CHAPTER 7

Lists and Tuples

TOPICS

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7.1 Sequences

CONCEPT: A sequence is an object that holds multiple items of data, stored one after the other. You can perform operations on a sequence to examine and manipulate the items stored in it.

A *sequence* is an object that contains multiple items of data. The items that are in a sequence are stored one after the other. Python provides various ways to perform operations on the items that are stored in a sequence.

There are several different types of sequence objects in Python. In this chapter we will look at two of the fundamental sequence types: lists and tuples. Both lists and tuples are sequences that can hold various types of data. The difference between lists and tuples is simple: a list is mutable, which means that a program can change its contents, but a tuple is immutable, which means that once it is created, its contents cannot be changed. We will explore some of the operations that you may perform on these sequences, including ways to access and manipulate their contents.

7.2 Introduction to Lists

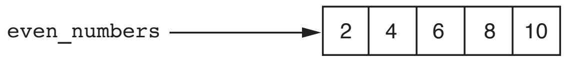
CONCEPT: A list is an object that contains multiple data items. Lists are mutable, which means that their contents can be changed during a program's execution. Lists are dynamic data structures, meaning that items may be added to them or removed from them. You can use indexing, slicing, and various methods to work with lists in a program.

A *list* is an object that contains multiple data items. Each item that is stored in a list is called an *element*. Here is a statement that creates a list of integers:

```
even_numbers = [2, 4, 6, 8, 10]
```

The items that are enclosed in brackets and separated by commas are the list elements. After this statement executes, the variable `even_numbers` will reference the list, as shown in Figure 7-1.

Figure 7-1 A list of integers

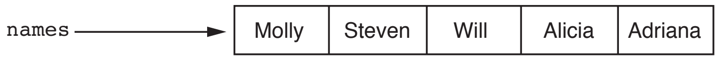


The following is another example:

```
names = ['Molly', 'Steven', 'Will', 'Alicia', 'Adriana']
```

This statement creates a list of five strings. After the statement executes, the `name` variable will reference the list as shown in Figure 7-2.

Figure 7-2 A list of strings

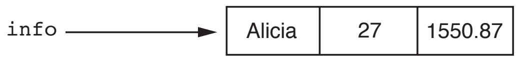


A list can hold items of different types, as shown in the following example:

```
info = ['Alicia', 27, 1550.87]
```

This statement creates a list containing a string, an integer, and a floating-point number. After the statement executes, the `info` variable will reference the list as shown in Figure 7-3.

Figure 7-3 A list holding different types



You can use the `print` function to display an entire list, as shown here:

```
numbers = [5, 10, 15, 20]
print(numbers)
```

In this example, the `print` function will display the elements of the list like this:

```
[5, 10, 15, 20]
```

Python also has a built-in `list()` function that can convert certain types of objects to lists. For example, recall from Chapter 4 that the `range` function returns an iterable, which is an object that holds a series of values that can be iterated over. You can use a statement such as the following to convert the `range` function's iterable object to a list:

```
numbers = list(range(5))
```

When this statement executes, the following things happen:

- The `range` function is called with 5 passed as an argument. The function returns an iterable containing the values 0, 1, 2, 3, 4.
- The `iterable` is passed as an argument to the `list()` function. The `list()` function returns the list `[0, 1, 2, 3, 4]`.
- The list `[0, 1, 2, 3, 4]` is assigned to the `numbers` variable.

Here is another example:

```
numbers = list(range(1, 10, 2))
```

Recall from Chapter 4 that when you pass three arguments to the `range` function, the first argument is the starting value, the second argument is the ending limit, and the third argument is the step value. This statement will assign the list `[1, 3, 5, 7, 9]` to the `numbers` variable.

The Repetition Operator

You learned in Chapter 2 that the `*` symbol multiplies two numbers. However, when the operand on the left side of the `*` symbol is a sequence (such as a list) and the operand on the right side is an integer, it becomes the *repetition operator*. The repetition operator makes multiple copies of a list and joins them all together. Here is the general format:

```
list * n
```

In the general format, *`list`* is a list and *`n`* is the number of copies to make. The following interactive session demonstrates:

```
1  >>> numbers = [0] * 5 Enter
2  >>> print(numbers) Enter
3  [0, 0, 0, 0, 0]
4  >>>
```

Let's take a closer look at each statement:

- In line 1 the expression `[0] * 5` makes five copies of the list `[0]` and joins them all together in a single list. The resulting list is assigned to the `numbers` variable.
- In line 2 the `numbers` variable is passed to the `print` function. The function's output is shown in line 3.

Here is another interactive mode demonstration:

```
1  >>> numbers = [1, 2, 3] * 3 Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 1, 2, 3, 1, 2, 3]
4  >>>
```

NOTE: Most programming languages allow you to create sequence structures known as *arrays*, which are similar to lists, but are much more limited in their capabilities. You cannot create traditional arrays in Python because lists serve the same purpose and provide many more built-in capabilities.

Iterating over a List with the `for` Loop

In Section 7.1 we discussed techniques for accessing the individual characters in a string. Many of the same programming techniques also apply to lists. For example, you can iterate over a list with the `for` loop, as shown here:

```
numbers = [99, 100, 101, 102]
for n in numbers:
    print(n)
```

If we run this code, it will print:

```
99
100
101
102
```

Indexing

Another way that you can access the individual elements in a list is with an *index*. Each element in a list has an index that specifies its position in the list. Indexing starts at 0, so the index of the first element is 0, the index of the second element is 1, and so forth. The index of the last element in a list is 1 less than the number of elements in the list.

