world!'.partition('XYZ')
('Hello, world!', '', '')
```

You can use the multiple assignment trick to assign the three returned strings to three variables:

```
>>> before, sep, after = 'Hello, world!'.partition(' ')
>>> before
'Hello,'
>>> after
'world!'
```

The `partition()` method is useful for splitting a string whenever you need the parts before, including, and after a particular separator string.

Justifying Text with the rjust(), ljust(), and center() Methods

The `rjust()` and `ljust()` string methods return a padded version of the string they are called on, with spaces inserted to justify the text. The first argument to both methods is an integer length for the justified string. Enter the following into the interactive shell:

```
>>> 'Hello'.rjust(10)
'     Hello'
>>> 'Hello'.rjust(20)
'               Hello'
>>> 'Hello, World'.rjust(20)
```

```
'         Hello, World'
>>> 'Hello'.ljust(10)
'Hello     '
```

'Hello'.rjust(10) says that we want to right-justify 'Hello' in a string of total length 10. 'Hello' is five characters, so five spaces will be added to its left, giving us a string of 10 characters with 'Hello' justified right.

An optional second argument to rjust() and ljust() will specify a fill character other than a space character. Enter the following into the interactive shell:

```
>>> 'Hello'.rjust(20, '*')
'***************Hello'
>>> 'Hello'.ljust(20, '-')
'Hello---------------'
```

The center() string method works like ljust() and rjust() but centers the text rather than justifying it to the left or right. Enter the following into the interactive shell:

```
>>> 'Hello'.center(20)
'       Hello        '
>>> 'Hello'.center(20, '=')
'=======Hello========'
```

These methods are especially useful when you need to print tabular data that has correct spacing. Open a new file editor window and enter the following code, saving it as *picnicTable.py*:

```
def printPicnic(itemsDict, leftWidth, rightWidth):
    print('PICNIC ITEMS'.center(leftWidth + rightWidth, '-'))
    for k, v in itemsDict.items():
        print(k.ljust(leftWidth, '.') + str(v).rjust(rightWidth))

picnicItems = {'sandwiches': 4, 'apples': 12, 'cups': 4, 'cookies': 8000}
printPicnic(picnicItems, 12, 5)
printPicnic(picnicItems, 20, 6)
```

You can view the execution of this program at *https://autbor.com/picnictable/*. In this program, we define a printPicnic() method that will take in a dictionary of information and use center(), ljust(), and rjust() to display that information in a neatly aligned table-like format.

The dictionary that we'll pass to printPicnic() is picnicItems. In picnicItems, we have 4 sandwiches, 12 apples, 4 cups, and 8,000 cookies. We want to organize this information into two columns, with the name of the item on the left and the quantity on the right.

To do this, we decide how wide we want the left and right columns to be. Along with our dictionary, we'll pass these values to printPicnic().

The printPicnic() function takes in a dictionary, a leftWidth for the left column of a table, and a rightWidth for the right column. It prints a title, PICNIC ITEMS, centered above the table. Then, it loops through the dictionary, printing each key-value pair on a line with the key justified left and padded by periods, and the value justified right and padded by spaces.

After defining printPicnic(), we define the dictionary picnicItems and call printPicnic() twice, passing it different widths for the left and right table columns.

When you run this program, the picnic items are displayed twice. The first time the left column is 12 characters wide, and the right column is 5 characters wide. The second time they are 20 and 6 characters wide, respectively.

```
---PICNIC ITEMS--
sandwiches..    4
apples......   12
cups........    4
cookies..... 8000
-------PICNIC ITEMS-------
sandwiches..........     4
apples..............    12
cups................     4
cookies.............  8000
```

Using rjust(), ljust(), and center() lets you ensure that strings are neatly aligned, even if you aren't sure how many characters long your strings are.

Removing Whitespace with the strip(), rstrip(), and lstrip() Methods

Sometimes you may want to strip off whitespace characters (space, tab, and newline) from the left side, right side, or both sides of a string. The strip() string method will return a new string without any whitespace characters at the beginning or end. The lstrip() and rstrip() methods will remove whitespace characters from the left and right ends, respectively. Enter the following into the interactive shell:

```
>>> spam = '    Hello, World    '
>>> spam.strip()
'Hello, World'
>>> spam.lstrip()
'Hello, World    '
>>> spam.rstrip()
'    Hello, World'
```

Optionally, a string argument will specify which characters on the ends should be stripped. Enter the following into the interactive shell:

```
>>> spam = 'SpamSpamBaconSpamEggsSpamSpam'
>>> spam.strip('ampS')
'BaconSpamEggs'
```

Passing strip() the argument 'ampS' will tell it to strip occurrences of a, m, p, and capital S from the ends of the string stored in spam. The order of the characters in the string passed to strip() does not matter: strip('ampS') will do the same thing as strip('mapS') or strip('Spam').

Numeric Values of Characters with the ord() and chr() Functions

Computers store information as bytes—strings of binary numbers, which means we need to be able to convert text to numbers. Because of this, every text character has a corresponding numeric value called a *Unicode code point*. For example, the numeric code point is 65 for 'A', 52 for '4', and 33 for '!'. You can use the ord() function to get the code point of a one-character string, and the chr() function to get the one-character string of an integer code point. Enter the following into the interactive shell:

```
>>> ord('A')
65
>>> ord('4')
52
>>> ord('!')
33
>>> chr(65)
'A'
```

These functions are useful when you need to do an ordering or mathematical operation on characters:

```
>>> ord('B')
66
>>> ord('A') < ord('B')
True
>>> chr(ord('A'))
'A'
>>> chr(ord('A') + 1)
'B'
```

There is more to Unicode and code points, but those details are beyond the scope of this book. If you'd like to know more, I recommend watching Ned Batchelder's 2012 PyCon talk, "Pragmatic Unicode, or, How Do I Stop the Pain?" at *https://youtu.be/sgHbC6udIqc*.

Copying and Pasting Strings with the pyperclip Module

The pyperclip module has copy() and paste() functions that can send text to and receive text from your computer's clipboard. Sending the output of your program to the clipboard will make it easy to paste it into an email, word processor, or some other software.

RUNNING PYTHON SCRIPTS OUTSIDE OF MU

So far, you've been running your Python scripts using the interactive shell and file editor in Mu. However, you won't want to go through the inconvenience of opening Mu and the Python script each time you want to run a script. Fortunately, there are shortcuts you can set up to make running Python scripts easier. The steps are slightly different for Windows, macOS, and Linux, but each is described in Appendix B. Turn to Appendix B to learn how to run your Python scripts conveniently and be able to pass command line arguments to them. (You will not be able to pass command line arguments to your programs using Mu.)

The `pyperclip` module does not come with Python. To install it, follow the directions for installing third-party modules in Appendix A. After installing `pyperclip`, enter the following into the interactive shell:

```
>>> import pyperclip
>>> pyperclip.copy('Hello, world!')
>>> pyperclip.paste()
'Hello, world!'
```

Of course, if something outside of your program changes the clipboard contents, the `paste()` function will return it. For example, if I copied this sentence to the clipboard and then called `paste()`, it would look like this:

```
>>> pyperclip.paste()
'For example, if I copied this sentence to the clipboard and then called
paste(), it would look like this:'
```

Project: Multi-Clipboard Automatic Messages

If you've responded to a large number of emails with similar phrasing, you've probably had to do a lot of repetitive typing. Maybe you keep a text document with these phrases so you can easily copy and paste them using the clipboard. But your clipboard can only store one message at a time, which isn't very convenient. Let's make this process a bit easier with a program that stores multiple phrases.

Step 1: Program Design and Data Structures

You want to be able to run this program with a command line argument that is a short key phrase—for instance, *agree* or *busy*. The message associated with that key phrase will be copied to the clipboard so that the user can paste it into an email. This way, the user can have long, detailed messages without having to retype them.

THE CHAPTER PROJECTS

This is the first "chapter project" of the book. From here on, each chapter will have projects that demonstrate the concepts covered in the chapter. The projects are written in a style that takes you from a blank file editor window to a full, working program. Just like with the interactive shell examples, don't only read the project sections—follow along on your computer!

Open a new file editor window and save the program as *mclip.py*. You need to start the program with a `#!` (*shebang*) line (see Appendix B) and should also write a comment that briefly describes the program. Since you want to associate each piece of text with its key phrase, you can store these as strings in a dictionary. The dictionary will be the data structure that organizes your key phrases and text. Make your program look like the following:

```
#! python3
# mclip.py - A multi-clipboard program.

