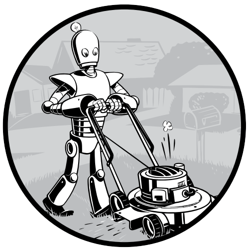
PART II

AUTOMATING TASKS

7

PATTERN MATCHING WITH REGULAR EXPRESSIONS



You may be familiar with searching for text by pressing CTRL-F and typing in the words you're looking for. *Regular expressions* go one step further: They allow you to specify a *pattern* of text to search for. You may not know a business's exact phone number, but if you live in the United States or Canada, you know it will be three digits, followed by a hyphen, and then four more digits (and optionally, a three-digit area code at the start). This is how you, as a human, know a phone number when you see it: 415-555-1234 is a phone number, but 4,155,551,234 is not.

Regular expressions are helpful, but not many non-programmers know about them even though most modern text editors and word processors, such as Microsoft Word or OpenOffice, have find and find-and-replace features that can search based on regular expressions. Regular expressions are huge time-savers, not just for software users but also for programmers. In fact, tech writer Cory Doctorow argues that even before teaching programming, we should be teaching regular expressions:

> "Knowing [regular expressions] can mean the difference between solving a problem in 3 steps and solving it in 3,000 steps. When you're a nerd, you forget that the problems you solve with a couple keystrokes can take other people days of tedious, error-prone work to slog through."[1]

In this chapter, you'll start by writing a program to find text patterns *without* using regular expressions and then see how to use regular expressions to make the code much less bloated. I'll show you basic matching with regular expressions and then move on to some more powerful features, such as string substitution and creating your own character classes. Finally, at the end of the chapter, you'll write a program that can automatically extract phone numbers and email addresses from a block of text.

Finding Patterns of Text Without Regular Expressions

Say you want to find a phone number in a string. You know the pattern: three numbers, a hyphen, three numbers, a hyphen, and four numbers. Here's an example: 415-555-4242.

Let's use a function named `isPhoneNumber()` to check whether a string matches this pattern, returning either `True` or `False`. Open a new file editor window and enter the following code; then save the file as *isPhoneNumber.py*:

```
   def isPhoneNumber(text):
❶      if len(text) != 12:
           return False
       for i in range(0, 3):
❷          if not text[i].isdecimal():
               return False
❸      if text[3] != '-':
           return False
       for i in range(4, 7):
❹          if not text[i].isdecimal():
               return False
❺      if text[7] != '-':
           return False
       for i in range(8, 12):
❻          if not text[i].isdecimal():
               return False
❼      return True

   print('415-555-4242 is a phone number:')
   print(isPhoneNumber('415-555-4242'))
   print('Moshi moshi is a phone number:')
   print(isPhoneNumber('Moshi moshi'))
```

1. Cory Doctorow, "Here's what ICT should really teach kids: how to do regular expressions," *Guardian*, December 4, 2012, *http://www.theguardian.com/technology/2012/dec/04/ict-teach-kids-regular-expressions/*.

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

```
415-555-4242 is a phone number:
True
Moshi moshi is a phone number:
False
```

The `isPhoneNumber()` function has code that does several checks to see whether the string in `text` is a valid phone number. If any of these checks fail, the function returns `False`. First the code checks that the string is exactly 12 characters ❶. Then it checks that the area code (that is, the first three characters in `text`) consists of only numeric characters ❷. The rest of the function checks that the string follows the pattern of a phone number: The number must have the first hyphen after the area code ❸, three more numeric characters ❹, then another hyphen ❺, and finally four more numbers ❻. If the program execution manages to get past all the checks, it returns `True` ❼.

Calling `isPhoneNumber()` with the argument `'415-555-4242'` will return `True`. Calling `isPhoneNumber()` with `'Moshi moshi'` will return `False`; the first test fails because `'Moshi moshi'` is not 12 characters long.

You would have to add even more code to find this pattern of text in a larger string. Replace the last four `print()` function calls in *isPhoneNumber.py* with the following:

```
  message = 'Call me at 415-555-1011 tomorrow. 415-555-9999 is my office.'
  for i in range(len(message)):
❶     chunk = message[i:i+12]
❷     if isPhoneNumber(chunk):
        print('Phone number found: ' + chunk)
  print('Done')
```

When this program is run, the output will look like this:

```
Phone number found: 415-555-1011
Phone number found: 415-555-9999
Done
```

On each iteration of the `for` loop, a new chunk of 12 characters from `message` is assigned to the variable `chunk` ❶. For example, on the first iteration, `i` is `0`, and `chunk` is assigned `message[0:12]` (that is, the string `'Call me at 4'`). On the next iteration, `i` is `1`, and `chunk` is assigned `message[1:13]` (the string `'all me at 41'`).

You pass `chunk` to `isPhoneNumber()` to see whether it matches the phone number pattern ❷, and if so, you print the chunk.

Continue to loop through `message`, and eventually the 12 characters in `chunk` will be a phone number. The loop goes through the entire string, testing each 12-character piece and printing any `chunk` it finds that satisfies `isPhoneNumber()`. Once we're done going through `message`, we print `Done`.

While the string in `message` is short in this example, it could be millions of characters long and the program would still run in less than a second. A similar program that finds phone numbers using regular expressions would also run in less than a second, but regular expressions make it quicker to write these programs.

Finding Patterns of Text with Regular Expressions

The previous phone number–finding program works, but it uses a lot of code to do something limited: The `isPhoneNumber()` function is 17 lines but can find only one pattern of phone numbers. What about a phone number formatted like 415.555.4242 or (415) 555-4242? What if the phone number had an extension, like 415-555-4242 x99? The `isPhoneNumber()` function would fail to validate them. You could add yet more code for these additional patterns, but there is an easier way.

Regular expressions, called *regexes* for short, are descriptions for a pattern of text. For example, a `\d` in a regex stands for a digit character—that is, any single numeral 0 to 9. The regex `\d\d\d-\d\d\d-\d\d\d\d` is used by Python to match the same text the previous `isPhoneNumber()` function did: a string of three numbers, a hyphen, three more numbers, another hyphen, and four numbers. Any other string would not match the `\d\d\d-\d\d\d-\d\d\d\d` regex.

But regular expressions can be much more sophisticated. For example, adding a `3` in curly brackets (`{3}`) after a pattern is like saying, "Match this pattern three times." So the slightly shorter regex `\d{3}-\d{3}-\d{4}` also matches the correct phone number format.

Creating Regex Objects

All the regex functions in Python are in the `re` module. Enter the following into the interactive shell to import this module:

```
>>> import re
```

NOTE *Most of the examples that follow in this chapter will require the `re` module, so remember to import it at the beginning of any script you write or any time you restart IDLE. Otherwise, you'll get a `NameError: name 're' is not defined` error message.*

Passing a string value representing your regular expression to `re.compile()` returns a `Regex` pattern object (or simply, a `Regex` object).

To create a `Regex` object that matches the phone number pattern, enter the following into the interactive shell. (Remember that `\d` means "a digit character" and `\d\d\d-\d\d\d-\d\d\d\d` is the regular expression for the correct phone number pattern.)

```
>>> phoneNumRegex = re.compile(r'\d\d\d-\d\d\d-\d\d\d\d')
```

Now the `phoneNumRegex` variable contains a `Regex` object.

PASSING RAW STRINGS TO RE.COMPILE()

Remember that escape characters in Python use the backslash (\). The string value `'\n'` represents a single newline character, not a backslash followed by a lowercase *n*. You need to enter the escape character `\\` to print a single backslash. So `'\\n'` is the string that represents a backslash followed by a lowercase *n*. However, by putting an `r` before the first quote of the string value, you can mark the string as a *raw string*, which does not escape characters.

Since regular expressions frequently use backslashes in them, it is convenient to pass raw strings to the `re.compile()` function instead of typing extra backslashes. Typing `r'\d\d\d-\d\d\d-\d\d\d\d'` is much easier than typing `'\\d\\d\\d-\\d\\d\\d-\\d\\d\\d\\d'`.

Matching Regex Objects

A `Regex` object's `search()` method searches the string it is passed for any matches to the regex. The `search()` method will return `None` if the regex pattern is not found in the string. If the pattern *is* found, the `search()` method returns a `Match` object. `Match` objects have a `group()` method that will return the actual matched text from the searched string. (I'll explain groups shortly.) For example, enter the following into the interactive shell:

```
>>> phoneNumRegex = re.compile(r'\d\d\d-\d\d\d-\d\d\d\d')
>>> mo = phoneNumRegex.search('My number is 415-555-4242.')
>>> print('Phone number found: ' + mo.group())
Phone number found: 415-555-4242
```

The `mo` variable name is just a generic name to use for `Match` objects. This example might seem complicated at first, but it is much shorter than the earlier *isPhoneNumber.py* program and does the same thing.

Here, we pass our desired pattern to `re.compile()` and store the resulting `Regex` object in `phoneNumRegex`. Then we call `search()` on `phoneNumRegex` and pass `search()` the string we want to search for a match. The result of the search gets stored in the variable `mo`. In this example, we know that our pattern will be found in the string, so we know that a `Match` object will be returned. Knowing that `mo` contains a `Match` object and not the null value `None`, we can call `group()` on `mo` to return the match. Writing `mo.group()` inside our print statement displays the whole match, `415-555-4242`.

Review of Regular Expression Matching

While there are several steps to using regular expressions in Python, each step is fairly simple.

1. Import the regex module with `import re`.
2. Create a `Regex` object with the `re.compile()` function. (Remember to use a raw string.)
3. Pass the string you want to search into the `Regex` object's `search()` method. This returns a `Match` object.
4. Call the `Match` object's `group()` method to return a string of the actual matched text.

NOTE *While I encourage you to enter the example code into the interactive shell, you should also make use of web-based regular expression testers, which can show you exactly how a regex matches a piece of text that you enter. I recommend the tester at* http://regexpal.com/.

More Pattern Matching with Regular Expressions

Now that you know the basic steps for creating and finding regular expression objects with Python, you're ready to try some of their more powerful pattern-matching capabilities.

Grouping with Parentheses

Say you want to separate the area code from the rest of the phone number. Adding parentheses will create *groups* in the regex: `(\d\d\d)-(\d\d\d-\d\d\d\d)`. Then you can use the `group()` match object method to grab the matching text from just one group.

The first set of parentheses in a regex string will be group `1`. The second set will be group `2`. By passing the integer `1` or `2` to the `group()` match object method, you can grab different parts of the matched text. Passing `0` or nothing to the `group()` method will return the entire matched text. Enter the following into the interactive shell:

```
>>> phoneNumRegex = re.compile(r'(\d\d\d)-(\d\d\d-\d\d\d\d)')
>>> mo = phoneNumRegex.search('My number is 415-555-4242.')
>>> mo.group(1)
'415'
>>> mo.group(2)
'555-4242'
>>> mo.group(0)
'415-555-4242'
>>> mo.group()
'415-555-4242'
```

If you would like to retrieve all the groups at once, use the `groups()` method—note the plural form for the name.

```
>>> mo.groups()
('415', '555-4242')
>>> areaCode, mainNumber = mo.groups()
>>> print(areaCode)
415
>>> print(mainNumber)
555-4242
```

Since `mo.groups()` returns a tuple of multiple values, you can use the multiple-assignment trick to assign each value to a separate variable, as in the previous `areaCode, mainNumber = mo.groups()` line.

Parentheses have a special meaning in regular expressions, but what do you do if you need to match a parenthesis in your text? For instance, maybe the phone numbers you are trying to match have the area code set in parentheses. In this case, you need to escape the `(` and `)` characters with a backslash. Enter the following into the interactive shell:

```
>>> phoneNumRegex = re.compile(r'(\(\d\d\d\)) (\d\d\d-\d\d\d\d)')
>>> mo = phoneNumRegex.search('My phone number is (415) 555-4242.')
>>> mo.group(1)
'(415)'
>>> mo.group(2)
'555-4242'
```

The `\(` and `\)` escape characters in the raw string passed to `re.compile()` will match actual parenthesis characters.

Matching Multiple Groups with the Pipe

The `|` character is called a *pipe*. You can use it anywhere you want to match one of many expressions. For example, the regular expression `r'Batman|Tina Fey'` will match either `'Batman'` or `'Tina Fey'`.

When *both* Batman and Tina Fey occur in the searched string, the first occurrence of matching text will be returned as the `Match` object. Enter the following into the interactive shell:

```
>>> heroRegex = re.compile (r'Batman|Tina Fey')
>>> mo1 = heroRegex.search('Batman and Tina Fey.')
>>> mo1.group()
'Batman'

>>> mo2 = heroRegex.search('Tina Fey and Batman.')
>>> mo2.group()
'Tina Fey'
```

NOTE *You can find* all *matching occurrences with the `findall()` method that's discussed in "The `findall()` Method" on page 157.*

You can also use the pipe to match one of several patterns as part of your regex. For example, say you wanted to match any of the strings `'Batman'`, `'Batmobile'`, `'Batcopter'`, and `'Batbat'`. Since all these strings start with `Bat`, it would be nice if you could specify that prefix only once. This can be done with parentheses. Enter the following into the interactive shell:

```
>>> batRegex = re.compile(r'Bat(man|mobile|copter|bat)')
>>> mo = batRegex.search('Batmobile lost a wheel')
>>> mo.group()
'Batmobile'
>>> mo.group(1)
'mobile'
```

The method call `mo.group()` returns the full matched text `'Batmobile'`, while `mo.group(1)` returns just the part of the matched text inside the first parentheses group, `'mobile'`. By using the pipe character and grouping parentheses, you can specify several alternative patterns you would like your regex to match.

If you need to match an actual pipe character, escape it with a backslash, like `\|`.

Optional Matching with the Question Mark

Sometimes there is a pattern that you want to match only optionally. That is, the regex should find a match whether or not that bit of text is there. The `?` character flags the group that precedes it as an optional part of the pattern. For example, enter the following into the interactive shell:

```
>>> batRegex = re.compile(r'Bat(wo)?man')
>>> mo1 = batRegex.search('The Adventures of Batman')
>>> mo1.group()
'Batman'

>>> mo2 = batRegex.search('The Adventures of Batwoman')
>>> mo2.group()
'Batwoman'
```

The `(wo)?` part of the regular expression means that the pattern `wo` is an optional group. The regex will match text that has zero instances or one instance of *wo* in it. This is why the regex matches both `'Batwoman'` and `'Batman'`.

Using the earlier phone number example, you can make the regex look for phone numbers that do or do not have an area code. Enter the following into the interactive shell:

```
>>> phoneRegex = re.compile(r'(\d\d\d-)?\d\d\d-\d\d\d\d')
>>> mo1 = phoneRegex.search('My number is 415-555-4242')
>>> mo1.group()
'415-555-4242'
```

```
>>> mo2 = phoneRegex.search('My number is 555-4242')
>>> mo2.group()
'555-4242'
```

You can think of the ? as saying, "Match zero or one of the group preceding this question mark."

If you need to match an actual question mark character, escape it with \?.

Matching Zero or More with the Star

The * (called the *star* or *asterisk*) means "match zero or more"—the group that precedes the star can occur any number of times in the text. It can be completely absent or repeated over and over again. Let's look at the Batman example again.

```
>>> batRegex = re.compile(r'Bat(wo)*man')
>>> mo1 = batRegex.search('The Adventures of Batman')
>>> mo1.group()
'Batman'

>>> mo2 = batRegex.search('The Adventures of Batwoman')
>>> mo2.group()
'Batwoman'

>>> mo3 = batRegex.search('The Adventures of Batwowowowoman')
>>> mo3.group()
'Batwowowowoman'
```

For 'Batman', the (wo)* part of the regex matches zero instances of wo in the string; for 'Batwoman', the (wo)* matches one instance of wo; and for 'Batwowowowoman', (wo)* matches four instances of wo.

If you need to match an actual star character, prefix the star in the regular expression with a backslash, *.

Matching One or More with the Plus

While * means "match zero or more," the + (or *plus*) means "match one or more." Unlike the star, which does not require its group to appear in the matched string, the group preceding a plus must appear *at least once*. It is not optional. Enter the following into the interactive shell, and compare it with the star regexes in the previous section:

```
>>> batRegex = re.compile(r'Bat(wo)+man')
>>> mo1 = batRegex.search('The Adventures of Batwoman')
>>> mo1.group()
'Batwoman'

>>> mo2 = batRegex.search('The Adventures of Batwowowowoman')
>>> mo2.group()
'Batwowowowoman'
```

```
>>> mo3 = batRegex.search('The Adventures of Batman')
>>> mo3 == None
True
```

The regex `Bat(wo)+man` will not match the string `'The Adventures of Batman'` because at least one `wo` is required by the plus sign.

If you need to match an actual plus sign character, prefix the plus sign with a backslash to escape it: `\+`.

Matching Specific Repetitions with Curly Brackets

If you have a group that you want to repeat a specific number of times, follow the group in your regex with a number in curly brackets. For example, the regex `(Ha){3}` will match the string `'HaHaHa'`, but it will not match `'HaHa'`, since the latter has only two repeats of the `(Ha)` group.

Instead of one number, you can specify a range by writing a minimum, a comma, and a maximum in between the curly brackets. For example, the regex `(Ha){3,5}` will match `'HaHaHa'`, `'HaHaHaHa'`, and `'HaHaHaHaHa'`.

You can also leave out the first or second number in the curly brackets to leave the minimum or maximum unbounded. For example, `(Ha){3,}` will match three or more instances of the `(Ha)` group, while `(Ha){,5}` will match zero to five instances. Curly brackets can help make your regular expressions shorter. These two regular expressions match identical patterns:

```
(Ha){3}
(Ha)(Ha)(Ha)
```

And these two regular expressions also match identical patterns:

```
(Ha){3,5}
((Ha)(Ha)(Ha))|((Ha)(Ha)(Ha)(Ha))|((Ha)(Ha)(Ha)(Ha)(Ha))
```

Enter the following into the interactive shell:

```
>>> haRegex = re.compile(r'(Ha){3}')
>>> mo1 = haRegex.search('HaHaHa')
>>> mo1.group()
'HaHaHa'

>>> mo2 = haRegex.search('Ha')
>>> mo2 == None
True
```

Here, `(Ha){3}` matches `'HaHaHa'` but not `'Ha'`. Since it doesn't match `'Ha'`, `search()` returns `None`.

Greedy and Nongreedy Matching

Since `(Ha){3,5}` can match three, four, or five instances of `Ha` in the string `'HaHaHaHaHa'`, you may wonder why the `Match` object's call to `group()` in the previous curly bracket example returns 'HaHaHaHaHa' instead of the shorter possibilities. After all, 'HaHaHa' and 'HaHaHaHa' are also valid matches of the regular expression (Ha){3,5}.

Python's regular expressions are *greedy* by default, which means that in ambiguous situations they will match the longest string possible. The *non-greedy* version of the curly brackets, which matches the shortest string possible, has the closing curly bracket followed by a question mark.

Enter the following into the interactive shell, and notice the difference between the greedy and nongreedy forms of the curly brackets searching the same string:

```
>>> greedyHaRegex = re.compile(r'(Ha){3,5}')
>>> mo1 = greedyHaRegex.search('HaHaHaHaHa')
>>> mo1.group()
'HaHaHaHaHa'

>>> nongreedyHaRegex = re.compile(r'(Ha){3,5}?')
>>> mo2 = nongreedyHaRegex.search('HaHaHaHaHa')
>>> mo2.group()
'HaHaHa'
```

Note that the question mark can have two meanings in regular expressions: declaring a nongreedy match or flagging an optional group. These meanings are entirely unrelated.

The findall() Method

In addition to the search() method, Regex objects also have a findall() method. While search() will return a Match object of the *first* matched text in the searched string, the findall() method will return the strings of *every* match in the searched string. To see how search() returns a Match object only on the first instance of matching text, enter the following into the interactive shell:

```
>>> phoneNumRegex = re.compile(r'\d\d\d-\d\d\d-\d\d\d\d')
>>> mo = phoneNumRegex.search('Cell: 415-555-9999 Work: 212-555-0000')
>>> mo.group()
'415-555-9999'
```

On the other hand, findall() will not return a Match object but a list of strings—*as long as there are no groups in the regular expression*. Each string in the list is a piece of the searched text that matched the regular expression. Enter the following into the interactive shell:

```
>>> phoneNumRegex = re.compile(r'\d\d\d-\d\d\d-\d\d\d\d') # has no groups
>>> phoneNumRegex.findall('Cell: 415-555-9999 Work: 212-555-0000')
['415-555-9999', '212-555-0000']
```

If there *are* groups in the regular expression, then findall() will return a list of tuples. Each tuple represents a found match, and its items are the matched strings for each group in the regex. To see `findall()` in action, enter the following into the interactive shell (notice that the regular expression being compiled now has groups in parentheses):

```
>>> phoneNumRegex = re.compile(r'(\d\d\d)-(\d\d\d)-(\d\d\d\d)') # has groups
>>> phoneNumRegex.findall('Cell: 415-555-9999 Work: 212-555-0000')
[('415', '555', '1122'), ('212', '555', '0000')]
```

To summarize what the `findall()` method returns, remember the following:

1. When called on a regex with no groups, such as `\d\d\d-\d\d\d-\d\d\d\d`, the method `findall()` returns a list of string matches, such as `['415-555-9999', '212-555-0000']`.
2. When called on a regex that has groups, such as `(\d\d\d)-(\d\d\d)-(\d\d\d\d)`, the method `findall()` returns a list of tuples of strings (one string for each group), such as `[('415', '555', '1122'), ('212', '555', '0000')]`.

Character Classes

In the earlier phone number regex example, you learned that `\d` could stand for any numeric digit. That is, `\d` is shorthand for the regular expression `(0|1|2|3|4|5|6|7|8|9)`. There are many such *shorthand character classes*, as shown in Table 7-1.

Table 7-1: Shorthand Codes for Common Character Classes

Shorthand character class	Represents
`\d`	Any numeric digit from 0 to 9.
`\D`	Any character that is *not* a numeric digit from 0 to 9.
`\w`	Any letter, numeric digit, or the underscore character. (Think of this as matching "word" characters.)
`\W`	Any character that is *not* a letter, numeric digit, or the underscore character.
`\s`	Any space, tab, or newline character. (Think of this as matching "space" characters.)
`\S`	Any character that is *not* a space, tab, or newline.

Character classes are nice for shortening regular expressions. The character class `[0-5]` will match only the numbers `0` to `5`; this is much shorter than typing `(0|1|2|3|4|5)`.

For example, enter the following into the interactive shell:

```
>>> xmasRegex = re.compile(r'\d+\s\w+')
>>> xmasRegex.findall('12 drummers, 11 pipers, 10 lords, 9 ladies, 8 maids, 7
swans, 6 geese, 5 rings, 4 birds, 3 hens, 2 doves, 1 partridge')
['12 drummers', '11 pipers', '10 lords', '9 ladies', '8 maids', '7 swans', '6
geese', '5 rings', '4 birds', '3 hens', '2 doves', '1 partridge']
```

The regular expression \d+\s\w+ will match text that has one or more numeric digits (\d+), followed by a whitespace character (\s), followed by one or more letter/digit/underscore characters (\w+). The findall() method returns all matching strings of the regex pattern in a list.

Making Your Own Character Classes

There are times when you want to match a set of characters but the shorthand character classes (\d, \w, \s, and so on) are too broad. You can define your own character class using square brackets. For example, the character class [aeiouAEIOU] will match any vowel, both lowercase and uppercase. Enter the following into the interactive shell:

```
>>> vowelRegex = re.compile(r'[aeiouAEIOU]')
>>> vowelRegex.findall('RoboCop eats baby food. BABY FOOD.')
['o', 'o', 'o', 'e', 'a', 'a', 'o', 'o', 'A', 'O', 'O']
```

You can also include ranges of letters or numbers by using a hyphen. For example, the character class [a-zA-Z0-9] will match all lowercase letters, uppercase letters, and numbers.

Note that inside the square brackets, the normal regular expression symbols are not interpreted as such. This means you do not need to escape the ., *, ?, or () characters with a preceding backslash. For example, the character class [0-5.] will match digits 0 to 5 and a period. You do not need to write it as [0-5\.].

By placing a caret character (^) just after the character class's opening bracket, you can make a *negative character class*. A negative character class will match all the characters that are *not* in the character class. For example, enter the following into the interactive shell:

```
>>> consonantRegex = re.compile(r'[^aeiouAEIOU]')
>>> consonantRegex.findall('RoboCop eats baby food. BABY FOOD.')
['R', 'b', 'c', 'p', ' ', 't', 's', ' ', 'b', 'b', 'y', ' ', 'f', 'd', '.', '
', 'B', 'B', 'Y', ' ', 'F', 'D', '.']
```

Now, instead of matching every vowel, we're matching every character that isn't a vowel.

The Caret and Dollar Sign Characters

You can also use the caret symbol (^) at the start of a regex to indicate that a match must occur at the *beginning* of the searched text. Likewise, you can put a dollar sign ($) at the end of the regex to indicate the string must *end* with this regex pattern. And you can use the ^ and $ together to indicate that the entire string must match the regex—that is, it's not enough for a match to be made on some subset of the string.

For example, the `r'^Hello'` regular expression string matches strings that begin with `'Hello'`. Enter the following into the interactive shell:

```
>>> beginsWithHello = re.compile(r'^Hello')
>>> beginsWithHello.search('Hello world!')
<_sre.SRE_Match object; span=(0, 5), match='Hello'>
>>> beginsWithHello.search('He said hello.') == None
True
```

The `r'\d$'` regular expression string matches strings that end with a numeric character from 0 to 9. Enter the following into the interactive shell:

```
>>> endsWithNumber = re.compile(r'\d$')
>>> endsWithNumber.search('Your number is 42')
<_sre.SRE_Match object; span=(16, 17), match='2'>
>>> endsWithNumber.search('Your number is forty two.') == None
True
```

The `r'^\d+$'` regular expression string matches strings that both begin and end with one or more numeric characters. Enter the following into the interactive shell:

```
>>> wholeStringIsNum = re.compile(r'^\d+$')
>>> wholeStringIsNum.search('1234567890')
<_sre.SRE_Match object; span=(0, 10), match='1234567890'>
>>> wholeStringIsNum.search('12345xyz67890') == None
True
>>> wholeStringIsNum.search('12  34567890') == None
True
```

The last two `search()` calls in the previous interactive shell example demonstrate how the entire string must match the regex if `^` and `$` are used.

I always confuse the meanings of these two symbols, so I use the mnemonic "Carrots cost dollars" to remind myself that the caret comes first and the dollar sign comes last.

The Wildcard Character

The `.` (or *dot*) character in a regular expression is called a *wildcard* and will match any character except for a newline. For example, enter the following into the interactive shell:

```
>>> atRegex = re.compile(r'.at')
>>> atRegex.findall('The cat in the hat sat on the flat mat.')
['cat', 'hat', 'sat', 'lat', 'mat']
```

Remember that the dot character will match just one character, which is why the match for the text flat in the previous example matched only lat. To match an actual dot, escape the dot with a backslash: \..

Matching Everything with Dot-Star

Sometimes you will want to match everything and anything. For example, say you want to match the string 'First Name:', followed by any and all text, followed by 'Last Name:', and then followed by anything again. You can use the dot-star (.*) to stand in for that "anything." Remember that the dot character means "any single character except the newline," and the star character means "zero or more of the preceding character."

Enter the following into the interactive shell:

```
>>> nameRegex = re.compile(r'First Name: (.*) Last Name: (.*)')
>>> mo = nameRegex.search('First Name: Al Last Name: Sweigart')
>>> mo.group(1)
'Al'
>>> mo.group(2)
'Sweigart'
```

The dot-star uses *greedy* mode: It will always try to match as much text as possible. To match any and all text in a *nongreedy* fashion, use the dot, star, and question mark (.*?). Like with curly brackets, the question mark tells Python to match in a nongreedy way.

Enter the following into the interactive shell to see the difference between the greedy and nongreedy versions:

```
>>> nongreedyRegex = re.compile(r'<.*?>')
>>> mo = nongreedyRegex.search('<To serve man> for dinner.>')
>>> mo.group()
'<To serve man>'

>>> greedyRegex = re.compile(r'<.*>')
>>> mo = greedyRegex.search('<To serve man> for dinner.>')
>>> mo.group()
'<To serve man> for dinner.>'
```

Both regexes roughly translate to "Match an opening angle bracket, followed by anything, followed by a closing angle bracket." But the string '<To serve man> for dinner.>' has two possible matches for the closing angle bracket. In the nongreedy version of the regex, Python matches the shortest possible string: '<To serve man>'. In the greedy version, Python matches the longest possible string: '<To serve man> for dinner.>'.

Matching Newlines with the Dot Character

The dot-star will match everything except a newline. By passing `re.DOTALL` as the second argument to `re.compile()`, you can make the dot character match *all* characters, including the newline character.

Enter the following into the interactive shell:

```
>>> noNewlineRegex = re.compile('.*')
>>> noNewlineRegex.search('Serve the public trust.\nProtect the innocent.
\nUphold the law.').group()
'Serve the public trust.'

>>> newlineRegex = re.compile('.*', re.DOTALL)
>>> newlineRegex.search('Serve the public trust.\nProtect the innocent.
\nUphold the law.').group()
'Serve the public trust.\nProtect the innocent.\nUphold the law.'
```

The regex `noNewlineRegex`, which did not have `re.DOTALL` passed to the `re.compile()` call that created it, will match everything only up to the first newline character, whereas `newlineRegex`, which *did* have `re.DOTALL` passed to `re.compile()`, matches everything. This is why the `newlineRegex.search()` call matches the full string, including its newline characters.

Review of Regex Symbols

This chapter covered a lot of notation, so here's a quick review of what you learned:

- The `?` matches zero or one of the preceding group.
- The `*` matches zero or more of the preceding group.
- The `+` matches one or more of the preceding group.
- The `{n}` matches exactly *n* of the preceding group.
- The `{n,}` matches *n* or more of the preceding group.
- The `{,m}` matches 0 to *m* of the preceding group.
- The `{n,m}` matches at least *n* and at most *m* of the preceding group.
- `{n,m}?` or `*?` or `+?` performs a nongreedy match of the preceding group.
- `^spam` means the string must begin with *spam*.
- `spam$` means the string must end with *spam*.
- The `.` matches any character, except newline characters.
- `\d`, `\w`, and `\s` match a digit, word, or space character, respectively.
- `\D`, `\W`, and `\S` match anything except a digit, word, or space character, respectively.
- `[abc]` matches any character between the brackets (such as *a*, *b*, or *c*).
- `[^abc]` matches any character that isn't between the brackets.

Case-Insensitive Matching

Normally, regular expressions match text with the exact casing you specify. For example, the following regexes match completely different strings:

```
>>> regex1 = re.compile('RoboCop')
>>> regex2 = re.compile('ROBOCOP')
>>> regex3 = re.compile('robOcop')
>>> regex4 = re.compile('RobocOp')
```

But sometimes you care only about matching the letters without worrying whether they're uppercase or lowercase. To make your regex case-insensitive, you can pass `re.IGNORECASE` or `re.I` as a second argument to `re.compile()`. Enter the following into the interactive shell:

```
>>> robocop = re.compile(r'robocop', re.I)
>>> robocop.search('RoboCop is part man, part machine, all cop.').group()
'RoboCop'

>>> robocop.search('ROBOCOP protects the innocent.').group()
'ROBOCOP'

>>> robocop.search('Al, why does your programming book talk about robocop so much?').group()
'robocop'
```

Substituting Strings with the sub() Method

Regular expressions can not only find text patterns but can also substitute new text in place of those patterns. The `sub()` method for `Regex` objects is passed two arguments. The first argument is a string to replace any matches. The second is the string for the regular expression. The `sub()` method returns a string with the substitutions applied.

For example, enter the following into the interactive shell:

```
>>> namesRegex = re.compile(r'Agent \w+')
>>> namesRegex.sub('CENSORED', 'Agent Alice gave the secret documents to Agent Bob.')
'CENSORED gave the secret documents to CENSORED.'
```

Sometimes you may need to use the matched text itself as part of the substitution. In the first argument to `sub()`, you can type `\1`, `\2`, `\3`, and so on, to mean "Enter the text of group `1`, `2`, `3`, and so on, in the substitution."

For example, say you want to censor the names of the secret agents by showing just the first letters of their names. To do this, you could use the regex `Agent (\w)\w*` and pass `r'\1****'` as the first argument to `sub()`. The `\1` in that string will be replaced by whatever text was matched by group `1`—that is, the `(\w)` group of the regular expression.

```
>>> agentNamesRegex = re.compile(r'Agent (\w)\w*')
>>> agentNamesRegex.sub(r'\1****', 'Agent Alice told Agent Carol that Agent
Eve knew Agent Bob was a double agent.')
A**** told C**** that E**** knew B**** was a double agent.'
```

Managing Complex Regexes

Regular expressions are fine if the text pattern you need to match is simple. But matching complicated text patterns might require long, convoluted regular expressions. You can mitigate this by telling the `re.compile()` function to ignore whitespace and comments inside the regular expression string. This "verbose mode" can be enabled by passing the variable `re.VERBOSE` as the second argument to `re.compile()`.

Now instead of a hard-to-read regular expression like this:

```
phoneRegex = re.compile(r'((\d{3}|\(\d{3}\))?(\s|-|\.)?\d{3}(\s|-|\.)\d{4}
(\s*(ext|x|ext.)\s*\d{2,5})?)')
```

you can spread the regular expression over multiple lines with comments like this:

```
phoneRegex = re.compile(r'''(
    (\d{3}|\(\d{3}\))?            # area code
    (\s|-|\.)?                    # separator
    \d{3}                         # first 3 digits
    (\s|-|\.)                     # separator
    \d{4}                         # last 4 digits
    (\s*(ext|x|ext.)\s*\d{2,5})?  # extension
    )''', re.VERBOSE)
```

Note how the previous example uses the triple-quote syntax (`'''`) to create a multiline string so that you can spread the regular expression definition over many lines, making it much more legible.

The comment rules inside the regular expression string are the same as regular Python code: The `#` symbol and everything after it to the end of the line are ignored. Also, the extra spaces inside the multiline string for the regular expression are not considered part of the text pattern to be matched. This lets you organize the regular expression so it's easier to read.

Combining re.IGNORECASE, re.DOTALL, and re.VERBOSE

What if you want to use `re.VERBOSE` to write comments in your regular expression but also want to use `re.IGNORECASE` to ignore capitalization? Unfortunately, the `re.compile()` function takes only a single value as its second argument. You can get around this limitation by combining the `re.IGNORECASE`, `re.DOTALL`, and `re.VERBOSE` variables using the pipe character (`|`), which in this context is known as the *bitwise or* operator.

So if you want a regular expression that's case-insensitive *and* includes newlines to match the dot character, you would form your `re.compile()` call like this:

```
>>> someRegexValue = re.compile('foo', re.IGNORECASE | re.DOTALL)
```

All three options for the second argument will look like this:

```
>>> someRegexValue = re.compile('foo', re.IGNORECASE | re.DOTALL | re.VERBOSE)
```

This syntax is a little old-fashioned and originates from early versions of Python. The details of the bitwise operators are beyond the scope of this book, but check out the resources at *http://nostarch.com/automatestuff/* for more information. You can also pass other options for the second argument; they're uncommon, but you can read more about them in the resources, too.

Project: Phone Number and Email Address Extractor

Say you have the boring task of finding every phone number and email address in a long web page or document. If you manually scroll through the page, you might end up searching for a long time. But if you had a program that could search the text in your clipboard for phone numbers and email addresses, you could simply press CTRL-A to select all the text, press CTRL-C to copy it to the clipboard, and then run your program. It could replace the text on the clipboard with just the phone numbers and email addresses it finds.

Whenever you're tackling a new project, it can be tempting to dive right into writing code. But more often than not, it's best to take a step back and consider the bigger picture. I recommend first drawing up a high-level plan for what your program needs to do. Don't think about the actual code yet—you can worry about that later. Right now, stick to broad strokes.

For example, your phone and email address extractor will need to do the following:

- Get the text off the clipboard.
- Find all phone numbers and email addresses in the text.
- Paste them onto the clipboard.

Now you can start thinking about how this might work in code. The code will need to do the following:

- Use the `pyperclip` module to copy and paste strings.
- Create two regexes, one for matching phone numbers and the other for matching email addresses.
- Find all matches, not just the first match, of both regexes.
- Neatly format the matched strings into a single string to paste.
- Display some kind of message if no matches were found in the text.

This list is like a road map for the project. As you write the code, you can focus on each of these steps separately. Each step is fairly manageable and expressed in terms of things you already know how to do in Python.

Step 1: Create a Regex for Phone Numbers

First, you have to create a regular expression to search for phone numbers. Create a new file, enter the following, and save it as *phoneAndEmail.py*:

```
#! python3
# phoneAndEmail.py - Finds phone numbers and email addresses on the clipboard.

import pyperclip, re

phoneRegex = re.compile(r'''(
    (\d{3}|\(\d{3}\))?                # area code
    (\s|-|\.)?                        # separator
    (\d{3})                           # first 3 digits
    (\s|-|\.)                         # separator
    (\d{4})                           # last 4 digits
    (\s*(ext|x|ext.)\s*(\d{2,5}))?    # extension
    )''', re.VERBOSE)

# TODO: Create email regex.

# TODO: Find matches in clipboard text.

# TODO: Copy results to the clipboard.
```

The `TODO` comments are just a skeleton for the program. They'll be replaced as you write the actual code.

The phone number begins with an *optional* area code, so the area code group is followed with a question mark. Since the area code can be just three digits (that is, `\d{3}`) *or* three digits within parentheses (that is, `\(\d{3}\)`), you should have a pipe joining those parts. You can add the regex comment `# Area code` to this part of the multiline string to help you remember what `(\d{3}|\(\d{3}\))?` is supposed to match.

The phone number separator character can be a space (`\s`), hyphen (`-`), or period (`.`), so these parts should also be joined by pipes. The next few parts of the regular expression are straightforward: three digits, followed by another separator, followed by four digits. The last part is an optional extension made up of any number of spaces followed by `ext`, `x`, or `ext.`, followed by two to five digits.

Step 2: Create a Regex for Email Addresses

You will also need a regular expression that can match email addresses. Make your program look like the following:

```
#! python3
# phoneAndEmail.py - Finds phone numbers and email addresses on the clipboard.
```

```
import pyperclip, re

phoneRegex = re.compile(r'''(
--snip--

# Create email regex.
emailRegex = re.compile(r'''(
❶    [a-zA-Z0-9._%+-]+      # username
❷    @                      # @ symbol
❸    [a-zA-Z0-9.-]+         # domain name
     (\.[a-zA-Z]{2,4})      # dot-something
     )''', re.VERBOSE)

# TODO: Find matches in clipboard text.

# TODO: Copy results to the clipboard.
```

The username part of the email address ❶ is one or more characters that can be any of the following: lowercase and uppercase letters, numbers, a dot, an underscore, a percent sign, a plus sign, or a hyphen. You can put all of these into a character class: `[a-zA-Z0-9._%+-]`.

The domain and username are separated by an @ symbol ❷. The domain name ❸ has a slightly less permissive character class with only letters, numbers, periods, and hyphens: `[a-zA-Z0-9.-]`. And last will be the "dot-com" part (technically known as the *top-level domain*), which can really be dot-anything. This is between two and four characters.

The format for email addresses has a lot of weird rules. This regular expression won't match every possible valid email address, but it'll match almost any typical email address you'll encounter.

Step 3: Find All Matches in the Clipboard Text

Now that you have specified the regular expressions for phone numbers and email addresses, you can let Python's `re` module do the hard work of finding all the matches on the clipboard. The `pyperclip.paste()` function will get a string value of the text on the clipboard, and the `findall()` regex method will return a list of tuples.