TEXT = {'agree': """Yes, I agree. That sounds fine to me.""",
        'busy': """Sorry, can we do this later this week or next week?""",
        'upsell': """Would you consider making this a monthly donation?"""}
```

Step 2: Handle Command Line Arguments

The command line arguments will be stored in the variable `sys.argv`. (See Appendix B for more information on how to use command line arguments in your programs.) The first item in the `sys.argv` list should always be a string containing the program's filename (`'mclip.py'`), and the second item should be the first command line argument. For this program, this argument is the key phrase of the message you want. Since the command line argument is mandatory, you display a usage message to the user if they forget to add it (that is, if the `sys.argv` list has fewer than two values in it). Make your program look like the following:

```
#! python3
# mclip.py - A multi-clipboard program.

TEXT = {'agree': """Yes, I agree. That sounds fine to me.""",
        'busy': """Sorry, can we do this later this week or next week?""",
        'upsell': """Would you consider making this a monthly donation?"""}

import sys
if len(sys.argv) < 2:
    print('Usage: python mclip.py [keyphrase] - copy phrase text')
    sys.exit()

keyphrase = sys.argv[1]    # first command line arg is the keyphrase
```

Step 3: Copy the Right Phrase

Now that the key phrase is stored as a string in the variable `keyphrase`, you need to see whether it exists in the `TEXT` dictionary as a key. If so, you want to copy the key's value to the clipboard using `pyperclip.copy()`. (Since you're using the `pyperclip` module, you need to import it.) Note that you don't actually *need* the `keyphrase` variable; you could just use `sys.argv[1]` everywhere `keyphrase` is used in this program. But a variable named `keyphrase` is much more readable than something cryptic like `sys.argv[1]`.

Make your program look like the following:

```
#! python3
# mclip.py - A multi-clipboard program.

TEXT = {'agree': """Yes, I agree. That sounds fine to me.""",
        'busy': """Sorry, can we do this later this week or next week?""",
        'upsell': """Would you consider making this a monthly donation?"""}

import sys, pyperclip
if len(sys.argv) < 2:
    print('Usage: py mclip.py [keyphrase] - copy phrase text')
    sys.exit()

keyphrase = sys.argv[1]    # first command line arg is the keyphrase

if keyphrase in TEXT:
    pyperclip.copy(TEXT[keyphrase])
    print('Text for ' + keyphrase + ' copied to clipboard.')
else:
    print('There is no text for ' + keyphrase)
```

This new code looks in the `TEXT` dictionary for the key phrase. If the key phrase is a key in the dictionary, we get the value corresponding to that key, copy it to the clipboard, and print a message saying that we copied the value. Otherwise, we print a message saying there's no key phrase with that name.

That's the complete script. Using the instructions in Appendix B for launching command line programs easily, you now have a fast way to copy messages to the clipboard. You will have to modify the `TEXT` dictionary value in the source whenever you want to update the program with a new message.

On Windows, you can create a batch file to run this program with the WIN-R Run window. (For more about batch files, see Appendix B.) Enter the following into the file editor and save the file as *mclip.bat* in the *C:\Windows* folder:

```
@py.exe C:\path_to_file\mclip.py %*
@pause
```

With this batch file created, running the multi-clipboard program on Windows is just a matter of pressing WIN-R and typing `mclip` *`key phrase`*.

Project: Adding Bullets to Wiki Markup

When editing a Wikipedia article, you can create a bulleted list by putting each list item on its own line and placing a star in front. But say you have a really large list that you want to add bullet points to. You could just type those stars at the beginning of each line, one by one. Or you could automate this task with a short Python script.

The *bulletPointAdder.py* script will get the text from the clipboard, add a star and space to the beginning of each line, and then paste this new text to the clipboard. For example, if I copied the following text (for the Wikipedia article "List of Lists of Lists") to the clipboard:

```
Lists of animals
Lists of aquarium life
Lists of biologists by author abbreviation
Lists of cultivars
```

and then ran the *bulletPointAdder.py* program, the clipboard would then contain the following:

```
* Lists of animals
* Lists of aquarium life
* Lists of biologists by author abbreviation
* Lists of cultivars
```

This star-prefixed text is ready to be pasted into a Wikipedia article as a bulleted list.

Step 1: Copy and Paste from the Clipboard

You want the *bulletPointAdder.py* program to do the following:

1. Paste text from the clipboard.
2. Do something to it.
3. Copy the new text to the clipboard.

That second step is a little tricky, but steps 1 and 3 are pretty straightforward: they just involve the `pyperclip.copy()` and `pyperclip.paste()` functions. For now, let's just write the part of the program that covers steps 1 and 3. Enter the following, saving the program as *bulletPointAdder.py*:

```
#! python3
# bulletPointAdder.py - Adds Wikipedia bullet points to the start
# of each line of text on the clipboard.

import pyperclip
text = pyperclip.paste()

# TODO: Separate lines and add stars.

pyperclip.copy(text)
```

The TODO comment is a reminder that you should complete this part of the program eventually. The next step is to actually implement that piece of the program.

Step 2: Separate the Lines of Text and Add the Star

The call to pyperclip.paste() returns all the text on the clipboard as one big string. If we used the "List of Lists of Lists" example, the string stored in text would look like this:

```
'Lists of animals\nLists of aquarium life\nLists of biologists by author
abbreviation\nLists of cultivars'
```

The \n newline characters in this string cause it to be displayed with multiple lines when it is printed or pasted from the clipboard. There are many "lines" in this one string value. You want to add a star to the start of each of these lines.

You could write code that searches for each \n newline character in the string and then adds the star just after that. But it would be easier to use the split() method to return a list of strings, one for each line in the original string, and then add the star to the front of each string in the list.

Make your program look like the following:

```
#! python3
# bulletPointAdder.py - Adds Wikipedia bullet points to the start
# of each line of text on the clipboard.

import pyperclip
text = pyperclip.paste()

# Separate lines and add stars.
lines = text.split('\n')
for i in range(len(lines)):    # loop through all indexes in the "lines" list
    lines[i] = '* ' + lines[i] # add star to each string in "lines" list

pyperclip.copy(text)
```

We split the text along its newlines to get a list in which each item is one line of the text. We store the list in lines and then loop through the items in lines. For each line, we add a star and a space to the start of the line. Now each string in lines begins with a star.

Step 3: Join the Modified Lines

The lines list now contains modified lines that start with stars. But pyperclip .copy() is expecting a single string value, however, not a list of string values. To make this single string value, pass lines into the join() method to get a single string joined from the list's strings. Make your program look like the following:

```
#! python3
# bulletPointAdder.py - Adds Wikipedia bullet points to the start
# of each line of text on the clipboard.

import pyperclip
text = pyperclip.paste()

# Separate lines and add stars.
lines = text.split('\n')
for i in range(len(lines)):    # loop through all indexes for "lines" list
    lines[i] = '* ' + lines[i] # add star to each string in "lines" list
text = '\n'.join(lines)
pyperclip.copy(text)
```

When this program is run, it replaces the text on the clipboard with text that has stars at the start of each line. Now the program is complete, and you can try running it with text copied to the clipboard.

Even if you don't need to automate this specific task, you might want to automate some other kind of text manipulation, such as removing trailing spaces from the end of lines or converting text to uppercase or lowercase. Whatever your needs, you can use the clipboard for input and output.

A Short Progam: Pig Latin

Pig Latin is a silly made-up language that alters English words. If a word begins with a vowel, the word *yay* is added to the end of it. If a word begins with a consonant or consonant cluster (like *ch* or *gr*), that consonant or cluster is moved to the end of the word followed by *ay*.

Let's write a Pig Latin program that will output something like this:

```
Enter the English message to translate into Pig Latin:
My name is AL SWEIGART and I am 4,000 years old.
Ymay amenay isyay ALYAY EIGARTSWAY andyay Iyay amyay 4,000 yearsyay oldyay.
```

This program works by altering a string using the methods introduced in this chapter. Type the following source code into the file editor, and save the file as *pigLat.py*:

```
# English to Pig Latin
print('Enter the English message to translate into Pig Latin:')
message = input()

VOWELS = ('a', 'e', 'i', 'o', 'u', 'y')

pigLatin = [] # A list of the words in Pig Latin.
for word in message.split():
    # Separate the non-letters at the start of this word:
    prefixNonLetters = ''
    while len(word) > 0 and not word[0].isalpha():
        prefixNonLetters += word[0]
        word = word[1:]
    if len(word) == 0:
        pigLatin.append(prefixNonLetters)
        continue

    # Separate the non-letters at the end of this word:
    suffixNonLetters = ''
    while not word[-1].isalpha():
        suffixNonLetters += word[-1]
        word = word[:-1]

    # Remember if the word was in uppercase or title case.
    wasUpper = word.isupper()
    wasTitle = word.istitle()

    word = word.lower() # Make the word lowercase for translation.