Make your program look like the following:

```
#! python3
# phoneAndEmail.py - Finds phone numbers and email addresses on the clipboard.

import pyperclip, re

phoneRegex = re.compile(r'''(
--snip--

# Find matches in clipboard text.
text = str(pyperclip.paste())
```

```
❶ matches = []
❷ for groups in phoneRegex.findall(text):
      phoneNum = '-'.join([groups[1], groups[3], groups[5]])
      if groups[8] != '':
          phoneNum += ' x' + groups[8]
      matches.append(phoneNum)
❸ for groups in emailRegex.findall(text):
      matches.append(groups[0])

  # TODO: Copy results to the clipboard.
```

There is one tuple for each match, and each tuple contains strings for each group in the regular expression. Remember that group 0 matches the entire regular expression, so the group at index 0 of the tuple is the one you are interested in.

As you can see at ❶, you'll store the matches in a list variable named `matches`. It starts off as an empty list, and a couple `for` loops. For the email addresses, you append group 0 of each match ❸. For the matched phone numbers, you don't want to just append group 0. While the program *detects* phone numbers in several formats, you want the phone number appended to be in a single, standard format. The `phoneNum` variable contains a string built from groups 1, 3, 5, and 8 of the matched text ❷. (These groups are the area code, first three digits, last four digits, and extension.)

Step 4: Join the Matches into a String for the Clipboard

Now that you have the email addresses and phone numbers as a list of strings in `matches`, you want to put them on the clipboard. The `pyperclip.copy()` function takes only a single string value, not a list of strings, so you call the `join()` method on `matches`.

To make it easier to see that the program is working, let's print any matches you find to the terminal. And if no phone numbers or email addresses were found, the program should tell the user this.

Make your program look like the following:

```
#! python3
# phoneAndEmail.py - Finds phone numbers and email addresses on the clipboard.

--snip--
for groups in emailRegex.findall(text):
    matches.append(groups[0])

# Copy results to the clipboard.
if len(matches) > 0:
    pyperclip.copy('\n'.join(matches))
    print('Copied to clipboard:')
    print('\n'.join(matches))
else:
    print('No phone numbers or email addresses found.')
```

Running the Program

For an example, open your web browser to the No Starch Press contact page at *http://www.nostarch.com/contactus.htm*, press CTRL-A to select all the text on the page, and press CTRL-C to copy it to the clipboard. When you run this program, the output will look something like this:

```
Copied to clipboard:
800-420-7240
415-863-9900
415-863-9950
info@nostarch.com
media@nostarch.com
academic@nostarch.com
help@nostarch.com
```

Ideas for Similar Programs

Identifying patterns of text (and possibly substituting them with the `sub()` method) has many different potential applications.

- Find website URLs that begin with *http://* or *https://*.
- Clean up dates in different date formats (such as 3/14/2015, 03-14-2015, and 2015/3/14) by replacing them with dates in a single, standard format.
- Remove sensitive information such as Social Security or credit card numbers.
- Find common typos such as multiple   spaces between   words, accidentally accidentally repeated words, or multiple exclamation marks at the end of sentences. Those are annoying!!

Summary

While a computer can search for text quickly, it must be told precisely what to look for. Regular expressions allow you to specify the precise patterns of characters you are looking for. In fact, some word processing and spreadsheet applications provide find-and-replace features that allow you to search using regular expressions.

The `re` module that comes with Python lets you compile `Regex` objects. These values have several methods: `search()` to find a single match, `findall()` to find all matching instances, and `sub()` to do a find-and-replace substitution of text.

There's a bit more to regular expression syntax than is described in this chapter. You can find out more in the official Python documentation at *http://docs.python.org/3/library/re.html*. The tutorial website *http://www.regular-expressions.info/* is also a useful resource.

Now that you have expertise manipulating and matching strings, it's time to dive into how to read from and write to files on your computer's hard drive.

Practice Questions

1. What is the function that creates `Regex` objects?
2. Why are raw strings often used when creating `Regex` objects?
3. What does the `search()` method return?
4. How do you get the actual strings that match the pattern from a `Match` object?
5. In the regex created from `r'(\d\d\d)-(\d\d\d-\d\d\d\d)'`, what does group `0` cover? Group `1`? Group `2`?
6. Parentheses and periods have specific meanings in regular expression syntax. How would you specify that you want a regex to match actual parentheses and period characters?
7. The `findall()` method returns a list of strings or a list of tuples of strings. What makes it return one or the other?
8. What does the `|` character signify in regular expressions?
9. What two things does the `?` character signify in regular expressions?
10. What is the difference between the `+` and `*` characters in regular expressions?
11. What is the difference between `{3}` and `{3,5}` in regular expressions?
12. What do the `\d`, `\w`, and `\s` shorthand character classes signify in regular expressions?
13. What do the `\D`, `\W`, and `\S` shorthand character classes signify in regular expressions?
14. How do you make a regular expression case-insensitive?
15. What does the `.` character normally match? What does it match if `re.DOTALL` is passed as the second argument to `re.compile()`?
16. What is the difference between `.*` and `.*?`?
17. What is the character class syntax to match all numbers and lowercase letters?
18. If `numRegex = re.compile(r'\d+')`, what will `numRegex.sub('X', '12 drummers, 11 pipers, five rings, 3 hens')` return?
19. What does passing `re.VERBOSE` as the second argument to `re.compile()` allow you to do?
20. How would you write a regex that matches a number with commas for every three digits? It must match the following:
    - `'42'`
    - `'1,234'`
    - `'6,368,745'`

    but not the following:
    - `'12,34,567'` (which has only two digits between the commas)
    - `'1234'` (which lacks commas)

21. How would you write a regex that matches the full name of someone whose last name is Nakamoto? You can assume that the first name that comes before it will always be one word that begins with a capital letter. The regex must match the following:
    - `'Satoshi Nakamoto'`
    - `'Alice Nakamoto'`
    - `'RoboCop Nakamoto'`

    but not the following:
    - `'satoshi Nakamoto'` (where the first name is not capitalized)
    - `'Mr. Nakamoto'` (where the preceding word has a nonletter character)
    - `'Nakamoto'` (which has no first name)
    - `'Satoshi nakamoto'` (where Nakamoto is not capitalized)
22. How would you write a regex that matches a sentence where the first word is either *Alice*, *Bob*, or *Carol*; the second word is either *eats*, *pets*, or *throws*; the third word is *apples*, *cats*, or *baseballs*; and the sentence ends with a period? This regex should be case-insensitive. It must match the following:
    - `'Alice eats apples.'`
    - `'Bob pets cats.'`
    - `'Carol throws baseballs.'`
    - `'Alice throws Apples.'`
    - `'BOB EATS CATS.'`

    but not the following:
    - `'RoboCop eats apples.'`
    - `'ALICE THROWS FOOTBALLS.'`
    - `'Carol eats 7 cats.'`

Practice Projects

For practice, write programs to do the following tasks.

Strong Password Detection

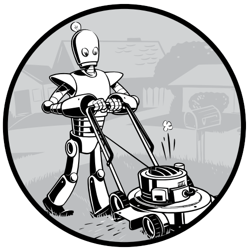
Write a function that uses regular expressions to make sure the password string it is passed is strong. A strong password is defined as one that is at least eight characters long, contains both uppercase and lowercase characters, and has at least one digit. You may need to test the string against multiple regex patterns to validate its strength.

Regex Version of strip()

Write a function that takes a string and does the same thing as the `strip()` string method. If no other arguments are passed other than the string to strip, then whitespace characters will be removed from the beginning and end of the string. Otherwise, the characters specified in the second argument to the function will be removed from the string.

8

READING AND WRITING FILES



Variables are a fine way to store data while your program is running, but if you want your data to persist even after your program has finished, you need to save it to a file. You can think of a file's contents as a single string value, potentially gigabytes in size. In this chapter, you will learn how to use Python to create, read, and save files on the hard drive.

Files and File Paths

A file has two key properties: a *filename* (usually written as one word) and a *path*. The path specifies the location of a file on the computer. For example, there is a file on my Windows 7 laptop with the filename *projects.docx* in the path *C:\Users\asweigart\Documents*. The part of the filename after the last period is called the file's *extension* and tells you a file's type. *project.docx* is a Word document, and *Users*, *asweigart*, and *Documents* all refer to *folders* (also called *directories*). Folders can contain files and other folders. For example, *project.docx* is in the *Documents* folder, which is inside the *asweigart* folder, which is inside the *Users* folder. Figure 8-1 shows this folder organization.

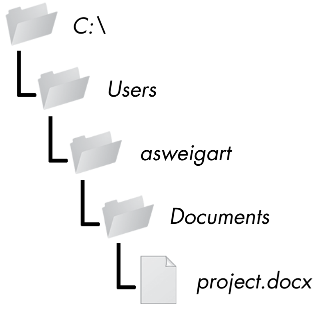


Figure 8-1: A file in a hierarchy of folders

The *C:\* part of the path is the *root folder*, which contains all other folders. On Windows, the root folder is named *C:\* and is also called the *C: drive*. On OS X and Linux, the root folder is */*. In this book, I'll be using the Windows-style root folder, *C:\*. If you are entering the interactive shell examples on OS X or Linux, enter `/` instead.

Additional *volumes*, such as a DVD drive or USB thumb drive, will appear differently on different operating systems. On Windows, they appear as new, lettered root drives, such as *D:\* or *E:\*. On OS X, they appear as new folders under the */Volumes* folder. On Linux, they appear as new folders under the */mnt* ("mount") folder. Also note that while folder names and filenames are not case sensitive on Windows and OS X, they are case sensitive on Linux.

Backslash on Windows and Forward Slash on OS X and Linux

On Windows, paths are written using backslashes (\) as the separator between folder names. OS X and Linux, however, use the forward slash (/) as their path separator. If you want your programs to work on all operating systems, you will have to write your Python scripts to handle both cases.

Fortunately, this is simple to do with the `os.path.join()` function. If you pass it the string values of individual file and folder names in your path, `os.path.join()` will return a string with a file path using the correct path separators. Enter the following into the interactive shell:

```
>>> import os
>>> os.path.join('usr', 'bin', 'spam')
'usr\\bin\\spam'
```

I'm running these interactive shell examples on Windows, so `os.path.join('usr', 'bin', 'spam')` returned `'usr\\bin\\spam'`. (Notice that the backslashes are doubled because each backslash needs to be escaped by another backslash character.) If I had called this function on OS X or Linux, the string would have been `'usr/bin/spam'`.

The os.path.join() function is helpful if you need to create strings for filenames. These strings will be passed to several of the file-related functions introduced in this chapter. For example, the following example joins names from a list of filenames to the end of a folder's name:

```
>>> myFiles = ['accounts.txt', 'details.csv', 'invite.docx']
>>> for filename in myFiles:
        print(os.path.join('C:\\Users\\asweigart', filename))
C:\Users\asweigart\accounts.txt
C:\Users\asweigart\details.csv
C:\Users\asweigart\invite.docx
```

The Current Working Directory

Every program that runs on your computer has a *current working directory*, or *cwd*. Any filenames or paths that do not begin with the root folder are assumed to be under the current working directory. You can get the current working directory as a string value with the `os.getcwd()` function and change it with `os.chdir()`. Enter the following into the interactive shell:

```
>>> import os
>>> os.getcwd()
'C:\\Python34'
>>> os.chdir('C:\\Windows\\System32')
>>> os.getcwd()
'C:\\Windows\\System32'
```

Here, the current working directory is set to *C:\Python34*, so the filename *project.docx* refers to *C:\Python34\project.docx*. When we change the current working directory to *C:\Windows*, *project.docx* is interpreted as *C:\Windows\project.docx*.

Python will display an error if you try to change to a directory that does not exist.

```
>>> os.chdir('C:\\ThisFolderDoesNotExist')
Traceback (most recent call last):
  File "<pyshell#18>", line 1, in <module>
    os.chdir('C:\\ThisFolderDoesNotExist')
FileNotFoundError: [WinError 2] The system cannot find the file specified:
'C:\\ThisFolderDoesNotExist'
```

NOTE *While folder is the more modern name for directory, note that* current working directory *(or just* working directory*) is the standard term, not current working folder.*

Absolute vs. Relative Paths

There are two ways to specify a file path.

- An *absolute path*, which always begins with the root folder
- A *relative path*, which is relative to the program's current working directory

There are also the *dot* (`.`) and *dot-dot* (`..`) folders. These are not real folders but special names that can be used in a path. A single period ("dot") for a folder name is shorthand for "this directory." Two periods ("dot-dot") means "the parent folder."

Figure 8-2 is an example of some folders and files. When the current working directory is set to *C:\bacon*, the relative paths for the other folders and files are set as they are in the figure.

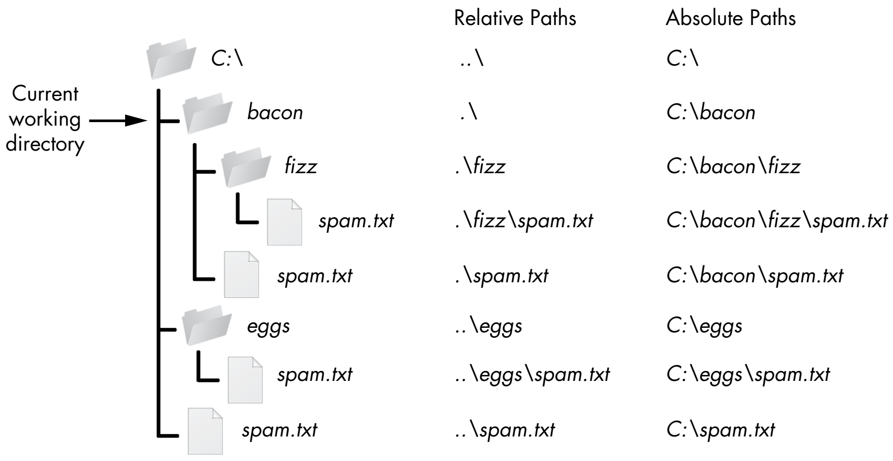


Figure 8-2: The relative paths for folders and files in the working directory C:\bacon

The .\ at the start of a relative path is optional. For example, *.\spam.txt* and *spam.txt* refer to the same file.

Creating New Folders with os.makedirs()

Your programs can create new folders (directories) with the `os.makedirs()` function. Enter the following into the interactive shell:

```
>>> import os
>>> os.makedirs('C:\\delicious\\walnut\\waffles')
```

This will create not just the *C:\delicious* folder but also a *walnut* folder inside *C:\delicious* and a *waffles* folder inside *C:\delicious\walnut*. That is, `os.makedirs()` will create any necessary intermediate folders in order to ensure that the full path exists. Figure 8-3 shows this hierarchy of folders.

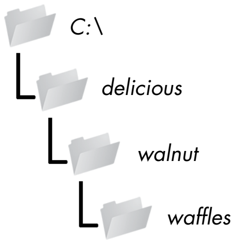


Figure 8-3: The result of `os.makedirs('C:\\delicious \\walnut\\waffles')`

The os.path Module

The `os.path` module contains many helpful functions related to filenames and file paths. For instance, you've already used `os.path.join()` to build paths in a way that will work on any operating system. Since `os.path` is a module inside the `os` module, you can import it by simply running `import os`. Whenever your programs need to work with files, folders, or file paths, you can refer to the short examples in this section. The full documentation for the `os.path` module is on the Python website at *http://docs.python.org/3/library/os.path.html.*

NOTE *Most of the examples that follow in this section will require the* `os` *module, so remember to import it at the beginning of any script you write and any time you restart IDLE. Otherwise, you'll get a* `NameError: name 'os' is not defined` *error message.*

Handling Absolute and Relative Paths

The `os.path` module provides functions for returning the absolute path of a relative path and for checking whether a given path is an absolute path.

- Calling `os.path.abspath(path)` will return a string of the absolute path of the argument. This is an easy way to convert a relative path into an absolute one.
- Calling `os.path.isabs(path)` will return `True` if the argument is an absolute path and `False` if it is a relative path.
- Calling `os.path.relpath(path, start)` will return a string of a relative path from the *start* path to *path*. If *start* is not provided, the current working directory is used as the start path.

Try these functions in the interactive shell:

```
>>> os.path.abspath('.')
'C:\\Python34'
>>> os.path.abspath('.\\Scripts')
'C:\\Python34\\Scripts'
>>> os.path.isabs('.')
False
>>> os.path.isabs(os.path.abspath('.'))
True
```

Since *C:\Python34* was the working directory when `os.path.abspath()` was called, the "single-dot" folder represents the absolute path `'C:\\Python34'`.

NOTE *Since your system probably has different files and folders on it than mine, you won't be able to follow every example in this chapter exactly. Still, try to follow along using folders that exist on your computer.*

Enter the following calls to `os.path.relpath()` into the interactive shell:

```
>>> os.path.relpath('C:\\Windows', 'C:\\')
'Windows'
>>> os.path.relpath('C:\\Windows', 'C:\\spam\\eggs')
'..\\..\\Windows'
>>> os.getcwd()
'C:\\Python34'
```

Calling `os.path.dirname(`*`path`*`)` will return a string of everything that comes before the last slash in the `path` argument. Calling `os.path.basename(`*`path`*`)` will return a string of everything that comes after the last slash in the `path` argument. The dir name and base name of a path are outlined in Figure 8-4.

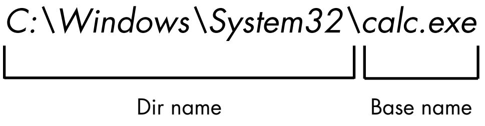


Figure 8-4: The base name follows the last slash in a path and is the same as the filename. The dir name is everything before the last slash.

For example, enter the following into the interactive shell:

```
>>> path = 'C:\\Windows\\System32\\calc.exe'
>>> os.path.basename(path)
'calc.exe'
>>> os.path.dirname(path)
'C:\\Windows\\System32'
```

If you need a path's dir name and base name together, you can just call `os.path.split()` to get a tuple value with these two strings, like so:

```
>>> calcFilePath = 'C:\\Windows\\System32\\calc.exe'
>>> os.path.split(calcFilePath)
('C:\\Windows\\System32', 'calc.exe')
```

Notice that you could create the same tuple by calling `os.path.dirname()` and `os.path.basename()` and placing their return values in a tuple.

```
>>> (os.path.dirname(calcFilePath), os.path.basename(calcFilePath))
('C:\\Windows\\System32', 'calc.exe')
```

But `os.path.split()` is a nice shortcut if you need both values.

Also, note that `os.path.split()` does *not* take a file path and return a list of strings of each folder. For that, use the `split()` string method and split on the string in `os.sep`. Recall from earlier that the `os.sep` variable is set to the correct folder-separating slash for the computer running the program.

For example, enter the following into the interactive shell:

```
>>> calcFilePath.split(os.path.sep)
['C:', 'Windows', 'System32', 'calc.exe']
```

On OS X and Linux systems, there will be a blank string at the start of the returned list:

```
>>> '/usr/bin'.split(os.path.sep)
['', 'usr', 'bin']
```

The `split()` string method will work to return a list of each part of the path. It will work on any operating system if you pass it `os.path.sep`.

Finding File Sizes and Folder Contents

Once you have ways of handling file paths, you can then start gathering information about specific files and folders. The `os.path` module provides functions for finding the size of a file in bytes and the files and folders inside a given folder.

- Calling `os.path.getsize(`*`path`*`)` will return the size in bytes of the file in the *path* argument.
- Calling `os.listdir(`*`path`*`)` will return a list of filename strings for each file in the *path* argument. (Note that this function is in the `os` module, not `os.path`.)

Here's what I get when I try these functions in the interactive shell:

```
>>> os.path.getsize('C:\\Windows\\System32\\calc.exe')
776192
>>> os.listdir('C:\\Windows\\System32')
['0409', '12520437.cpx', '12520850.cpx', '5U877.ax', 'aaclient.dll',
--snip--
'xwtpdui.dll', 'xwtpw32.dll', 'zh-CN', 'zh-HK', 'zh-TW', 'zipfldr.dll']
```

As you can see, the *calc.exe* program on my computer is 776,192 bytes in size, and I have a lot of files in *C:\Windows\system32*. If I want to find the total size of all the files in this directory, I can use `os.path.getsize()` and `os.listdir()` together.

```
>>> totalSize = 0
>>> for filename in os.listdir('C:\\Windows\\System32'):
      totalSize = totalSize + os.path.getsize(os.path.join('C:\\Windows\\System32', filename))

>>> print(totalSize)
1117846456
```

As I loop over each filename in the *C:\Windows\System32* folder, the totalSize variable is incremented by the size of each file. Notice how when I call os.path.getsize(), I use os.path.join() to join the folder name with the current filename. The integer that os.path.getsize() returns is added to the value of totalSize. After looping through all the files, I print totalSize to see the total size of the *C:\Windows\System32* folder.

Checking Path Validity

Many Python functions will crash with an error if you supply them with a path that does not exist. The os.path module provides functions to check whether a given path exists and whether it is a file or folder.

- Calling os.path.exists(*path*) will return True if the file or folder referred to in the argument exists and will return False if it does not exist.
- Calling os.path.isfile(*path*) will return True if the path argument exists and is a file and will return False otherwise.
- Calling os.path.isdir(*path*) will return True if the path argument exists and is a folder and will return False otherwise.

Here's what I get when I try these functions in the interactive shell:

```
>>> os.path.exists('C:\\Windows')
True
>>> os.path.exists('C:\\some_made_up_folder')
False
>>> os.path.isdir('C:\\Windows\\System32')
True
>>> os.path.isfile('C:\\Windows\\System32')
False
>>> os.path.isdir('C:\\Windows\\System32\\calc.exe')
False
>>> os.path.isfile('C:\\Windows\\System32\\calc.exe')
True
```

You can determine whether there is a DVD or flash drive currently attached to the computer by checking for it with the os.path.exists() function. For instance, if I wanted to check for a flash drive with the volume named *D:\* on my Windows computer, I could do that with the following:

```
>>> os.path.exists('D:\\')
False
```

Oops! It looks like I forgot to plug in my flash drive.

The File Reading/Writing Process

Once you are comfortable working with folders and relative paths, you'll be able to specify the location of files to read and write. The functions covered in the next few sections will apply to plaintext files. *Plaintext files* contain only basic text characters and do not include font, size, or color information. Text files with the *.txt* extension or Python script files with the *.py* extension are examples of plaintext files. These can be opened with Windows's Notepad or OS X's TextEdit application. Your programs can easily read the contents of plaintext files and treat them as an ordinary string value.

Binary files are all other file types, such as word processing documents, PDFs, images, spreadsheets, and executable programs. If you open a binary file in Notepad or TextEdit, it will look like scrambled nonsense, like in Figure 8-5.

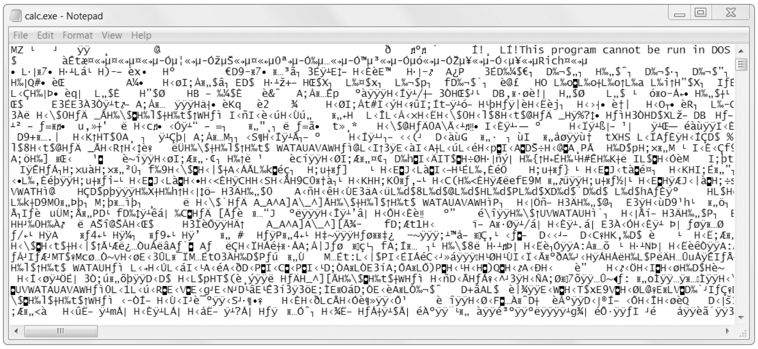

calc.exe - Notepad
File Edit Format View Help
MZ ... !This program cannot be run in DOS

Figure 8-5: The Windows `calc.exe` program opened in Notepad

Since every different type of binary file must be handled in its own way, this book will not go into reading and writing raw binary files directly. Fortunately, many modules make working with binary files easier—you will explore one of them, the `shelve` module, later in this chapter.

There are three steps to reading or writing files in Python.

1. Call the `open()` function to return a `File` object.
2. Call the `read()` or `write()` method on the `File` object.
3. Close the file by calling the `close()` method on the `File` object.

Opening Files with the open() Function

To open a file with the `open()` function, you pass it a string path indicating the file you want to open; it can be either an absolute or relative path. The `open()` function returns a `File` object.

Try it by creating a text file named *hello.txt* using Notepad or TextEdit. Type **`Hello world!`** as the content of this text file and save it in your user home folder. Then, if you're using Windows, enter the following into the interactive shell:

```
>>> helloFile = open('C:\\Users\\your_home_folder\\hello.txt')
```

If you're using OS X, enter the following into the interactive shell instead:

```
>>> helloFile = open('/Users/your_home_folder/hello.txt')
```

Make sure to replace *your_home_folder* with your computer username. For example, my username is *asweigart*, so I'd enter 'C:\\Users\\asweigart\\hello.txt' on Windows.

Both these commands will open the file in "reading plaintext" mode, or *read mode* for short. When a file is opened in read mode, Python lets you only read data from the file; you can't write or modify it in any way. Read mode is the default mode for files you open in Python. But if you don't want to rely on Python's defaults, you can explicitly specify the mode by passing the string value 'r' as a second argument to open(). So open('/Users/asweigart/hello.txt', 'r') and open('/Users/asweigart/hello.txt') do the same thing.

The call to open() returns a File object. A File object represents a file on your computer; it is simply another type of value in Python, much like the lists and dictionaries you're already familiar with. In the previous example, you stored the File object in the variable helloFile. Now, whenever you want to read from or write to the file, you can do so by calling methods on the File object in helloFile.

Reading the Contents of Files

Now that you have a File object, you can start reading from it. If you want to read the entire contents of a file as a string value, use the File object's read() method. Let's continue with the *hello.txt* File object you stored in helloFile . Enter the following into the interactive shell:

```
>>> helloContent = helloFile.read()
>>> helloContent
'Hello world!'
```

If you think of the contents of a file as a single large string value, the read() method returns the string that is stored in the file.

Alternatively, you can use the readlines() method to get a *list* of string values from the file, one string for each line of text. For example, create a file named *sonnet29.txt* in the same directory as *hello.txt* and write the following text in it:

```
When, in disgrace with fortune and men's eyes,
I all alone beweep my outcast state,
And trouble deaf heaven with my bootless cries,
And look upon myself and curse my fate,
```

Make sure to separate the four lines with line breaks. Then enter the following into the interactive shell:

```
>>> sonnetFile = open('sonnet29.txt')
>>> sonnetFile.readlines()
[When, in disgrace with fortune and men's eyes,\n', ' I all alone beweep my
outcast state,\n', And trouble deaf heaven with my bootless cries,\n', And
look upon myself and curse my fate,']
```

Note that each of the string values ends with a newline character, `\n` , except for the last line of the file. A list of strings is often easier to work with than a single large string value.

Writing to Files

Python allows you to write content to a file in a way similar to how the `print()` function "writes" strings to the screen. You can't write to a file you've opened in read mode, though. Instead, you need to open it in "write plaintext" mode or "append plaintext" mode, or *write mode* and *append mode* for short.

Write mode will overwrite the existing file and start from scratch, just like when you overwrite a variable's value with a new value. Pass `'w'` as the second argument to `open()` to open the file in write mode. Append mode, on the other hand, will append text to the end of the existing file. You can think of this as appending to a list in a variable, rather than overwriting the variable altogether. Pass `'a'` as the second argument to `open()` to open the file in append mode.

If the filename passed to `open()` does not exist, both write and append mode will create a new, blank file. After reading or writing a file, call the `close()` method before opening the file again.

Let's put these concepts together. Enter the following into the interactive shell:

```
>>> baconFile = open('bacon.txt', 'w')
>>> baconFile.write('Hello world!\n')
13
>>> baconFile.close()
>>> baconFile = open('bacon.txt', 'a')
>>> baconFile.write('Bacon is not a vegetable.')
25
>>> baconFile.close()
>>> baconFile = open('bacon.txt')
>>> content = baconFile.read()
>>> baconFile.close()
>>> print(content)
Hello world!
Bacon is not a vegetable.
```

First, we open *bacon.txt* in write mode. Since there isn't a *bacon.txt* yet, Python creates one. Calling `write()` on the opened file and passing `write()` the string argument `'Hello world! /n'` writes the string to the file and returns the number of characters written, including the newline. Then we close the file.

To add text to the existing contents of the file instead of replacing the string we just wrote, we open the file in append mode. We write `'Bacon is not a vegetable.'` to the file and close it. Finally, to print the file contents to the screen, we open the file in its default read mode, call `read()`, store the resulting `File` object in `content`, close the file, and print `content`.

Note that the write() method does not automatically add a newline character to the end of the string like the print() function does. You will have to add this character yourself.

Saving Variables with the shelve Module

You can save variables in your Python programs to binary shelf files using the shelve module. This way, your program can restore data to variables from the hard drive. The shelve module will let you add Save and Open features to your program. For example, if you ran a program and entered some configuration settings, you could save those settings to a shelf file and then have the program load them the next time it is run.

Enter the following into the interactive shell:

```
>>> import shelve
>>> shelfFile = shelve.open('mydata')
>>> cats = ['Zophie', 'Pooka', 'Simon']
>>> shelfFile['cats'] = cats
>>> shelfFile.close()
```

To read and write data using the shelve module, you first import shelve. Call shelve.open() and pass it a filename, and then store the returned shelf value in a variable. You can make changes to the shelf value as if it were a dictionary. When you're done, call close() on the shelf value. Here, our shelf value is stored in shelfFile. We create a list cats and write shelfFile['cats'] = cats to store the list in shelfFile as a value associated with the key 'cats' (like in a dictionary). Then we call close() on shelfFile.

After running the previous code on Windows, you will see three new files in the current working directory: *mydata.bak*, *mydata.dat*, and *mydata.dir*. On OS X, only a single *mydata.db* file will be created.

These binary files contain the data you stored in your shelf. The format of these binary files is not important; you only need to know what the shelve module does, not how it does it. The module frees you from worrying about how to store your program's data to a file.

Your programs can use the shelve module to later reopen and retrieve the data from these shelf files. Shelf values don't have to be opened in read or write mode—they can do both once opened. Enter the following into the interactive shell:

```
>>> shelfFile = shelve.open('mydata')
>>> type(shelfFile)
<class 'shelve.DbfilenameShelf'>
>>> shelfFile['cats']
['Zophie', 'Pooka', 'Simon']
>>> shelfFile.close()
```

Here, we open the shelf files to check that our data was stored correctly. Entering shelfFile['cats'] returns the same list that we stored earlier, so we know that the list is correctly stored, and we call close().

Just like dictionaries, shelf values have `keys()` and `values()` methods that will return list-like values of the keys and values in the shelf. Since these methods return list-like values instead of true lists, you should pass them to the `list()` function to get them in list form. Enter the following into the interactive shell:

```
>>> shelfFile = shelve.open('mydata')
>>> list(shelfFile.keys())
['cats']
>>> list(shelfFile.values())
[['Zophie', 'Pooka', 'Simon']]
>>> shelfFile.close()
```

Plaintext is useful for creating files that you'll read in a text editor such as Notepad or TextEdit, but if you want to save data from your Python programs, use the `shelve` module.

Saving Variables with the pprint.pformat() Function

Recall from "Pretty Printing" on page 111 that the `pprint.pprint()` function will "pretty print" the contents of a list or dictionary to the screen, while the `pprint.pformat()` function will return this same text as a string instead of printing it. Not only is this string formatted to be easy to read, but it is also syntactically correct Python code. Say you have a dictionary stored in a variable and you want to save this variable and its contents for future use. Using `pprint.pformat()` will give you a string that you can write to *.py* file. This file will be your very own module that you can import whenever you want to use the variable stored in it.

For example, enter the following into the interactive shell:

```
>>> import pprint
>>> cats = [{'name': 'Zophie', 'desc': 'chubby'}, {'name': 'Pooka', 'desc': 'fluffy'}]
>>> pprint.pformat(cats)
"[{'desc': 'chubby', 'name': 'Zophie'}, {'desc': 'fluffy', 'name': 'Pooka'}]"
>>> fileObj = open('myCats.py', 'w')
>>> fileObj.write('cats = ' + pprint.pformat(cats) + '\n')
83
>>> fileObj.close()
```

Here, we import `pprint` to let us use `pprint.pformat()`. We have a list of dictionaries, stored in a variable `cats`. To keep the list in `cats` available even after we close the shell, we use `pprint.pformat()` to return it as a string. Once we have the data in `cats` as a string, it's easy to write the string to a file, which we'll call *myCats.py*.

The modules that an `import` statement imports are themselves just Python scripts. When the string from `pprint.pformat()` is saved to a *.py* file, the file is a module that can be imported just like any other.

And since Python scripts are themselves just text files with the *.py* file extension, your Python programs can even generate other Python programs. You can then import these files into scripts.

```
>>> import myCats
>>> myCats.cats
[{'name': 'Zophie', 'desc': 'chubby'}, {'name': 'Pooka', 'desc': 'fluffy'}]
>>> myCats.cats[0]
{'name': 'Zophie', 'desc': 'chubby'}
>>> myCats.cats[0]['name']
'Zophie'
```

The benefit of creating a *.py* file (as opposed to saving variables with the `shelve` module) is that because it is a text file, the contents of the file can be read and modified by anyone with a simple text editor. For most applications, however, saving data using the `shelve` module is the preferred way to save variables to a file. Only basic data types such as integers, floats, strings, lists, and dictionaries can be written to a file as simple text. `File` objects, for example, cannot be encoded as text.

Project: Generating Random Quiz Files

Say you're a geography teacher with 35 students in your class and you want to give a pop quiz on US state capitals. Alas, your class has a few bad eggs in it, and you can't trust the students not to cheat. You'd like to randomize the order of questions so that each quiz is unique, making it impossible for anyone to crib answers from anyone else. Of course, doing this by hand would be a lengthy and boring affair. Fortunately, you know some Python.

Here is what the program does:

- Creates 35 different quizzes.
- Creates 50 multiple-choice questions for each quiz, in random order.
- Provides the correct answer and three random wrong answers for each question, in random order.
- Writes the quizzes to 35 text files.
- Writes the answer keys to 35 text files.

This means the code will need to do the following:

- Store the states and their capitals in a dictionary.
- Call `open()`, `write()`, and `close()` for the quiz and answer key text files.
- Use `random.shuffle()` to randomize the order of the questions and multiple-choice options.

Step 1: Store the Quiz Data in a Dictionary

The first step is to create a skeleton script and fill it with your quiz data. Create a file named *randomQuizGenerator.py*, and make it look like the following:

```
#! python3
# randomQuizGenerator.py - Creates quizzes with questions and answers in
# random order, along with the answer key.

❶ import random

# The quiz data. Keys are states and values are their capitals.
❷ capitals = {'Alabama': 'Montgomery', 'Alaska': 'Juneau', 'Arizona': 'Phoenix',
'Arkansas': 'Little Rock', 'California': 'Sacramento', 'Colorado': 'Denver',
'Connecticut': 'Hartford', 'Delaware': 'Dover', 'Florida': 'Tallahassee',
'Georgia': 'Atlanta', 'Hawaii': 'Honolulu', 'Idaho': 'Boise', 'Illinois':
'Springfield', 'Indiana': 'Indianapolis', 'Iowa': 'Des Moines', 'Kansas':
'Topeka', 'Kentucky': 'Frankfort', 'Louisiana': 'Baton Rouge', 'Maine':
'Augusta', 'Maryland': 'Annapolis', 'Massachusetts': 'Boston', 'Michigan':
'Lansing', 'Minnesota': 'Saint Paul', 'Mississippi': 'Jackson', 'Missouri':
'Jefferson City', 'Montana': 'Helena', 'Nebraska': 'Lincoln', 'Nevada':
'Carson City', 'New Hampshire': 'Concord', 'New Jersey': 'Trenton', 'New
Mexico': 'Santa Fe', 'New York': 'Albany', 'North Carolina': 'Raleigh',
'North Dakota': 'Bismarck', 'Ohio': 'Columbus', 'Oklahoma': 'Oklahoma City',
'Oregon': 'Salem', 'Pennsylvania': 'Harrisburg', 'Rhode Island': 'Providence',
'South Carolina': 'Columbia', 'South Dakota': 'Pierre', 'Tennessee':
'Nashville', 'Texas': 'Austin', 'Utah': 'Salt Lake City', 'Vermont':
'Montpelier', 'Virginia': 'Richmond', 'Washington': 'Olympia', 'West
Virginia': 'Charleston', 'Wisconsin': 'Madison', 'Wyoming': 'Cheyenne'}

# Generate 35 quiz files.
❸ for quizNum in range(35):
    # TODO: Create the quiz and answer key files.

    # TODO: Write out the header for the quiz.

    # TODO: Shuffle the order of the states.

    # TODO: Loop through all 50 states, making a question for each.
```

Since this program will be randomly ordering the questions and answers, you'll need to import the `random` module ❶ to make use of its functions. The `capitals` variable ❷ contains a dictionary with US states as keys and their capitals as values. And since you want to create 35 quizzes, the code that actually generates the quiz and answer key files (marked with `TODO` comments for now) will go inside a `for` loop that loops 35 times ❸. (This number can be changed to generate any number of quiz files.)

Step 2: Create the Quiz File and Shuffle the Question Order

Now it's time to start filling in those TODOs.

The code in the loop will be repeated 35 times—once for each quiz—so you have to worry about only one quiz at a time within the loop. First you'll create the actual quiz file. It needs to have a unique filename and should also have some kind of standard header in it, with places for the student to fill in a name, date, and class period. Then you'll need to get a list of states in randomized order, which can be used later to create the questions and answers for the quiz.

Add the following lines of code to *randomQuizGenerator.py*:

```
   #! python3
   # randomQuizGenerator.py - Creates quizzes with questions and answers in
   # random order, along with the answer key.

   --snip--

   # Generate 35 quiz files.
   for quizNum in range(35):
       # Create the quiz and answer key files.
❶      quizFile = open('capitalsquiz%s.txt' % (quizNum + 1), 'w')
❷      answerKeyFile = open('capitalsquiz_answers%s.txt' % (quizNum + 1), 'w')

       # Write out the header for the quiz.
❸      quizFile.write('Name:\n\nDate:\n\nPeriod:\n\n')
       quizFile.write((' ' * 20) + 'State Capitals Quiz (Form %s)' % (quizNum + 1))
       quizFile.write('\n\n')

       # Shuffle the order of the states.
       states = list(capitals.keys())
❹      random.shuffle(states)

       # TODO: Loop through all 50 states, making a question for each.
```

The filenames for the quizzes will be *capitalsquiz<N>.txt*, where *<N>* is a unique number for the quiz that comes from quizNum, the for loop's counter. The answer key for *capitalsquiz<N>.txt* will be stored in a text file named *capitalsquiz_answers<N>.txt*. Each time through the loop, the %s placeholder in 'capitalsquiz%s.txt' and 'capitalsquiz_answers%s.txt' will be replaced by (quizNum + 1), so the first quiz and answer key created will be *capitalsquiz1.txt* and *capitalsquiz_answers1.txt*. These files will be created with calls to the open() function at ❶ and ❷, with 'w' as the second argument to open them in write mode.

The write() statements at ❸ create a quiz header for the student to fill out. Finally, a randomized list of US states is created with the help of the random.shuffle() function ❹, which randomly reorders the values in any list that is passed to it.

Step 3: Create the Answer Options

Now you need to generate the answer options for each question, which will be multiple choice from A to D. You'll need to create another `for` loop—this one to generate the content for each of the 50 questions on the quiz. Then there will be a third `for` loop nested inside to generate the multiple-choice options for each question. Make your code look like the following:

```
#! python3
# randomQuizGenerator.py - Creates quizzes with questions and answers in
# random order, along with the answer key.

--snip--

    # Loop through all 50 states, making a question for each.
    for questionNum in range(50):

        # Get right and wrong answers.
❶       correctAnswer = capitals[states[questionNum]]
❷       wrongAnswers = list(capitals.values())
❸       del wrongAnswers[wrongAnswers.index(correctAnswer)]
❹       wrongAnswers = random.sample(wrongAnswers, 3)
❺       answerOptions = wrongAnswers + [correctAnswer]
❻       random.shuffle(answerOptions)

        # TODO: Write the question and answer options to the quiz file.

        # TODO: Write the answer key to a file.
```

The correct answer is easy to get—it's stored as a value in the `capitals` dictionary ❶. This loop will loop through the states in the shuffled `states` list, from `states[0]` to `states[49]`, find each state in `capitals`, and store that state's corresponding capital in `correctAnswer`.