    # Separate the consonants at the start of this word:
    prefixConsonants = ''
    while len(word) > 0 and not word[0] in VOWELS:
        prefixConsonants += word[0]
        word = word[1:]

    # Add the Pig Latin ending to the word:
    if prefixConsonants != '':
        word += prefixConsonants + 'ay'
    else:
        word += 'yay'

    # Set the word back to uppercase or title case:
    if wasUpper:
        word = word.upper()
    if wasTitle:
        word = word.title()

    # Add the non-letters back to the start or end of the word.
    pigLatin.append(prefixNonLetters + word + suffixNonLetters)

# Join all the words back together into a single string:
print(' '.join(pigLatin))
```

Let's look at this code line by line, starting at the top:

```
# English to Pig Latin
print('Enter the English message to translate into Pig Latin:')
message = input()

VOWELS = ('a', 'e', 'i', 'o', 'u', 'y')
```

First, we ask the user to enter the English text to translate into Pig Latin. Also, we create a constant that holds every lowercase vowel letter (and *y*) as a tuple of strings. This will be used later in our program.

Next, we're going to create the `pigLatin` variable to store the words as we translate them into Pig Latin:

```
pigLatin = [] # A list of the words in Pig Latin.
for word in message.split():
    # Separate the non-letters at the start of this word:
    prefixNonLetters = ''
    while len(word) > 0 and not word[0].isalpha():
        prefixNonLetters += word[0]
        word = word[1:]
    if len(word) == 0:
        pigLatin.append(prefixNonLetters)
        continue
```

We need each word to be its own string, so we call `message.split()` to get a list of the words as separate strings. The string `'My name is AL SWEIGART and I am 4,000 years old.'` would cause `split()` to return `['My', 'name', 'is', 'AL', 'SWEIGART', 'and', 'I', 'am', '4,000', 'years', 'old.']`.

We need to remove any non-letters from the start and end of each word so that strings like `'old.'` translate to `'oldyay.'` instead of `'old.yay'`. We'll save these non-letters to a variable named `prefixNonLetters`.

```
    # Separate the non-letters at the end of this word:
    suffixNonLetters = ''
    while not word[-1].isalpha():
        suffixNonLetters += word[-1]
        word = word[:-1]
```

A loop that calls `isalpha()` on the first character in the word will determine if we should remove a character from a word and concatenate it to the end of `prefixNonLetters`. If the entire word is made of non-letter characters, like `'4,000'`, we can simply append it to the `pigLatin` list and continue to the next word to translate. We also need to save the non-letters at the end of the `word` string. This code is similar to the previous loop.

Next, we'll make sure the program remembers if the word was in uppercase or title case so we can restore it after translating the word to Pig Latin:

```
    # Remember if the word was in uppercase or title case.
    wasUpper = word.isupper()
    wasTitle = word.istitle()

    word = word.lower() # Make the word lowercase for translation.
```

For the rest of the code in the `for` loop, we'll work on a lowercase version of `word`.

To convert a word like *sweigart* to *eigart-sway*, we need to remove all of the consonants from the beginning of word:

```
    # Separate the consonants at the start of this word:
    prefixConsonants = ''
    while len(word) > 0 and not word[0] in VOWELS:
        prefixConsonants += word[0]
        word = word[1:]
```

We use a loop similar to the loop that removed the non-letters from the start of word, except now we are pulling off consonants and storing them to a variable named prefixConsonants.

If there were any consonants at the start of the word, they are now in prefixConsonants and we should concatenate that variable and the string 'ay' to the end of word. Otherwise, we can assume word begins with a vowel and we only need to concatenate 'yay':

```
    # Add the Pig Latin ending to the word:
    if prefixConsonants != '':
        word += prefixConsonants + 'ay'
    else:
        word += 'yay'
```

Recall that we set word to its lowercase version with word = word.lower(). If word was originally in uppercase or title case, this code will convert word back to its original case:

```
    # Set the word back to uppercase or title case:
    if wasUpper:
        word = word.upper()
    if wasTitle:
        word = word.title()
```

At the end of the for loop, we append the word, along with any nonletter prefix or suffix it originally had, to the pigLatin list:

```
    # Add the non-letters back to the start or end of the word.
    pigLatin.append(prefixNonLetters + word + suffixNonLetters)

# Join all the words back together into a single string:
print(' '.join(pigLatin))
```

After this loop finishes, we combine the list of strings into a single string by calling the join() method. This single string is passed to print() to display our Pig Latin on the screen.

You can find other short, text-based Python programs like this one at *https://github.com/asweigart/pythonstdiogames/*.

Summary

Text is a common form of data, and Python comes with many helpful string methods to process the text stored in string values. You will make use of indexing, slicing, and string methods in almost every Python program you write.

The programs you are writing now don't seem too sophisticated—they don't have graphical user interfaces with images and colorful text. So far, you're displaying text with `print()` and letting the user enter text with `input()`. However, the user can quickly enter large amounts of text through the clipboard. This ability provides a useful avenue for writing programs that manipulate massive amounts of text. These text-based programs might not have flashy windows or graphics, but they can get a lot of useful work done quickly.

Another way to manipulate large amounts of text is reading and writing files directly off the hard drive. You'll learn how to do this with Python in Chapter 9.

That just about covers all the basic concepts of Python programming! You'll continue to learn new concepts throughout the rest of this book, but you now know enough to start writing some useful programs that can automate tasks. If you'd like to see a collection of short, simple Python programs built from the basic concepts you've learned so far, check out *https://github.com/asweigart/pythonstdiogames/*. Try copying the source code for each program by hand, and then make modifications to see how they affect the behavior of the program. Once you have an understanding of how the program works, try re-creating the program yourself from scratch. You don't need to re-create the source code exactly; just focus on what the program does rather than how it does it.

You might not think you have enough Python knowledge to do things such as download web pages, update spreadsheets, or send text messages, but that's where Python modules come in! These modules, written by other programmers, provide functions that make it easy for you to do all these things. So let's learn how to write real programs to do useful automated tasks.

Practice Questions

1. What are escape characters?
2. What do the `\n` and `\t` escape characters represent?
3. How can you put a \ backslash character in a string?
4. The string value `"Howl's Moving Castle"` is a valid string. Why isn't it a problem that the single quote character in the word `Howl's` isn't escaped?
5. If you don't want to put `\n` in your string, how can you write a string with newlines in it?

6. What do the following expressions evaluate to?
    - `'Hello, world!'[1]`
    - `'Hello, world!'[0:5]`
    - `'Hello, world!'[:5]`
    - `'Hello, world!'[3:]`
7. What do the following expressions evaluate to?
    - `'Hello'.upper()`
    - `'Hello'.upper().isupper()`
    - `'Hello'.upper().lower()`
8. What do the following expressions evaluate to?
    - `'Remember, remember, the fifth of November.'.split()`
    - `'-'.join('There can be only one.'.split())`
9. What string methods can you use to right-justify, left-justify, and center a string?
10. How can you trim whitespace characters from the beginning or end of a string?

Practice Projects

For practice, write programs that do the following.

Table Printer

Write a function named `printTable()` that takes a list of lists of strings and displays it in a well-organized table with each column right-justified. Assume that all the inner lists will contain the same number of strings. For example, the value could look like this:

```
tableData = [['apples', 'oranges', 'cherries', 'banana'],
             ['Alice', 'Bob', 'Carol', 'David'],
             ['dogs', 'cats', 'moose', 'goose']]
```

Your `printTable()` function would print the following:

```
   apples Alice  dogs
  oranges   Bob  cats
 cherries Carol moose
   banana David goose
```

Hint: your code will first have to find the longest string in each of the inner lists so that the whole column can be wide enough to fit all the strings. You can store the maximum width of each column as a list of integers. The `printTable()` function can begin with `colWidths = [0] * len(tableData)`, which will create a list containing the same number of `0` values as the number of inner lists in `tableData`. That way, `colWidths[0]` can store the width of the longest string in `tableData[0]`, `colWidths[1]` can store the width of the longest string in `tableData[1]`, and so on. You can then find the largest value in the `colWidths` list to find out what integer width to pass to the `rjust()` string method.

Zombie Dice Bots

Programming games are a game genre where instead of playing a game directly, players write bot programs to play the game autonomously. I've created a Zombie Dice simulator, which allows programmers to practice their skills while making game-playing AIs. Zombie Dice bots can be simple or incredibly complex, and are great for a class exercise or an individual programming challenge.

Zombie Dice is a quick, fun dice game from Steve Jackson Games. The players are zombies trying to eat as many human brains as possible without getting shot three times. There is a cup of 13 dice with brains, footsteps, and shotgun icons on their faces. The dice icons are colored, and each color has a different likelihood of each event occurring. Every die has two sides with footsteps, but dice with green icons have more sides with brains, red-icon dice have more shotguns, and yellow-icon dice have an even split of brains and shotguns. Do the following on each player's turn:

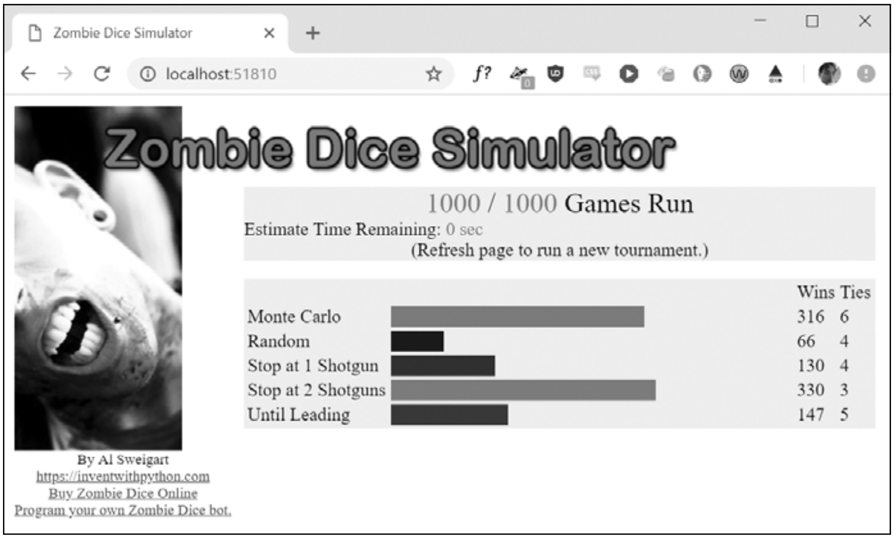
1. Place all 13 dice in the cup. The player randomly draws three dice from the cup and then rolls them. Players always roll exactly three dice.
2. They set aside and count up any brains (humans whose brains were eaten) and shotguns (humans who fought back). Accumulating three shotguns automatically ends a player's turn with zero points (regardless of how many brains they had). If they have between zero and two shotguns, they may continue rolling if they want. They may also choose to end their turn and collect one point per brain.
3. If the player decides to keep rolling, they must reroll all dice with footsteps. Remember that the player must always roll three dice; they must draw more dice out of the cup if they have fewer than three footsteps to roll. A player may keep rolling dice until either they get three shotguns—losing everything—or all 13 dice have been rolled. A player may not reroll only one or two dice, and may not stop mid-reroll.
4. When someone reaches 13 brains, the rest of the players finish out the round. The person with the most brains wins. If there's a tie, the tied players play one last tiebreaker round.

Zombie Dice has a push-your-luck game mechanic: the more you reroll the dice, the more brains you can get, but the more likely you'll eventually accrue three shotguns and lose everything. Once a player reaches 13 points, the rest of the players get one more turn (to potentially catch up) and the game ends. The player with the most points wins. You can find the complete rules at *https://github.com/asweigart/zombiedice/*.

Install the `zombiedice` module with pip by following the instructions in Appendix A. You can run a demo of the simulator with some pre-made bots by running the following in the interactive shell:

```
>>> import zombiedice
>>> zombiedice.demo()
Zombie Dice Visualization is running. Open your browser to http://
localhost:51810 to view it.
Press Ctrl-C to quit.
```

The program launches your web browser, which will look like Figure 6-1.



Zombie Dice Simulator

1000 / 1000 Games Run
Estimate Time Remaining: 0 sec
(Refresh page to run a new tournament.)

	Wins	Ties
Monte Carlo	316	6
Random	66	4
Stop at 1 Shotgun	130	4
Stop at 2 Shotguns	330	3
Until Leading	147	5

By Al Sweigart
https://inventwithpython.com
Buy Zombie Dice Online
Program your own Zombie Dice bot.

Figure 6-1: The web GUI for the Zombie Dice simulator

You'll create bots by writing a class with a `turn()` method, which is called by the simulator when it's your bot's turn to roll the dice. Classes are beyond the scope of this book, so the class code is already set up for you in the *myzombie.py* program, which is in the downloadable ZIP file for this book at *https://nostarch.com/automatestuff2/*. Writing a method is essentially the same as writing a function, and you can use the `turn()` code in the *myZombie.py* program as a template. Inside this `turn()` method, you'll call the `zombiedice.roll()` function as often as you want your bot to roll the dice.

```
import zombiedice

class MyZombie:
    def __init__(self, name):
        # All zombies must have a name:
        self.name = name

    def turn(self, gameState):
        # gameState is a dict with info about the current state of the game.
        # You can choose to ignore it in your code.

        diceRollResults = zombiedice.roll() # first roll
        # roll() returns a dictionary with keys 'brains', 'shotgun', and
        # 'footsteps' with how many rolls of each type there were.
        # The 'rolls' key is a list of (color, icon) tuples with the
        # exact roll result information.
        # Example of a roll() return value:
        # {'brains': 1, 'footsteps': 1, 'shotgun': 1,
        #  'rolls': [('yellow', 'brains'), ('red', 'footsteps'),
        #            ('green', 'shotgun')]}

        # REPLACE THIS ZOMBIE CODE WITH YOUR OWN:
        brains = 0
        while diceRollResults is not None:
            brains += diceRollResults['brains']

            if brains < 2:
                diceRollResults = zombiedice.roll() # roll again
            else:
                break

zombies = (
    zombiedice.examples.RandomCoinFlipZombie(name='Random'),
    zombiedice.examples.RollsUntilInTheLeadZombie(name='Until Leading'),
    zombiedice.examples.MinNumShotgunsThenStopsZombie(name='Stop at 2
Shotguns', minShotguns=2),
    zombiedice.examples.MinNumShotgunsThenStopsZombie(name='Stop at 1
Shotgun', minShotguns=1),
    MyZombie(name='My Zombie Bot'),
    # Add any other zombie players here.
)

# Uncomment one of the following lines to run in CLI or Web GUI mode:
#zombiedice.runTournament(zombies=zombies, numGames=1000)
zombiedice.runWebGui(zombies=zombies, numGames=1000)
```

The `turn()` method takes two parameters: `self` and `gameState`. You can ignore these in your first few zombie bots and consult the online documentation for details later if you want to learn more. The `turn()` method should call `zombiedice.roll()` at least once for the initial roll. Then, depending on the strategy the bot uses, it can call `zombiedice.roll()` again as many times as it wants. In *myZombie.py*, the `turn()` method calls `zombiedice.roll()` twice, which means the zombie bot will always roll its dice two times per turn regardless of the results of the roll.

The return value of `zombiedice.roll()` tells your code the results of the dice roll. It is a dictionary with four keys. Three of the keys, `'shotgun'`, `'brains'`, and `'footsteps'`, have integer values of how many dice came up with those icons. The fourth `'rolls'` key has a value that is a list of tuples for each die roll. The tuples contain two strings: the color of the die at index `0` and the icon rolled at index `1`. Look at the code comments in the `turn()`

method's definition for an example. If the bot has already rolled three shotguns, then `zombiedice.roll()` will return `None`.

Try writing some of your own bots to play Zombie Dice and see how they compare against the other bots. Specifically, try to create the following bots:

- A bot that, after the first roll, randomly decides if it will continue or stop
- A bot that stops rolling after it has rolled two brains
- A bot that stops rolling after it has rolled two shotguns
- A bot that initially decides it'll roll the dice one to four times, but will stop early if it rolls two shotguns
- A bot that stops rolling after it has rolled more shotguns than brains

Run these bots through the simulator and see how they compare to each other. You can also examine the code of some premade bots at *https://github.com/asweigart/zombiedice/*. If you find yourself playing this game in the real world, you'll have the benefit of thousands of simulated games telling you that one of the best strategies is to simply stop once you've rolled two shotguns. But you could always try pressing your luck . . .