The list of possible wrong answers is trickier. You can get it by duplicating *all* the values in the `capitals` dictionary ❷, deleting the correct answer ❸, and selecting three random values from this list ❹. The `random.sample()` function makes it easy to do this selection. Its first argument is the list you want to select from; the second argument is the number of values you want to select. The full list of answer options is the combination of these three wrong answers with the correct answers ❺. Finally, the answers need to be randomized ❻ so that the correct response isn't always choice D.

Step 4: Write Content to the Quiz and Answer Key Files

All that is left is to write the question to the quiz file and the answer to the answer key file. Make your code look like the following:

```
#! python3
# randomQuizGenerator.py - Creates quizzes with questions and answers in
# random order, along with the answer key.

--snip--
```

```
    # Loop through all 50 states, making a question for each.
    for questionNum in range(50):
        --snip--

        # Write the question and the answer options to the quiz file.
        quizFile.write('%s. What is the capital of %s?\n' % (questionNum + 1,
            states[questionNum]))
❶       for i in range(4):
❷           quizFile.write('    %s. %s\n' % ('ABCD'[i], answerOptions[i]))
        quizFile.write('\n')

        # Write the answer key to a file.
❸       answerKeyFile.write('%s. %s\n' % (questionNum + 1, 'ABCD'[
           answerOptions.index(correctAnswer)]))
    quizFile.close()
    answerKeyFile.close()
```

A `for` loop that goes through integers `0` to `3` will write the answer options in the `answerOptions` list ❶. The expression `'ABCD'[i]` at ❷ treats the string `'ABCD'` as an array and will evaluate to `'A'`,`'B'`, `'C'`, and then `'D'` on each respective iteration through the loop.

In the final line ❸, the expression `answerOptions.index(correctAnswer)` will find the integer index of the correct answer in the randomly ordered answer options, and `'ABCD'[answerOptions.index(correctAnswer)]` will evaluate to the correct answer's letter to be written to the answer key file.

After you run the program, this is how your *capitalsquiz1.txt* file will look, though of course your questions and answer options may be different from those shown here, depending on the outcome of your `random.shuffle()` calls:

```
Name:

Date:

Period:

                    State Capitals Quiz (Form 1)

1. What is the capital of West Virginia?
    A. Hartford
    B. Santa Fe
    C. Harrisburg
    D. Charleston

2. What is the capital of Colorado?
    A. Raleigh
    B. Harrisburg
    C. Denver
    D. Lincoln

--snip--
```

The corresponding *capitalsquiz_answers1.txt* text file will look like this:

```
1. D
2. C
3. A
4. C
--snip--
```

Project: Multiclipboard

Say you have the boring task of filling out many forms in a web page or software with several text fields. The clipboard saves you from typing the same text over and over again. But only one thing can be on the clipboard at a time. If you have several different pieces of text that you need to copy and paste, you have to keep highlighting and copying the same few things over and over again.

You can write a Python program to keep track of multiple pieces of text. This "multiclipboard" will be named *mcb.pyw* (since "mcb" is shorter to type than "multiclipboard"). The *.pyw* extension means that Python won't show a Terminal window when it runs this program. (See Appendix B for more details.)

The program will save each piece of clipboard text under a keyword. For example, when you run `py mcb.pyw save spam`, the current contents of the clipboard will be saved with the keyword *spam*. This text can later be loaded to the clipboard again by running `py mcb.pyw spam`. And if the user forgets what keywords they have, they can run `py mcb.pyw list` to copy a list of all keywords to the clipboard.

Here's what the program does:

- The command line argument for the keyword is checked.
- If the argument is `save`, then the clipboard contents are saved to the keyword.
- If the argument is `list`, then all the keywords are copied to the clipboard.
- Otherwise, the text for the keyword is copied to the keyboard.

This means the code will need to do the following:

- Read the command line arguments from `sys.argv`.
- Read and write to the clipboard.
- Save and load to a shelf file.

If you use Windows, you can easily run this script from the Run… window by creating a batch file named *mcb.bat* with the following content:

```
@pyw.exe C:\Python34\mcb.pyw %*
```

Step 1: Comments and Shelf Setup

Let's start by making a skeleton script with some comments and basic setup. Make your code look like the following:

```
  #! python3
  # mcb.pyw - Saves and loads pieces of text to the clipboard.
❶ # Usage: py.exe mcb.pyw save <keyword> - Saves clipboard to keyword.
  #        py.exe mcb.pyw <keyword> - Loads keyword to clipboard.
  #        py.exe mcb.pyw list - Loads all keywords to clipboard.

❷ import shelve, pyperclip, sys

❸ mcbShelf = shelve.open('mcb')

  # TODO: Save clipboard content.

  # TODO: List keywords and load content.

  mcbShelf.close()
```

It's common practice to put general usage information in comments at the top of the file ❶. If you ever forget how to run your script, you can always look at these comments for a reminder. Then you import your modules ❷. Copying and pasting will require the `pyperclip` module, and reading the command line arguments will require the `sys` module. The `shelve` module will also come in handy: Whenever the user wants to save a new piece of clipboard text, you'll save it to a shelf file. Then, when the user wants to paste the text back to their clipboard, you'll open the shelf file and load it back into your program. The shelf file will be named with the prefix *mcb* ❸.

Step 2: Save Clipboard Content with a Keyword

The program does different things depending on whether the user wants to save text to a keyword, load text into the clipboard, or list all the existing keywords. Let's deal with that first case. Make your code look like the following:

```
  #! python3
  # mcb.pyw - Saves and loads pieces of text to the clipboard.
  --snip--

  # Save clipboard content.
❶ if len(sys.argv) == 3 and sys.argv[1].lower() == 'save':
❷         mcbShelf[sys.argv[2]] = pyperclip.paste()
  elif len(sys.argv) == 2:
❸     # TODO: List keywords and load content.

  mcbShelf.close()
```

If the first command line argument (which will always be at index `1` of the `sys.argv` list) is `'save'` ❶, the second command line argument is the keyword for the current content of the clipboard. The keyword will be used as the key for `mcbShelf`, and the value will be the text currently on the clipboard ❷.

If there is only one command line argument, you will assume it is either `'list'` or a keyword to load content onto the clipboard. You will implement that code later. For now, just put a `TODO` comment there ❸.

Step 3: List Keywords and Load a Keyword's Content

Finally, let's implement the two remaining cases: The user wants to load clipboard text in from a keyword, or they want a list of all available keywords. Make your code look like the following:

```
   #! python3
   # mcb.pyw - Saves and loads pieces of text to the clipboard.
   --snip--

   # Save clipboard content.
   if len(sys.argv) == 3 and sys.argv[1].lower() == 'save':
           mcbShelf[sys.argv[2]] = pyperclip.paste()
   elif len(sys.argv) == 2:
       # List keywords and load content.
❶      if sys.argv[1].lower() == 'list':
❷          pyperclip.copy(str(list(mcbShelf.keys())))
       elif sys.argv[1] in mcbShelf:
❸          pyperclip.copy(mcbShelf[sys.argv[1]])

   mcbShelf.close()
```

If there is only one command line argument, first let's check whether it's `'list'` ❶. If so, a string representation of the list of shelf keys will be copied to the clipboard ❷. The user can paste this list into an open text editor to read it.

Otherwise, you can assume the command line argument is a keyword. If this keyword exists in the `mcbShelf` shelf as a key, you can load the value onto the clipboard ❸.

And that's it! Launching this program has different steps depending on what operating system your computer uses. See Appendix B for details for your operating system.

Recall the password locker program you created in Chapter 6 that stored the passwords in a dictionary. Updating the passwords required changing the source code of the program. This isn't ideal because average users don't feel comfortable changing source code to update their software. Also, every time you modify the source code to a program, you run the risk of accidentally introducing new bugs. By storing the data for a program in a different place than the code, you can make your programs easier for others to use and more resistant to bugs.

Summary

Files are organized into folders (also called directories), and a path describes the location of a file. Every program running on your computer has a current working directory, which allows you to specify file paths relative to the current location instead of always typing the full (or absolute) path. The `os.path` module has many functions for manipulating file paths.

Your programs can also directly interact with the contents of text files. The `open()` function can open these files to read in their contents as one large string (with the `read()` method) or as a list of strings (with the `readlines()` method). The `open()` function can open files in write or append mode to create new text files or add to existing text files, respectively.

In previous chapters, you used the clipboard as a way of getting large amounts of text into a program, rather than typing it all in. Now you can have your programs read files directly from the hard drive, which is a big improvement, since files are much less volatile than the clipboard.

In the next chapter, you will learn how to handle the files themselves, by copying them, deleting them, renaming them, moving them, and more.

Practice Questions

1. What is a relative path relative to?
2. What does an absolute path start with?
3. What do the `os.getcwd()` and `os.chdir()` functions do?
4. What are the `.` and `..` folders?
5. In *C:\bacon\eggs\spam.txt*, which part is the dir name, and which part is the base name?
6. What are the three "mode" arguments that can be passed to the `open()` function?
7. What happens if an existing file is opened in write mode?
8. What is the difference between the `read()` and `readlines()` methods?
9. What data structure does a shelf value resemble?

Practice Projects

For practice, design and write the following programs.

Extending the Multiclipboard

Extend the multiclipboard program in this chapter so that it has a `delete <keyword>` command line argument that will delete a keyword from the shelf. Then add a `delete` command line argument that will delete *all* keywords.

Mad Libs

Create a Mad Libs program that reads in text files and lets the user add their own text anywhere the word *ADJECTIVE*, *NOUN*, *ADVERB*, or *VERB* appears in the text file. For example, a text file may look like this:

```
The ADJECTIVE panda walked to the NOUN and then VERB. A nearby NOUN was
unaffected by these events.
```

The program would find these occurrences and prompt the user to replace them.

```
Enter an adjective:
silly
Enter a noun:
chandelier
Enter a verb:
screamed
Enter a noun:
pickup truck
```

The following text file would then be created:

```
The silly panda walked to the chandelier and then screamed. A nearby pickup
truck was unaffected by these events.
```

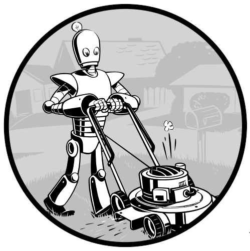
The results should be printed to the screen and saved to a new text file.

Regex Search

Write a program that opens all *.txt* files in a folder and searches for any line that matches a user-supplied regular expression. The results should be printed to the screen.

9

ORGANIZING FILES



In the previous chapter, you learned how to create and write to new files in Python. Your programs can also organize preexisting files on the hard drive. Maybe you've had the experience of going through a folder full of dozens, hundreds, or even thousands of files and copying, renaming, moving, or compressing them all by hand. Or consider tasks such as these:

- Making copies of all PDF files (and *only* the PDF files) in every subfolder of a folder
- Removing the leading zeros in the filenames for every file in a folder of hundreds of files named *spam001.txt*, *spam002.txt*, *spam003.txt*, and so on
- Compressing the contents of several folders into one ZIP file (which could be a simple backup system)

All this boring stuff is just begging to be automated in Python. By programming your computer to do these tasks, you can transform it into a quick-working file clerk who never makes mistakes.

As you begin working with files, you may find it helpful to be able to quickly see what the extension (*.txt*, *.pdf*, *.jpg*, and so on) of a file is. With OS X and Linux, your file browser most likely shows extensions automatically. With Windows, file extensions may be hidden by default. To show extensions, go to **Start ▸ Control Panel ▸ Appearance and Personalization ▸ Folder Options**. On the View tab, under Advanced Settings, uncheck the **Hide extensions for known file types** checkbox.

The shutil Module

The shutil (or shell utilities) module has functions to let you copy, move, rename, and delete files in your Python programs. To use the shutil functions, you will first need to use import shutil.

Copying Files and Folders

The shutil module provides functions for copying files, as well as entire folders.

Calling shutil.copy(*source, destination*) will copy the file at the path *source* to the folder at the path *destination*. (Both *source* and *destination* are strings.) If *destination* is a filename, it will be used as the new name of the copied file. This function returns a string of the path of the copied file.

Enter the following into the interactive shell to see how shutil.copy() works:

```
  >>> import shutil, os
  >>> os.chdir('C:\\')
❶ >>> shutil.copy('C:\\spam.txt', 'C:\\delicious')
  'C:\\delicious\\spam.txt'
❷ >>> shutil.copy('eggs.txt', 'C:\\delicious\\eggs2.txt')
  'C:\\delicious\\eggs2.txt'
```

The first shutil.copy() call copies the file at *C:\spam.txt* to the folder *C:\delicious*. The return value is the path of the newly copied file. Note that since a folder was specified as the destination ❶, the original *spam.txt* filename is used for the new, copied file's filename. The second shutil.copy() call ❷ also copies the file at *C:\eggs.txt* to the folder *C:\delicious* but gives the copied file the name *eggs2.txt*.

While shutil.copy() will copy a single file, shutil.copytree() will copy an entire folder and every folder and file contained in it. Calling shutil.copytree(*source, destination*) will copy the folder at the path *source*, along with all of its files and subfolders, to the folder at the path *destination*. The *source* and *destination* parameters are both strings. The function returns a string of the path of the copied folder.

Enter the following into the interactive shell:

```
>>> import shutil, os
>>> os.chdir('C:\\')
>>> shutil.copytree('C:\\bacon', 'C:\\bacon_backup')
'C:\\bacon_backup'
```

The `shutil.copytree()` call creates a new folder named *bacon_backup* with the same content as the original *bacon* folder. You have now safely backed up your precious, precious bacon.

Moving and Renaming Files and Folders

Calling `shutil.move(`*`source, destination`*`)` will move the file or folder at the path *`source`* to the path *`destination`* and will return a string of the absolute path of the new location.

If *`destination`* points to a folder, the *`source`* file gets moved into *`destination`* and keeps its current filename. For example, enter the following into the interactive shell:

```
>>> import shutil
>>> shutil.move('C:\\bacon.txt', 'C:\\eggs')
'C:\\eggs\\bacon.txt'
```

Assuming a folder named *eggs* already exists in the *C:\* directory, this `shutil.move()` calls says, "Move *C:\bacon.txt* into the folder *C:\eggs*."

If there had been a *bacon.txt* file already in *C:\eggs*, it would have been overwritten. Since it's easy to accidentally overwrite files in this way, you should take some care when using `move()`.

The *`destination`* path can also specify a filename. In the following example, the *`source`* file is moved *and* renamed.

```
>>> shutil.move('C:\\bacon.txt', 'C:\\eggs\\new_bacon.txt')
'C:\\eggs\\new_bacon.txt'
```

This line says, "Move *C:\bacon.txt* into the folder *C:\eggs*, and while you're at it, rename that *bacon.txt* file to *new_bacon.txt*."

Both of the previous examples worked under the assumption that there was a folder *eggs* in the *C:\* directory. But if there is no *eggs* folder, then `move()` will rename *bacon.txt* to a file named *eggs*.

```
>>> shutil.move('C:\\bacon.txt', 'C:\\eggs')
'C:\\eggs'
```

Here, `move()` can't find a folder named *eggs* in the *C:\* directory and so assumes that *`destination`* must be specifying a filename, not a folder. So the *bacon.txt* text file is renamed to *eggs* (a text file without the *.txt* file extension)—probably not what you wanted! This can be a tough-to-spot bug in your programs since the move() call can happily do something that might be quite different from what you were expecting. This is yet another reason to be careful when using move().

Finally, the folders that make up the destination must already exist, or else Python will throw an exception. Enter the following into the interactive shell:

```
>>> shutil.move('spam.txt', 'c:\\does_not_exist\\eggs\\ham')
Traceback (most recent call last):
  File "C:\Python34\lib\shutil.py", line 521, in move
    os.rename(src, real_dst)
FileNotFoundError: [WinError 3] The system cannot find the path specified:
'spam.txt' -> 'c:\\does_not_exist\\eggs\\ham'

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "<pyshell#29>", line 1, in <module>
    shutil.move('spam.txt', 'c:\\does_not_exist\\eggs\\ham')
  File "C:\Python34\lib\shutil.py", line 533, in move
    copy2(src, real_dst)
  File "C:\Python34\lib\shutil.py", line 244, in copy2
    copyfile(src, dst, follow_symlinks=follow_symlinks)
  File "C:\Python34\lib\shutil.py", line 108, in copyfile
    with open(dst, 'wb') as fdst:
FileNotFoundError: [Errno 2] No such file or directory: 'c:\\does_not_exist\\
eggs\\ham'
```

Python looks for *eggs* and *ham* inside the directory *does_not_exist*. It doesn't find the nonexistent directory, so it can't move *spam.txt* to the path you specified.

Permanently Deleting Files and Folders

You can delete a single file or a single empty folder with functions in the os module, whereas to delete a folder and all of its contents, you use the shutil module.

- Calling os.unlink(*path*) will delete the file at *path*.
- Calling os.rmdir(*path*) will delete the folder at *path*. This folder must be empty of any files or folders.
- Calling shutil.rmtree(*path*) will remove the folder at *path*, and all files and folders it contains will also be deleted.

Be careful when using these functions in your programs! It's often a good idea to first run your program with these calls commented out and with print() calls added to show the files that would be deleted. Here is a Python program that was intended to delete files that have the *.txt* file extension but has a typo (highlighted in bold) that causes it to delete *.rxt* files instead:

```
import os
for filename in os.listdir():
    if filename.endswith('.rxt'):
        os.unlink(filename)
```

If you had any important files ending with *.rxt,* they would have been accidentally, permanently deleted. Instead, you should have first run the program like this:

```
import os
for filename in os.listdir():
    if filename.endswith('.rxt'):
        #os.unlink(filename)
        print(filename)
```

Now the `os.unlink()` call is commented, so Python ignores it. Instead, you will print the filename of the file that would have been deleted. Running this version of the program first will show you that you've accidentally told the program to delete *.rxt* files instead of *.txt* files.

Once you are certain the program works as intended, delete the `print(filename)` line and uncomment the `os.unlink(filename)` line. Then run the program again to actually delete the files.

Safe Deletes with the send2trash Module

Since Python's built-in `shutil.rmtree()` function irreversibly deletes files and folders, it can be dangerous to use. A much better way to delete files and folders is with the third-party `send2trash` module. You can install this module by running `pip install send2trash` from a Terminal window. (See Appendix A for a more in-depth explanation of how to install third-party modules.)

Using `send2trash` is much safer than Python's regular delete functions, because it will send folders and files to your computer's trash or recycle bin instead of permanently deleting them. If a bug in your program deletes something with `send2trash` you didn't intend to delete, you can later restore it from the recycle bin.

After you have installed `send2trash`, enter the following into the interactive shell:

```
>>> import send2trash
>>> baconFile = open('bacon.txt', 'a')   # creates the file
>>> baconFile.write('Bacon is not a vegetable.')
25
>>> baconFile.close()
>>> send2trash.send2trash('bacon.txt')
```

In general, you should always use the send2trash.send2trash() function to delete files and folders. But while sending files to the recycle bin lets you recover them later, it will not free up disk space like permanently deleting them does. If you want your program to free up disk space, use the os and shutil functions for deleting files and folders. Note that the send2trash() function can only send files to the recycle bin; it cannot pull files out of it.

Walking a Directory Tree

Say you want to rename every file in some folder and also every file in every subfolder of that folder. That is, you want to walk through the directory tree, touching each file as you go. Writing a program to do this could get tricky; fortunately, Python provides a function to handle this process for you.

Let's look at the *C:\delicious* folder with its contents, shown in Figure 9-1.

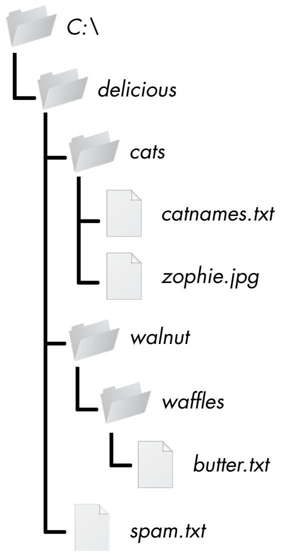


Figure 9-1: An example folder that contains three folders and four files

Here is an example program that uses the os.walk() function on the directory tree from Figure 9-1:

```
import os

for folderName, subfolders, filenames in os.walk('C:\\delicious'):
    print('The current folder is ' + folderName)

    for subfolder in subfolders:
        print('SUBFOLDER OF ' + folderName + ': ' + subfolder)
    for filename in filenames:
        print('FILE INSIDE ' + folderName + ': '+ filename)

    print('')
```

The `os.walk()` function is passed a single string value: the path of a folder. You can use `os.walk()` in a `for` loop statement to walk a directory tree, much like how you can use the `range()` function to walk over a range of numbers. Unlike `range()`, the `os.walk()` function will return three values on each iteration through the loop:

1. A string of the current folder's name
2. A list of strings of the folders in the current folder
3. A list of strings of the files in the current folder

(By current folder, I mean the folder for the current iteration of the `for` loop. The current working directory of the program is *not* changed by `os.walk()`.)

Just like you can choose the variable name `i` in the code `for i in range(10):`, you can also choose the variable names for the three values listed earlier. I usually use the names `foldername`, `subfolders`, and `filenames`.

When you run this program, it will output the following:

```
The current folder is C:\delicious
SUBFOLDER OF C:\delicious: cats
SUBFOLDER OF C:\delicious: walnut
FILE INSIDE C:\delicious: spam.txt

The current folder is C:\delicious\cats
FILE INSIDE C:\delicious\cats: catnames.txt
FILE INSIDE C:\delicious\cats: zophie.jpg

The current folder is C:\delicious\walnut
SUBFOLDER OF C:\delicious\walnut: waffles

The current folder is C:\delicious\walnut\waffles
FILE INSIDE C:\delicious\walnut\waffles: butter.txt.
```

Since `os.walk()` returns lists of strings for the `subfolder` and `filename` variables, you can use these lists in their own `for` loops. Replace the `print()` function calls with your own custom code. (Or if you don't need one or both of them, remove the `for` loops.)

Compressing Files with the zipfile Module

You may be familiar with ZIP files (with the *.zip* file extension), which can hold the compressed contents of many other files. Compressing a file reduces its size, which is useful when transferring it over the Internet. And since a ZIP file can also contain multiple files and subfolders, it's a handy way to package several files into one. This single file, called an *archive file*, can then be, say, attached to an email.

Your Python programs can both create and open (or *extract*) ZIP files using functions in the `zipfile` module. Say you have a ZIP file named *example.zip* that has the contents shown in Figure 9-2.

You can download this ZIP file from *http://nostarch.com/automatestuff/* or just follow along using a ZIP file already on your computer.

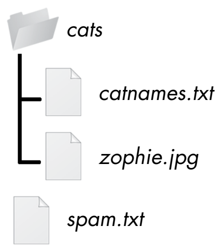


Figure 9-2: The contents of example.zip

Reading ZIP Files

To read the contents of a ZIP file, first you must create a `ZipFile` object (note the capital letters *Z* and *F*). `ZipFile` objects are conceptually similar to the `File` objects you saw returned by the `open()` function in the previous chapter: They are values through which the program interacts with the file. To create a `ZipFile` object, call the `zipfile.ZipFile()` function, passing it a string of the *.zip* file's filename. Note that `zipfile` is the name of the Python module, and `ZipFile()` is the name of the function.

For example, enter the following into the interactive shell:

```
>>> import zipfile, os
>>> os.chdir('C:\\')    # move to the folder with example.zip
>>> exampleZip = zipfile.ZipFile('example.zip')
>>> exampleZip.namelist()
['spam.txt', 'cats/', 'cats/catnames.txt', 'cats/zophie.jpg']
>>> spamInfo = exampleZip.getinfo('spam.txt')
>>> spamInfo.file_size
13908
>>> spamInfo.compress_size
3828
❶ >>> 'Compressed file is %sx smaller!' % (round(spamInfo.file_size / spamInfo
.compress_size, 2))
'Compressed file is 3.63x smaller!'
>>> exampleZip.close()
```

A `ZipFile` object has a `namelist()` method that returns a list of strings for all the files and folders contained in the ZIP file. These strings can be passed to the `getinfo()` `ZipFile` method to return a `ZipInfo` object about that particular file. `ZipInfo` objects have their own attributes, such as `file_size` and `compress_size` in bytes, which hold integers of the original file size and compressed file size, respectively. While a `ZipFile` object represents an entire archive file, a `ZipInfo` object holds useful information about a *single file* in the archive.

The command at ❶ calculates how efficiently *example.zip* is compressed by dividing the original file size by the compressed file size and prints this information using a string formatted with `%s`.

Extracting from ZIP Files

The `extractall()` method for `ZipFile` objects extracts all the files and folders from a ZIP file into the current working directory.

```
   >>> import zipfile, os
   >>> os.chdir('C:\\')    # move to the folder with example.zip
   >>> exampleZip = zipfile.ZipFile('example.zip')
❶ >>> exampleZip.extractall()
   >>> exampleZip.close()
```

After running this code, the contents of *example.zip* will be extracted to *C:\*. Optionally, you can pass a folder name to `extractall()` to have it extract the files into a folder other than the current working directory. If the folder passed to the `extractall()` method does not exist, it will be created. For instance, if you replaced the call at ❶ with `exampleZip.extractall('C:\\delicious')`, the code would extract the files from *example.zip* into a newly created *C:\delicious* folder.

The `extract()` method for `ZipFile` objects will extract a single file from the ZIP file. Continue the interactive shell example:

```
>>> exampleZip.extract('spam.txt')
'C:\\spam.txt'
>>> exampleZip.extract('spam.txt', 'C:\\some\\new\\folders')
'C:\\some\\new\\folders\\spam.txt'
>>> exampleZip.close()
```

The string you pass to `extract()` must match one of the strings in the list returned by `namelist()`. Optionally, you can pass a second argument to `extract()` to extract the file into a folder other than the current working directory. If this second argument is a folder that doesn't yet exist, Python will create the folder. The value that `extract()` returns is the absolute path to which the file was extracted.

Creating and Adding to ZIP Files

To create your own compressed ZIP files, you must open the `ZipFile` object in *write mode* by passing `'w'` as the second argument. (This is similar to opening a text file in write mode by passing `'w'` to the `open()` function.)

When you pass a path to the `write()` method of a `ZipFile` object, Python will compress the file at that path and add it into the ZIP file. The `write()` method's first argument is a string of the filename to add. The second argument is the *compression type* parameter, which tells the computer what algorithm it should use to compress the files; you can always just set this value to `zipfile.ZIP_DEFLATED`. (This specifies the *deflate* compression algorithm, which works well on all types of data.) Enter the following into the interactive shell:

```
>>> import zipfile
>>> newZip = zipfile.ZipFile('new.zip', 'w')
>>> newZip.write('spam.txt', compress_type=zipfile.ZIP_DEFLATED)
>>> newZip.close()
```

This code will create a new ZIP file named *new.zip* that has the compressed contents of *spam.txt*.

Keep in mind that, just as with writing to files, write mode will erase all existing contents of a ZIP file. If you want to simply add files to an existing ZIP file, pass `'a'` as the second argument to `zipfile.ZipFile()` to open the ZIP file in *append mode*.

Project: Renaming Files with American-Style Dates to European-Style Dates

Say your boss emails you thousands of files with American-style dates (MM-DD-YYYY) in their names and needs them renamed to European-style dates (DD-MM-YYYY). This boring task could take all day to do by hand! Let's write a program to do it instead.

Here's what the program does:

- It searches all the filenames in the current working directory for American-style dates.
- When one is found, it renames the file with the month and day swapped to make it European-style.

This means the code will need to do the following:

- Create a regex that can identify the text pattern of American-style dates.
- Call `os.listdir()` to find all the files in the working directory.
- Loop over each filename, using the regex to check whether it has a date.
- If it has a date, rename the file with `shutil.move()`.

For this project, open a new file editor window and save your code as *renameDates.py*.

Step 1: Create a Regex for American-Style Dates

The first part of the program will need to import the necessary modules and create a regex that can identify MM-DD-YYYY dates. The to-do comments will remind you what's left to write in this program. Typing them as `TODO` makes them easy to find using IDLE's CTRL-F find feature. Make your code look like the following:

```
  #! python3
  # renameDates.py - Renames filenames with American MM-DD-YYYY date format
  # to European DD-MM-YYYY.

❶ import shutil, os, re

  # Create a regex that matches files with the American date format.
❷ datePattern = re.compile(r"""^(.*?) # all text before the date
      ((0|1)?\d)-                     # one or two digits for the month
```

```
    ((0|1|2|3)?\d)-              # one or two digits for the day
    ((19|20)\d\d)                # four digits for the year
    (.*?)$                       # all text after the date
❸   """, re.VERBOSE)

# TODO: Loop over the files in the working directory.

# TODO: Skip files without a date.

# TODO: Get the different parts of the filename.

# TODO: Form the European-style filename.

# TODO: Get the full, absolute file paths.

# TODO: Rename the files.
```

From this chapter, you know the `shutil.move()` function can be used to rename files: Its arguments are the name of the file to rename and the new filename. Because this function exists in the `shutil` module, you must import that module ❶.

But before renaming the files, you need to identify which files you want to rename. Filenames with dates such as *spam4-4-1984.txt* and *01-03-2014eggs.zip* should be renamed, while filenames without dates such as *littlebrother.epub* can be ignored.

You can use a regular expression to identify this pattern. After importing the `re` module at the top, call `re.compile()` to create a `Regex` object ❷. Passing `re.VERBOSE` for the second argument ❸ will allow whitespace and comments in the regex string to make it more readable.

The regular expression string begins with `^(.*?)` to match any text at the beginning of the filename that might come before the date. The `((0|1)?\d)` group matches the month. The first digit can be either `0` or `1`, so the regex matches `12` for December but also `02` for February. This digit is also optional so that the month can be `04` or `4` for April. The group for the day is `((0|1|2|3)?\d)` and follows similar logic; `3`, `03`, and `31` are all valid numbers for days. (Yes, this regex will accept some invalid dates such as `4-31-2014`, `2-29-2013`, and `0-15-2014`. Dates have a lot of thorny special cases that can be easy to miss. But for simplicity, the regex in this program works well enough.)

While 1885 is a valid year, you can just look for years in the 20th or 21st century. This will keep your program from accidentally matching nondate filenames with a date-like format, such as *10-10-1000.txt*.

The `(.*?)$` part of the regex will match any text that comes after the date.

Step 2: Identify the Date Parts from the Filenames

Next, the program will have to loop over the list of filename strings returned from `os.listdir()` and match them against the regex. Any files that do not have a date in them should be skipped. For filenames that have a date, the matched text will be stored in several variables. Fill in the first three `TODO`s in your program with the following code:

```
   #! python3
   # renameDates.py - Renames filenames with American MM-DD-YYYY date format
   # to European DD-MM-YYYY.

   --snip--

   # Loop over the files in the working directory.
   for amerFilename in os.listdir('.'):
       mo = datePattern.search(amerFilename)

       # Skip files without a date.
❶     if mo == None:
❷         continue

❸     # Get the different parts of the filename.
       beforePart = mo.group(1)
       monthPart  = mo.group(2)
       dayPart    = mo.group(4)
       yearPart   = mo.group(6)
       afterPart  = mo.group(8)

   --snip--
```

If the `Match` object returned from the `search()` method is `None` ❶, then the filename in `amerFilename` does not match the regular expression. The `continue` statement ❷ will skip the rest of the loop and move on to the next filename.

Otherwise, the various strings matched in the regular expression groups are stored in variables named `beforePart`, `monthPart`, `dayPart`, `yearPart`, and `afterPart` ❸. The strings in these variables will be used to form the European-style filename in the next step.

To keep the group numbers straight, try reading the regex from the beginning and count up each time you encounter an opening parenthesis. Without thinking about the code, just write an outline of the regular expression. This can help you visualize the groups. For example:

```
datePattern = re.compile(r"""^(1) # all text before the date
    (2 (3) )-                  # one or two digits for the month
    (4 (5) )-                  # one or two digits for the day
    (6 (7) )                   # four digits for the year
    (8)$                       # all text after the date
    """, re.VERBOSE)
```

Here, the numbers **1** through **8** represent the groups in the regular expression you wrote. Making an outline of the regular expression, with just the parentheses and group numbers, can give you a clearer understanding of your regex before you move on with the rest of the program.

Step 3: Form the New Filename and Rename the Files

As the final step, concatenate the strings in the variables made in the previous step with the European-style date: The date comes before the month. Fill in the three remaining TODOs in your program with the following code:

```
   #! python3
   # renameDates.py - Renames filenames with American MM-DD-YYYY date format
   # to European DD-MM-YYYY.

   --snip--

       # Form the European-style filename.
❶      euroFilename = beforePart + dayPart + '-' + monthPart + '-' + yearPart +
                      afterPart

       # Get the full, absolute file paths.
       absWorkingDir = os.path.abspath('.')
       amerFilename = os.path.join(absWorkingDir, amerFilename)
       euroFilename = os.path.join(absWorkingDir, euroFilename)

       # Rename the files.
❷      print('Renaming "%s" to "%s"...' % (amerFilename, euroFilename))
❸      #shutil.move(amerFilename, euroFilename)   # uncomment after testing
```

Store the concatenated string in a variable named `euroFilename` ❶. Then, pass the original filename in `amerFilename` and the new `euroFilename` variable to the `shutil.move()` function to rename the file ❸.

This program has the `shutil.move()` call commented out and instead prints the filenames that will be renamed ❷. Running the program like this first can let you double-check that the files are renamed correctly. Then you can uncomment the `shutil.move()` call and run the program again to actually rename the files.

Ideas for Similar Programs

There are many other reasons why you might want to rename a large number of files.

- To add a prefix to the start of the filename, such as adding *spam_* to rename *eggs.txt* to *spam_eggs.txt*
- To change filenames with European-style dates to American-style dates
- To remove the zeros from files such as *spam0042.txt*

Project: Backing Up a Folder into a ZIP File

Say you're working on a project whose files you keep in a folder named *C:\AlsPythonBook*. You're worried about losing your work, so you'd like to create ZIP file "snapshots" of the entire folder. You'd like to keep different versions, so you want the ZIP file's filename to increment each time it is made; for example, *AlsPythonBook_1.zip*, *AlsPythonBook_2.zip*, *AlsPythonBook_3.zip*, and so on. You could do this by hand, but it is rather annoying, and you might accidentally misnumber the ZIP files' names. It would be much simpler to run a program that does this boring task for you.

For this project, open a new file editor window and save it as *backupToZip.py*.

Step 1: Figure Out the ZIP File's Name

The code for this program will be placed into a function named `backupToZip()`. This will make it easy to copy and paste the function into other Python programs that need this functionality. At the end of the program, the function will be called to perform the backup. Make your program look like this:

```
   #! python3
   # backupToZip.py - Copies an entire folder and its contents into
   # a ZIP file whose filename increments.

❶ import zipfile, os

   def backupToZip(folder):
       # Backup the entire contents of "folder" into a ZIP file.

       folder = os.path.abspath(folder)   # make sure folder is absolute

       # Figure out the filename this code should use based on
       # what files already exist.
❷     number = 1
❸     while True:
           zipFilename = os.path.basename(folder) + '_' + str(number) + '.zip'
           if not os.path.exists(zipFilename):
               break
           number = number + 1

❹     # TODO: Create the ZIP file.

       # TODO: Walk the entire folder tree and compress the files in each folder.
       print('Done.')

   backupToZip('C:\\delicious')
```

Do the basics first: Add the shebang (`#!`) line, describe what the program does, and import the `zipfile` and `os` modules ❶.

Define a `backupToZip()` function that takes just one parameter, `folder`. This parameter is a string path to the folder whose contents should be backed up. The function will determine what filename to use for the ZIP file it will create; then the function will create the file, walk the `folder` folder, and add each of the subfolders and files to the ZIP file. Write `TODO` comments for these steps in the source code to remind yourself to do them later ❹.

The first part, naming the ZIP file, uses the base name of the absolute path of `folder`. If the folder being backed up is *C:\delicious*, the ZIP file's name should be *delicious_N.zip*, where $N = 1$ is the first time you run the program, $N = 2$ is the second time, and so on.

You can determine what *N* should be by checking whether *delicious_1.zip* already exists, then checking whether *delicious_2.zip* already exists, and so on. Use a variable named `number` for *N* ❷, and keep incrementing it inside the loop that calls `os.path.exists()` to check whether the file exists ❸. The first nonexistent filename found will cause the loop to `break`, since it will have found the filename of the new zip.

Step 2: Create the New ZIP File

Next let's create the ZIP file. Make your program look like the following:

```
#! python3
# backupToZip.py - Copies an entire folder and its contents into
# a ZIP file whose filename increments.

--snip--
    while True:
        zipFilename = os.path.basename(folder) + '_' + str(number) + '.zip'
        if not os.path.exists(zipFilename):
            break
        number = number + 1

    # Create the ZIP file.
    print('Creating %s...' % (zipFilename))
❶   backupZip = zipfile.ZipFile(zipFilename, 'w')

    # TODO: Walk the entire folder tree and compress the files in each folder.
    print('Done.')

backupToZip('C:\\delicious')
```

Now that the new ZIP file's name is stored in the `zipFilename` variable, you can call `zipfile.ZipFile()` to actually create the ZIP file ❶. Be sure to pass `'w'` as the second argument so that the ZIP file is opened in write mode.

Step 3: Walk the Directory Tree and Add to the ZIP File

Now you need to use the `os.walk()` function to do the work of listing every file in the folder and its subfolders. Make your program look like the following:

```
#! python3
# backupToZip.py - Copies an entire folder and its contents into
# a ZIP file whose filename increments.

--snip--

    # Walk the entire folder tree and compress the files in each folder.
❶   for foldername, subfolders, filenames in os.walk(folder):
        print('Adding files in %s...' % (foldername))
        # Add the current folder to the ZIP file.
❷       backupZip.write(foldername)
```

```
        # Add all the files in this folder to the ZIP file.
❸       for filename in filenames:
            newBase / os.path.basename(folder) + '_'
            if filename.startswith(newBase) and filename.endswith('.zip')
                continue   # don't backup the backup ZIP files
            backupZip.write(os.path.join(foldername, filename))
    backupZip.close()
    print('Done.')


backupToZip('C:\\delicious')
```

You can use `os.walk()` in a `for` loop ❶, and on each iteration it will return the iteration's current folder name, the subfolders in that folder, and the filenames in that folder.

In the `for` loop, the folder is added to the ZIP file ❷. The nested `for` loop can go through each filename in the `filenames` list ❸. Each of these is added to the ZIP file, except for previously made backup ZIPs.

When you run this program, it will produce output that will look something like this:

```
Creating delicious_1.zip...
Adding files in C:\delicious...
Adding files in C:\delicious\cats...
Adding files in C:\delicious\waffles...
Adding files in C:\delicious\walnut...
Adding files in C:\delicious\walnut\waffles...
Done.
```

The second time you run it, it will put all the files in *C:\delicious* into a ZIP file named *delicious_2.zip*, and so on.

Ideas for Similar Programs

You can walk a directory tree and add files to compressed ZIP archives in several other programs. For example, you can write programs that do the following:

- Walk a directory tree and archive just files with certain extensions, such as *.txt* or *.py*, and nothing else
- Walk a directory tree and archive every file except the *.txt* and *.py* ones
- Find the folder in a directory tree that has the greatest number of files or the folder that uses the most disk space

Summary

Even if you are an experienced computer user, you probably handle files manually with the mouse and keyboard. Modern file explorers make it easy to work with a few files. But sometimes you'll need to perform a task that would take hours using your computer's file explorer.

The `os` and `shutil` modules offer functions for copying, moving, renaming, and deleting files. When deleting files, you might want to use the `send2trash` module to move files to the recycle bin or trash rather than permanently deleting them. And when writing programs that handle files, it's a good idea to comment out the code that does the actual copy/move/rename/delete and add a `print()` call instead so you can run the program and verify exactly what it will do.

Often you will need to perform these operations not only on files in one folder but also on every folder in that folder, every folder in those folders, and so on. The `os.walk()` function handles this trek across the folders for you so that you can concentrate on what your program needs to do with the files in them.

The `zipfile` module gives you a way of compressing and extracting files in *.zip* archives through Python. Combined with the file-handling functions of `os` and `shutil`, `zipfile` makes it easy to package up several files from anywhere on your hard drive. These *.zip* files are much easier to upload to websites or send as email attachments than many separate files.

Previous chapters of this book have provided source code for you to copy. But when you write your own programs, they probably won't come out perfectly the first time. The next chapter focuses on some Python modules that will help you analyze and debug your programs so that you can quickly get them working correctly.

Practice Questions

1. What is the difference between `shutil.copy()` and `shutil.copytree()`?
2. What function is used to rename files?
3. What is the difference between the delete functions in the `send2trash` and `shutil` modules?
4. `ZipFile` objects have a `close()` method just like `File` objects' `close()` method. What `ZipFile` method is equivalent to `File` objects' `open()` method?

Practice Projects

For practice, write programs to do the following tasks.

Selective Copy

Write a program that walks through a folder tree and searches for files with a certain file extension (such as *.pdf* or *.jpg*). Copy these files from whatever location they are in to a new folder.

Deleting Unneeded Files

It's not uncommon for a few unneeded but humongous files or folders to take up the bulk of the space on your hard drive. If you're trying to free up room on your computer, you'll get the most bang for your buck by deleting the most massive of the unwanted files. But first you have to find them.

Write a program that walks through a folder tree and searches for exceptionally large files or folders—say, ones that have a file size of more than 100MB. (Remember, to get a file's size, you can use `os.path.getsize()` from the `os` module.) Print these files with their absolute path to the screen.

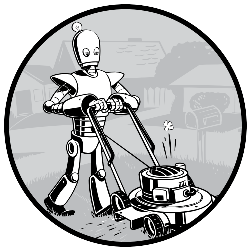
Filling in the Gaps

Write a program that finds all files with a given prefix, such as *spam001.txt*, *spam002.txt*, and so on, in a single folder and locates any gaps in the numbering (such as if there is a *spam001.txt* and *spam003.txt* but no *spam002.txt*). Have the program rename all the later files to close this gap.

As an added challenge, write another program that can insert gaps into numbered files so that a new file can be added.

10

DEBUGGING



Now that you know enough to write more complicated programs, you may start finding not-so-simple bugs in them. This chapter covers some tools and techniques for finding the root cause of bugs in your program to help you fix bugs faster and with less effort.

To paraphrase an old joke among programmers, "Writing code accounts for 90 percent of programming. Debugging code accounts for the other 90 percent."

Your computer will do only what you tell it to do; it won't read your mind and do what you *intended* it to do. Even professional programmers create bugs all the time, so don't feel discouraged if your program has a problem.

Fortunately, there are a few tools and techniques to identify what exactly your code is doing and where it's going wrong. First, you will look at logging and assertions, two features that can help you detect bugs early. In general, the earlier you catch bugs, the easier they will be to fix.

Second, you will look at how to use the debugger. The debugger is a feature of IDLE that executes a program one instruction at a time, giving you a chance to inspect the values in variables while your code runs, and track how the values change over the course of your program. This is much slower than running the program at full speed, but it is helpful to see the actual values in a program while it runs, rather than deducing what the values might be from the source code.

Raising Exceptions

Python raises an exception whenever it tries to execute invalid code. In Chapter 3, you read about how to handle Python's exceptions with `try` and `except` statements so that your program can recover from exceptions that you anticipated. But you can also raise your own exceptions in your code. Raising an exception is a way of saying, "Stop running the code in this function and move the program execution to the `except` statement."

Exceptions are raised with a `raise` statement. In code, a `raise` statement consists of the following:

- The `raise` keyword
- A call to the `Exception()` function
- A string with a helpful error message passed to the `Exception()` function

For example, enter the following into the interactive shell:

```
>>> raise Exception('This is the error message.')
Traceback (most recent call last):
  File "<pyshell#191>", line 1, in <module>
    raise Exception('This is the error message.')
Exception: This is the error message.
```

If there are no `try` and `except` statements covering the `raise` statement that raised the exception, the program simply crashes and displays the exception's error message.

Often it's the code that calls the function, not the fuction itself, that knows how to handle an expection. So you will commonly see a `raise` statement inside a function and the `try` and `except` statements in the code calling the function. For example, open a new file editor window, enter the following code, and save the program as *boxPrint.py*:

```
def boxPrint(symbol, width, height):
    if len(symbol) != 1:
❶       raise Exception('Symbol must be a single character string.')
    if width <= 2:
❷       raise Exception('Width must be greater than 2.')
    if height <= 2:
❸       raise Exception('Height must be greater than 2.')
```

```
    print(symbol * width)
    for i in range(height - 2):
        print(symbol + (' ' * (width - 2)) + symbol)
    print(symbol * width)

for sym, w, h in (('*', 4, 4), ('O', 20, 5), ('x', 1, 3), ('ZZ', 3, 3)):
    try:
        boxPrint(sym, w, h)
❹   except Exception as err:
❺       print('An exception happened: ' + str(err))
```

Here we've defined a `boxPrint()` function that takes a character, a width, and a height, and uses the character to make a little picture of a box with that width and height. This box shape is printed to the console.

Say we want the character to be a single character, and the width and height to be greater than 2. We add `if` statements to raise exceptions if these requirements aren't satisfied. Later, when we call `boxPrint()` with various arguments, our `try`/`except` will handle invalid arguments.

This program uses the `except Exception as err` form of the `except` statement ❹. If an `Exception` object is returned from `boxPrint()` ❶❷❸, this `except` statement will store it in a variable named `err`. The `Exception` object can then be converted to a string by passing it to `str()` to produce a user-friendly error message ❺. When you run this *boxPrint.py*, the output will look like this:

```
****
*  *
*  *
****
OOOOOOOOOOOOOOOOOOOO
O                  O
O                  O
O                  O
OOOOOOOOOOOOOOOOOOOO
An exception happened: Width must be greater than 2.
An exception happened: Symbol must be a single character string.
```

Using the `try` and `except` statements, you can handle errors more gracefully instead of letting the entire program crash.

Getting the Traceback as a String

When Python encounters an error, it produces a treasure trove of error information called the *traceback*. The traceback includes the error message, the line number of the line that caused the error, and the sequence of the function calls that led to the error. This sequence of calls is called the *call stack*.

Open a new file editor window in IDLE, enter the following program, and save it as *errorExample.py*:

```
def spam():
    bacon()
```

```
def bacon():
    raise Exception('This is the error message.')

spam()
```

When you run *errorExample.py*, the output will look like this:

```
Traceback (most recent call last):
  File "errorExample.py", line 7, in <module>
    spam()
  File "errorExample.py", line 2, in spam
    bacon()
  File "errorExample.py", line 5, in bacon
    raise Exception('This is the error message.')
Exception: This is the error message.
```

From the traceback, you can see that the error happened on line 5, in the `bacon()` function. This particular call to `bacon()` came from line 2, in the `spam()` function, which in turn was called on line 7. In programs where functions can be called from multiple places, the call stack can help you determine which call led to the error.

The traceback is displayed by Python whenever a raised exception goes unhandled. But you can also obtain it as a string by calling `traceback.format_exc()`. This function is useful if you want the information from an exception's traceback but also want an `except` statement to gracefully handle the exception. You will need to import Python's `traceback` module before calling this function.

For example, instead of crashing your program right when an exception occurs, you can write the traceback information to a log file and keep your program running. You can look at the log file later, when you're ready to debug your program. Enter the following into the interactive shell:

```
>>> import traceback
>>> try:
          raise Exception('This is the error message.')
except:
          errorFile = open('errorInfo.txt', 'w')
          errorFile.write(traceback.format_exc())
          errorFile.close()
          print('The traceback info was written to errorInfo.txt.')

116
The traceback info was written to errorInfo.txt.
```

The `116` is the return value from the `write()` method, since 116 characters were written to the file. The traceback text was written to *errorInfo.txt*.

```
Traceback (most recent call last):
  File "<pyshell#28>", line 2, in <module>
Exception: This is the error message.
```

Assertions

An *assertion* is a sanity check to make sure your code isn't doing something obviously wrong. These sanity checks are performed by assert statements. If the sanity check fails, then an AssertionError exception is raised. In code, an assert statement consists of the following:

- The assert keyword
- A condition (that is, an expression that evaluates to True or False)
- A comma
- A string to display when the condition is False

For example, enter the following into the interactive shell:

```
>>> podBayDoorStatus = 'open'
>>> assert podBayDoorStatus == 'open', 'The pod bay doors need to be "open".'
>>> podBayDoorStatus = 'I\'m sorry, Dave. I\'m afraid I can't do that.''
>>> assert podBayDoorStatus == 'open', 'The pod bay doors need to be "open".'
Traceback (most recent call last):
  File "<pyshell#10>", line 1, in <module>
    assert podBayDoorStatus == 'open', 'The pod bay doors need to be "open".'
AssertionError: The pod bay doors need to be "open".
```

Here we've set podBayDoorStatus to 'open', so from now on, we fully expect the value of this variable to be 'open'. In a program that uses this variable, we might have written a lot of code under the assumption that the value is 'open'—code that depends on its being 'open' in order to work as we expect. So we add an assertion to make sure we're right to assume podBayDoorStatus is 'open'. Here, we include the message 'The pod bay doors need to be "open".' so it'll be easy to see what's wrong if the assertion fails.

Later, say we make the obvious mistake of assigning podBayDoorStatus another value, but don't notice it among many lines of code. The assertion catches this mistake and clearly tells us what's wrong.

In plain English, an assert statement says, "I assert that this condition holds true, and if not, there is a bug somewhere in the program." Unlike exceptions, your code should *not* handle assert statements with try and except; if an assert fails, your program *should* crash. By failing fast like this, you shorten the time between the original cause of the bug and when you first notice the bug. This will reduce the amount of code you will have to check before finding the code that's causing the bug.

Assertions are for programmer errors, not user errors. For errors that can be recovered from (such as a file not being found or the user entering invalid data), raise an exception instead of detecting it with an assert statement.

Using an Assertion in a Traffic Light Simulation

Say you're building a traffic light simulation program. The data structure representing the stoplights at an intersection is a dictionary with keys 'ns' and 'ew', for the stoplights facing north-south and east-west, respectively. The values at these keys will be one of the strings 'green', 'yellow', or 'red'. The code would look something like this:

```
market_2nd = {'ns': 'green', 'ew': 'red'}
mission_16th = {'ns': 'red', 'ew': 'green'}
```

These two variables will be for the intersections of Market Street and 2nd Street, and Mission Street and 16th Street. To start the project, you want to write a switchLights() function, which will take an intersection dictionary as an argument and switch the lights.

At first, you might think that switchLights() should simply switch each light to the next color in the sequence: Any 'green' values should change to 'yellow', 'yellow' values should change to 'red', and 'red' values should change to 'green'. The code to implement this idea might look like this:

```
def switchLights(stoplight):
    for key in stoplight.keys():
        if stoplight[key] == 'green':
            stoplight[key] = 'yellow'
        elif stoplight[key] == 'yellow':
            stoplight[key] = 'red'
        elif stoplight[key] == 'red':
            stoplight[key] = 'green'

switchLights(market_2nd)
```

You may already see the problem with this code, but let's pretend you wrote the rest of the simulation code, thousands of lines long, without noticing it. When you finally do run the simulation, the program doesn't crash—but your virtual cars do!

Since you've already written the rest of the program, you have no idea where the bug could be. Maybe it's in the code simulating the cars or in the code simulating the virtual drivers. It could take hours to trace the bug back to the switchLights() function.

But if while writing switchLights() you had added an assertion to check that *at least one of the lights is always red*, you might have included the following at the bottom of the function:

```
assert 'red' in stoplight.values(), 'Neither light is red! ' + str(stoplight)
```

With this assertion in place, your program would crash with this error message:

```
  Traceback (most recent call last):
    File "carSim.py", line 14, in <module>
      switchLights(market_2nd)
    File "carSim.py", line 13, in switchLights
      assert 'red' in stoplight.values(), 'Neither light is red! ' + str(stoplight)
❶ AssertionError: Neither light is red! {'ns': 'yellow', 'ew': 'green'}
```

The important line here is the AssertionError ❶. While your program crashing is not ideal, it immediately points out that a sanity check failed: Neither direction of traffic has a red light, meaning that traffic could be going both ways. By failing fast early in the program's execution, you can save yourself a lot of future debugging effort.

Disabling Assertions

Assertions can be disabled by passing the -O option when running Python. This is good for when you have finished writing and testing your program and don't want it to be slowed down by performing sanity checks (although most of the time assert statements do not cause a noticeable speed difference). Assertions are for development, not the final product. By the time you hand off your program to someone else to run, it should be free of bugs and not require the sanity checks. See Appendix B for details about how to launch your probably-not-insane programs with the -O option.

Logging

If you've ever put a print() statement in your code to output some variable's value while your program is running, you've used a form of *logging* to debug your code. Logging is a great way to understand what's happening in your program and in what order its happening. Python's logging module makes it easy to create a record of custom messages that you write. These log messages will describe when the program execution has reached the logging function call and list any variables you have specified at that point in time. On the other hand, a missing log message indicates a part of the code was skipped and never executed.

Using the logging Module

To enable the logging module to display log messages on your screen as your program runs, copy the following to the top of your program (but under the #! python shebang line):

```
import logging
logging.basicConfig(level=logging.DEBUG, format=' %(asctime)s -  %(levelname)s
-  %(message)s')
```

You don't need to worry too much about how this works, but basically, when Python logs an event, it creates a LogRecord object that holds information about that event. The logging module's basicConfig() function lets you specify what details about the LogRecord object you want to see and how you want those details displayed.

Say you wrote a function to calculate the *factorial* of a number. In mathematics, factorial 4 is 1 × 2 × 3 × 4, or 24. Factorial 7 is 1 × 2 × 3 × 4 × 5 × 6 × 7, or 5,040. Open a new file editor window and enter the following code. It has a bug in it, but you will also enter several log messages to help yourself figure out what is going wrong. Save the program as *factorialLog.py*.

```
import logging
logging.basicConfig(level=logging.DEBUG, format=' %(asctime)s -  %(levelname)s
-  %(message)s')
logging.debug('Start of program')

def factorial(n):
    logging.debug('Start of factorial(%s%%)'  % (n))
    total = 1
    for i in range(n + 1):
        total *= i
        logging.debug('i is ' + str(i) + ', total is ' + str(total))
    logging.debug('End of factorial(%s%%)'  % (n))
    return total

print(factorial(5))
logging.debug('End of program')
```

Here, we use the `logging.debug()` function when we want to print log information. This `debug()` function will call `basicConfig()`, and a line of information will be printed. This information will be in the format we specified in `basicConfig()` and will include the messages we passed to `debug()`. The `print(factorial(5))` call is part of the original program, so the result is displayed even if logging messages are disabled.

The output of this program looks like this:

```
2015-05-23 16:20:12,664 - DEBUG - Start of program
2015-05-23 16:20:12,664 - DEBUG - Start of factorial(5)
2015-05-23 16:20:12,665 - DEBUG - i is 0, total is 0
2015-05-23 16:20:12,668 - DEBUG - i is 1, total is 0
2015-05-23 16:20:12,670 - DEBUG - i is 2, total is 0
2015-05-23 16:20:12,673 - DEBUG - i is 3, total is 0
2015-05-23 16:20:12,675 - DEBUG - i is 4, total is 0
2015-05-23 16:20:12,678 - DEBUG - i is 5, total is 0
2015-05-23 16:20:12,680 - DEBUG - End of factorial(5)
0
2015-05-23 16:20:12,684 - DEBUG - End of program
```

The `factorial()` function is returning `0` as the factorial of `5`, which isn't right. The `for` loop should be multiplying the value in `total` by the numbers from `1` to `5`. But the log messages displayed by `logging.debug()` show that the `i` variable is starting at `0` instead of `1`. Since zero times anything is zero, the rest of the iterations also have the wrong value for `total`. Logging messages provide a trail of breadcrumbs that can help you figure out when things started to go wrong.

Change the `for i in range(n + 1):` line to `for i in range(`**`1,`**` n + 1):`, and run the program again. The output will look like this:

```
2015-05-23 17:13:40,650 - DEBUG - Start of program
2015-05-23 17:13:40,651 - DEBUG - Start of factorial(5)
2015-05-23 17:13:40,651 - DEBUG - i is 1, total is 1
2015-05-23 17:13:40,654 - DEBUG - i is 2, total is 2
2015-05-23 17:13:40,656 - DEBUG - i is 3, total is 6
```

```
2015-05-23 17:13:40,659 - DEBUG - i is 4, total is 24
2015-05-23 17:13:40,661 - DEBUG - i is 5, total is 120
2015-05-23 17:13:40,661 - DEBUG - End of factorial(5)
120
2015-05-23 17:13:40,666 - DEBUG - End of program
```

The `factorial(5)` call correctly returns `120`. The log messages showed what was going on inside the loop, which led straight to the bug.

You can see that the `logging.debug()` calls printed out not just the strings passed to them but also a timestamp and the word *DEBUG*.

Don't Debug with print()

Typing `import logging` and `logging.basicConfig(level=logging.DEBUG, format= '%(asctime)s - %(levelname)s - %(message)s')` is somewhat unwieldy. You may want to use `print()` calls instead, but don't give in to this temptation! Once you're done debugging, you'll end up spending a lot of time removing `print()` calls from your code for each log message. You might even accidentally remove some `print()` calls that were being used for nonlog messages. The nice thing about log messages is that you're free to fill your program with as many as you like, and you can always disable them later by adding a single `logging.disable(logging.CRITICAL)` call. Unlike `print()`, the `logging` module makes it easy to switch between showing and hiding log messages.

Log messages are intended for the programmer, not the user. The user won't care about the contents of some dictionary value you need to see to help with debugging; use a log message for something like that. For messages that the user will want to see, like *File not found* or *Invalid input, please enter a number*, you should use a `print()` call. You don't want to deprive the user of useful information after you've disabled log messages.

Logging Levels

Logging levels provide a way to categorize your log messages by importance. There are five logging levels, described in Table 10-1 from least to most important. Messages can be logged at each level using a different logging function.

Table 10-1: Logging Levels in Python

Level	Logging Function	Description
DEBUG	`logging.debug()`	The lowest level. Used for small details. Usually you care about these messages only when diagnosing problems.
INFO	`logging.info()`	Used to record information on general events in your program or confirm that things are working at their point in the program.
WARNING	`logging.warning()`	Used to indicate a potential problem that doesn't prevent the program from working but might do so in the future.

(*continued*)

Table 10-1 (*continued*)

Level	Logging Function	Description
ERROR	`logging.error()`	Used to record an error that caused the program to fail to do something.
CRITICAL	`logging.critical()`	The highest level. Used to indicate a fatal error that has caused or is about to cause the program to stop running entirely.

Your logging message is passed as a string to these functions. The logging levels are suggestions. Ultimately, it is up to you to decide which category your log message falls into. Enter the following into the interactive shell:

```
>>> import logging
>>> logging.basicConfig(level=logging.DEBUG, format=' %(asctime)s -
%(levelname)s -  %(message)s')
>>> logging.debug('Some debugging details.')
2015-05-18 19:04:26,901 - DEBUG - Some debugging details.
>>> logging.info('The logging module is working.')
2015-05-18 19:04:35,569 - INFO - The logging module is working.
>>> logging.warning('An error message is about to be logged.')
2015-05-18 19:04:56,843 - WARNING - An error message is about to be logged.
>>> logging.error('An error has occurred.')
2015-05-18 19:05:07,737 - ERROR - An error has occurred.
>>> logging.critical('The program is unable to recover!')
2015-05-18 19:05:45,794 - CRITICAL - The program is unable to recover!
```

The benefit of logging levels is that you can change what priority of logging message you want to see. Passing `logging.DEBUG` to the `basicConfig()` function's `level` keyword argument will show messages from all the logging levels (DEBUG being the lowest level). But after developing your program some more, you may be interested only in errors. In that case, you can set `basicConfig()`'s `level` argument to `logging.ERROR`. This will show only ERROR and CRITICAL messages and skip the DEBUG, INFO, and WARNING messages.

Disabling Logging

After you've debugged your program, you probably don't want all these log messages cluttering the screen. The `logging.disable()` function disables these so that you don't have to go into your program and remove all the logging calls by hand. You simply pass `logging.disable()` a logging level, and it will suppress all log messages at that level or lower. So if you want to disable logging entirely, just add `logging.disable(logging.CRITICAL)` to your program. For example, enter the following into the interactive shell:

```
>>> import logging
>>> logging.basicConfig(level=logging.INFO, format=' %(asctime)s -
%(levelname)s -  %(message)s')
```

```
>>> logging.critical('Critical error! Critical error!')
2015-05-22 11:10:48,054 - CRITICAL - Critical error! Critical error!
>>> logging.disable(logging.CRITICAL)
>>> logging.critical('Critical error! Critical error!')
>>> logging.error('Error! Error!')
```

Since `logging.disable()` will disable all messages after it, you will probably want to add it near the `import logging` line of code in your program. This way, you can easily find it to comment out or uncomment that call to enable or disable logging messages as needed.

Logging to a File

Instead of displaying the log messages to the screen, you can write them to a text file. The `logging.basicConfig()` function takes a `filename` keyword argument, like so:

```
import logging
logging.basicConfig(filename='myProgramLog.txt', level=logging.DEBUG, format='
%(asctime)s -  %(levelname)s -  %(message)s')
```

The log messages will be saved to *myProgramLog.txt*. While logging messages are helpful, they can clutter your screen and make it hard to read the program's output. Writing the logging messages to a file will keep your screen clear and store the messages so you can read them after running the program. You can open this text file in any text editor, such as Notepad or TextEdit.

IDLE's Debugger

The *debugger* is a feature of IDLE that allows you to execute your program one line at a time. The debugger will run a single line of code and then wait for you to tell it to continue. By running your program "under the debugger" like this, you can take as much time as you want to examine the values in the variables at any given point during the program's lifetime. This is a valuable tool for tracking down bugs.

To enable IDLE's debugger, click **Debug ▸ Debugger** in the interactive shell window. This will bring up the Debug Control window, which looks like Figure 10-1.

When the Debug Control window appears, select all four of the **Stack**, **Locals**, **Source**, and **Globals** checkboxes so that the window shows the full set of debug information. While the Debug Control window is displayed, any time you run a program from the file editor, the debugger will pause execution before the first instruction and display the following:

- The line of code that is about to be executed
- A list of all local variables and their values
- A list of all global variables and their values

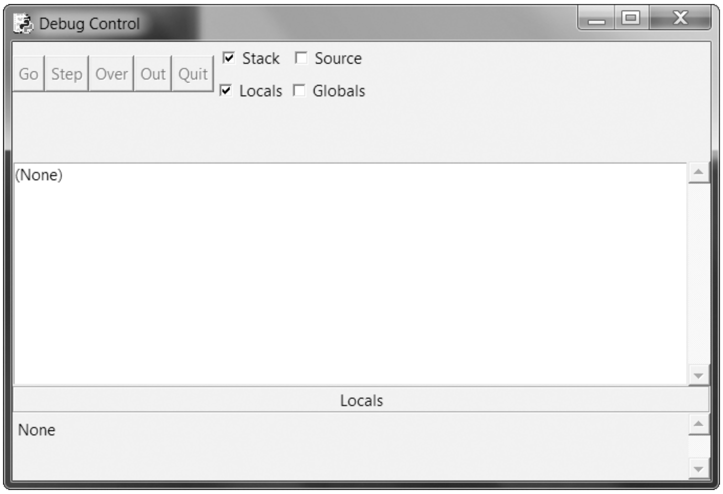


Figure 10-1: The Debug Control window

You'll notice that in the list of global variables there are several variables you haven't defined, such as `__builtins__`, `__doc__`, `__file__`, and so on. These are variables that Python automatically sets whenever it runs a program. The meaning of these variables is beyond the scope of this book, and you can comfortably ignore them.

The program will stay paused until you press one of the five buttons in the Debug Control window: Go, Step, Over, Out, or Quit.

Go

Clicking the Go button will cause the program to execute normally until it terminates or reaches a *breakpoint*. (Breakpoints are described later in this chapter.) If you are done debugging and want the program to continue normally, click the **Go** button.

Step

Clicking the Step button will cause the debugger to execute the next line of code and then pause again. The Debug Control window's list of global and local variables will be updated if their values change. If the next line of code is a function call, the debugger will "step into" that function and jump to the first line of code of that function.

Over

Clicking the Over button will execute the next line of code, similar to the Step button. However, if the next line of code is a function call, the Over button will "step over" the code in the function. The function's code will be executed at full speed, and the debugger will pause as soon as the function call returns. For example, if the next line of code is a `print()` call, you don't really care about code inside the built-in `print()` function; you just want the string you pass it printed to the screen. For this reason, using the Over button is more common than the Step button.

Out

Clicking the Out button will cause the debugger to execute lines of code at full speed until it returns from the current function. If you have stepped into a function call with the Step button and now simply want to keep executing instructions until you get back out, click the **Out** button to "step out" of the current function call.

Quit

If you want to stop debugging entirely and not bother to continue executing the rest of the program, click the **Quit** button. The Quit button will immediately terminate the program. If you want to run your program normally again, select **Debug ▸ Debugger** again to disable the debugger.

Debugging a Number Adding Program

Open a new file editor window and enter the following code:

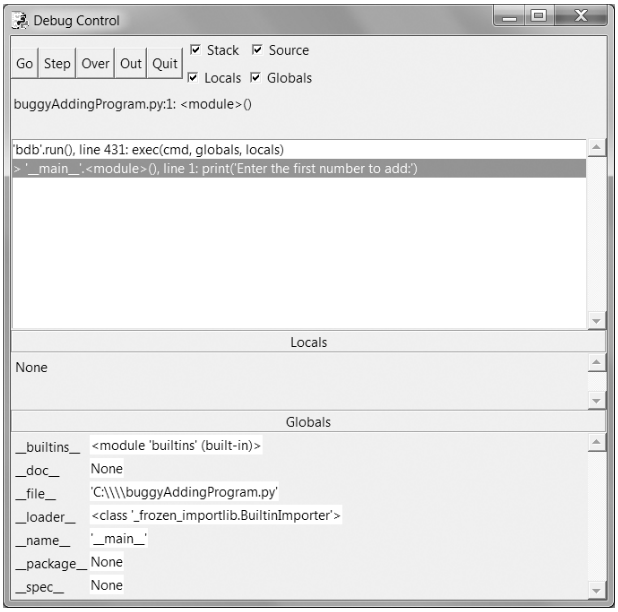
```
print('Enter the first number to add:')
first = input()
print('Enter the second number to add:')
second = input()
print('Enter the third number to add:')
third = input()
print('The sum is ' + first + second + third)
```

Save it as *buggyAddingProgram.py* and run it first without the debugger enabled. The program will output something like this:

```
Enter the first number to add:
5
Enter the second number to add:
3
Enter the third number to add:
42
The sum is 5342
```

The program hasn't crashed, but the sum is obviously wrong. Let's enable the Debug Control window and run it again, this time under the debugger.

When you press F5 or select **Run ▸ Run Module** (with **Debug ▸ Debugger** enabled and all four checkboxes on the Debug Control window checked), the program starts in a paused state on line 1. The debugger will always pause on the line of code it is about to execute. The Debug Control window will look like Figure 10-2.



```
buggyAddingProgram.py:1: <module>()

'bdb'.run(), line 431: exec(cmd, globals, locals)
> '__main__'.<module>(), line 1: print('Enter the first number to add:')
```

Locals

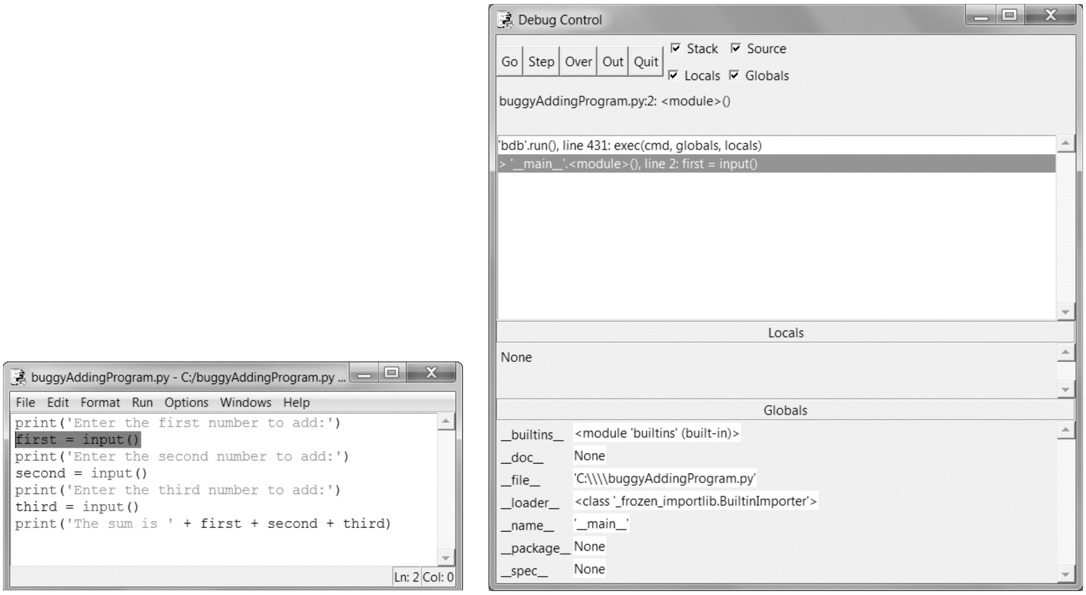
```
None
```

Globals

```
__builtins__  <module 'builtins' (built-in)>
__doc__       None
__file__      'C:\\\\buggyAddingProgram.py'
__loader__    <class '_frozen_importlib.BuiltinImporter'>
__name__      '__main__'
__package__   None
__spec__      None
```

Figure 10-2: The Debug Control window when the program first starts under the debugger

Click the **Over** button once to execute the first `print()` call. You should use Over instead of Step here, since you don't want to step into the code for the `print()` function. The Debug Control window will update to line 2, and line 2 in the file editor window will be highlighted, as shown in Figure 10-3. This shows you where the program execution currently is.


buggyAddingProgram.py - C:/buggyAddingProgram.py ...
File Edit Format Run Options Windows Help
Ln: 2 Col: 0
Debug Control
Go Step Over Out Quit
☑ Stack ☑ Source
☑ Locals ☑ Globals

```
print('Enter the first number to add:')
first = input()
print('Enter the second number to add:')
second = input()
print('Enter the third number to add:')
third = input()
print('The sum is ' + first + second + third)
```

```
buggyAddingProgram.py:2: <module>()

'bdb'.run(), line 431: exec(cmd, globals, locals)
> '__main__'.<module>(), line 2: first = input()
```

Locals

```
None
```

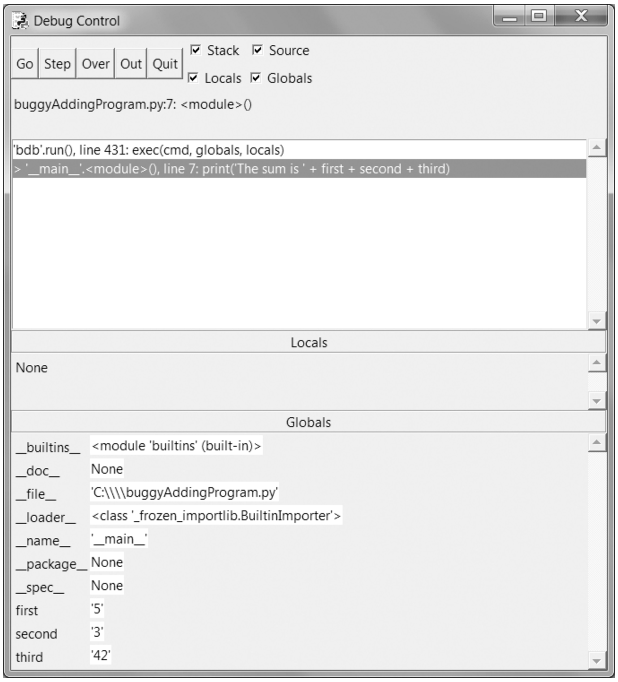
Globals

```
__builtins__  <module 'builtins' (built-in)>
__doc__       None
__file__      'C:\\\\buggyAddingProgram.py'
__loader__    <class '_frozen_importlib.BuiltinImporter'>
__name__      '__main__'
__package__   None
__spec__      None
```

Figure 10-3: The Debug Control window after clicking Over

Click **Over** again to execute the `input()` function call, and the buttons in the Debug Control window will disable themselves while IDLE waits for you to type something for the `input()` call into the interactive shell window. Enter **5** and press Return. The Debug Control window buttons will be reenabled.

Keep clicking **Over**, entering **3** and **42** as the next two numbers, until the debugger is on line 7, the final `print()` call in the program. The Debug Control window should look like Figure 10-4. You can see in the Globals section that the first, second, and third variables are set to string values `'5'`, `'3'`, and `'42'` instead of integer values `5`, `3`, and `42`. When the last line is executed, these strings are concatenated instead of added together, causing the bug.



☑ Stack ☑ Source
☑ Locals ☑ Globals

```
buggyAddingProgram.py:7: <module>()

'bdb'.run(), line 431: exec(cmd, globals, locals)
> '__main__'.<module>(), line 7: print('The sum is ' + first + second + third)
```

Locals

```
None
```

Globals

```
__builtins__  <module 'builtins' (built-in)>
__doc__       None
__file__      'C:\\\\buggyAddingProgram.py'
__loader__    <class '_frozen_importlib.BuiltinImporter'>
__name__      '__main__'
__package__   None
__spec__      None
first         '5'
second        '3'
third         '42'
```

Figure 10-4: The Debug Control window on the last line. The variables are set to strings, causing the bug.

Stepping through the program with the debugger is helpful but can also be slow. Often you'll want the program to run normally until it reaches a certain line of code. You can configure the debugger to do this with breakpoints.

Breakpoints

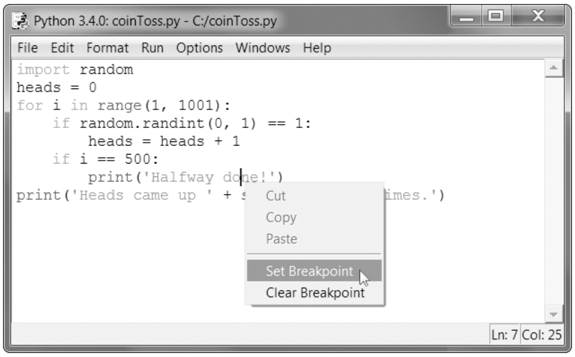
A *breakpoint* can be set on a specific line of code and forces the debugger to pause whenever the program execution reaches that line. Open a new file editor window and enter the following program, which simulates flipping a coin 1,000 times. Save it as *coinFlip.py*.

```
import random
heads = 0
for i in range(1, 1001):
❶    if random.randint(0, 1) == 1:
         heads = heads + 1
     if i == 500:
❷        print('Halfway done!')
print('Heads came up ' + str(heads) + ' times.')
```

The `random.randint(0, 1)` call ❶ will return `0` half of the time and `1` the other half of the time. This can be used to simulate a 50/50 coin flip where `1` represents heads. When you run this program without the debugger, it quickly outputs something like the following:

```
Halfway done!
Heads came up 490 times.
```

If you ran this program under the debugger, you would have to click the Over button thousands of times before the program terminated. If you were interested in the value of `heads` at the halfway point of the program's execution, when 500 of 1000 coin flips have been completed, you could instead just set a breakpoint on the line `print('Halfway done!')` ❷. To set a breakpoint, right-click the line in the file editor and select **Set Breakpoint**, as shown in Figure 10-5.



Python 3.4.0: coinToss.py - C:/coinToss.py
File Edit Format Run Options Windows Help
Cut
Copy
Paste
Set Breakpoint
Clear Breakpoint
Ln: 7 Col: 25

```
import random
heads = 0
for i in range(1, 1001):
    if random.randint(0, 1) == 1:
        heads = heads + 1
    if i == 500:
        print('Halfway done!')
print('Heads came up ' + s                imes.')
```

Figure 10-5: Setting a breakpoint

You don't want to set a breakpoint on the `if` statement line, since the `if` statement is executed on every single iteration through the loop. By setting the breakpoint on the code in the `if` statement, the debugger breaks only when the execution enters the `if` clause.

The line with the breakpoint will be highlighted in yellow in the file editor. When you run the program under the debugger, it will start in a paused state at the first line, as usual. But if you click Go, the program will run at full speed until it reaches the line with the breakpoint set on it. You can then click Go, Over, Step, or Out to continue as normal.

If you want to remove a breakpoint, right-click the line in the file editor and select **Clear Breakpoint** from the menu. The yellow highlighting will go away, and the debugger will not break on that line in the future.

Summary

Assertions, exceptions, logging, and the debugger are all valuable tools to find and prevent bugs in your program. Assertions with the Python `assert` statement are a good way to implement "sanity checks" that give you an early warning when a necessary condition doesn't hold true. Assertions are only for errors that the program shouldn't try to recover from and should fail fast. Otherwise, you should raise an exception.

An exception can be caught and handled by the `try` and `except` statements. The `logging` module is a good way to look into your code while it's running and is much more convenient to use than the `print()` function because of its different logging levels and ability to log to a text file.

The debugger lets you step through your program one line at a time. Alternatively, you can run your program at normal speed and have the debugger pause execution whenever it reaches a line with a breakpoint set. Using the debugger, you can see the state of any variable's value at any point during the program's lifetime.

These debugging tools and techniques will help you write programs that work. Accidentally introducing bugs into your code is a fact of life, no matter how many years of coding experience you have.

Practice Questions

1. Write an `assert` statement that triggers an `AssertionError` if the variable `spam` is an integer less than `10`.
2. Write an `assert` statement that triggers an `AssertionError` if the variables `eggs` and `bacon` contain strings that are the same as each other, even if their cases are different (that is, `'hello'` and `'hello'` are considered the same, and `'goodbye'` and `'GOODbye'` are also considered the same).
3. Write an `assert` statement that *always* triggers an `AssertionError`.
4. What are the two lines that your program must have in order to be able to call `logging.debug()`?
5. What are the two lines that your program must have in order to have `logging.debug()` send a logging message to a file named *programLog.txt*?
6. What are the five logging levels?
7. What line of code can you add to disable all logging messages in your program?
8. Why is using logging messages better than using `print()` to display the same message?
9. What are the differences between the Step, Over, and Out buttons in the Debug Control window?

10. After you click Go in the Debug Control window, when will the debugger stop?
11. What is a breakpoint?
12. How do you set a breakpoint on a line of code in IDLE?

Practice Project

For practice, write a program that does the following.

Debugging Coin Toss

The following program is meant to be a simple coin toss guessing game. The player gets two guesses (it's an easy game). However, the program has several bugs in it. Run through the program a few times to find the bugs that keep the program from working correctly.

```
import random
guess = ''
while guess not in ('heads', 'tails'):
    print('Guess the coin toss! Enter heads or tails:')
    guess = input()
toss = random.randint(0, 1) # 0 is tails, 1 is heads
if toss == guess:
    print('You got it!')
else:
    print('Nope! Guess again!')
    guesss = input()
    if toss == guess:
        print('You got it!')
    else:
        print('Nope. You are really bad at this game.')
```