For example, the following statement creates a list with 4 elements:

```
my_list = [10, 20, 30, 40]
```

The indexes of the elements in this list are 0, 1, 2, and 3. We can print the elements of the list with the following statement:

```
print(my_list[0], my_list[1], my_list[2], my_list[3])
```

The following loop also prints the elements of the list:

```
index = 0
while index < 4:
    print(my_list[index])
    index += 1
```

You can also use negative indexes with lists to identify element positions relative to the end of the list. The Python interpreter adds negative indexes to the length of the list to determine the element position. The index −1 identifies the last element in a list, −2 identifies the next to last element, and so forth. The following code shows an example:

```
my_list = [10, 20, 30, 40]
print(my_list[-1], my_list[-2], my_list[-3], my_list[-4])
```

In this example, the `print` function will display:

```
40    30    20    10
```

An `IndexError` exception will be raised if you use an invalid index with a list. For example, look at the following code:

```
# This code will cause an IndexError exception.
my_list = [10, 20, 30, 40]
```

```
index = 0
while index < 5:
    print(my_list[index])
    index += 1
```

The last time that this loop begins an iteration, the `index` variable will be assigned the value `4`, which is an invalid index for the list. As a result, the statement that calls the `print` function will cause an `IndexError` exception to be raised.

The `len` Function

Python has a built-in function named `len` that returns the length of a sequence, such as a list. The following code demonstrates:

```
my_list = [10, 20, 30, 40]
size = len(my_list)
```

The first statement assigns the list `[10, 20, 30, 40]` to the `my_list` variable. The second statement calls the `len` function, passing the `my_list` variable as an argument.

The function returns the value 4, which is the number of elements in the list. This value is assigned to the `size` variable.

The `len` function can be used to prevent an `IndexError` exception when iterating over a list with a loop. Here is an example:

```
my_list = [10, 20, 30, 40]
index = 0
while index < len(my_list):
    print(my_list[index])
    index += 1
```

Lists Are Mutable

Lists in Python are *mutable*, which means their elements can be changed. Consequently, an expression in the form *`list`*`[`*`index`*`]` can appear on the left side of an assignment operator. The following code shows an example:

```
1  numbers = [1, 2, 3, 4, 5]
2  print(numbers)
3  numbers[0] = 99
4  print(numbers)
```

The statement in line 2 will display

```
[1, 2, 3, 4, 5]
```

The statement in line 3 assigns 99 to `numbers[0]`. This changes the first value in the list to 99. When the statement in line 4 executes, it will display

```
[99, 2, 3, 4, 5]
```

When you use an indexing expression to assign a value to a list element, you must use a valid index for an existing element or an `IndexError` exception will occur. For example, look at the following code:

```
numbers = [1, 2, 3, 4, 5]     # Create a list with 5 elements.
numbers[5] = 99               # This raises an exception!
```

The `numbers` list that is created in the first statement has five elements, with the indexes 0 through 4. The second statement will raise an `IndexError` exception because the `numbers` list has no element at index 5.

If you want to use indexing expressions to fill a list with values, you have to create the list first, as shown here:

```
1  # Create a list with 5 elements.
2  numbers = [0] * 5
3
4  # Fill the list with the value 99.
5  index = 0
6  while index < len(numbers):
7    numbers[index] = 99
8    index += 1
```

The statement in line 2 creates a list with five elements, each element assigned the value 0. The loop in lines 6 through 8 then steps through the list elements, assigning 99 to each one.

Program 7-1 shows an example of how user input can be assigned to the elements of a list. This program gets sales amounts from the user and assigns them to a list.

Program 7-1 (sales_list.py)

```
# The NUM_DAYS constant holds the number of
# days that we will gather sales data for.
NUM_DAYS = 5

def main():
    # Create a list to hold the sales
    # for each day.
    sales = [0] * NUM_DAYS

    # Create a variable to hold an index.
    index = 0

    print('Enter the sales for each day.')

    # Get the sales for each day.
    while index < NUM_DAYS:
        print('Day #', index + 1, ': ', sep='', end='')
        sales[index] = float(input())
        index += 1

```

```
21      # Display the values entered.
22      print('Here are the values you entered:')
23      for value in sales:
24          print(value)
25
26  # Call the main function.
27  main()
```

Program Output (with input shown in bold)

```
Enter the sales for each day.
Day #1: 1000 Enter
Day #2: 2000 Enter
Day #3: 3000 Enter
Day #4: 4000 Enter
Day #5: 5000 Enter
Here are the values you entered:
1000.0
2000.0
3000.0
4000.0
5000.0
```

The statement in line 3 creates the variable `NUM_DAYS`, which is used as a constant for the number of days. The statement in line 8 creates a list with five elements, with each element assigned the value 0. Line 11 creates a variable named `index` and assigns the value 0 to it.

The loop in lines 16 through 19 iterates 5 times. The first time it iterates, `index` references the value 0, so the statement in line 18 assigns the user's input to `sales[0]`. The second time the loop iterates, index references the value 1, so the statement in line 18 assigns the user's input to `sales[1]`. This continues until input values have been assigned to all the elements in the list.

Concatenating Lists

To concatenate means to join two things together. You can use the + operator to concatenate two lists. Here is an example:

```
list1 = [1, 2, 3, 4]
list2 = [5, 6, 7, 8]
list3 = list1 + list2
```

After this code executes, `list1` and `list2` remain unchanged, and `list3` references the following list:

```
[1, 2, 3, 4, 5, 6, 7, 8]
```

The following interactive mode session also demonstrates list concatenation:

```
>>> girl_names = ['Joanne', 'Karen', 'Lori'] Enter
>>> boy_names = ['Chris', 'Jerry', 'Will'] Enter
>>> all_names = girl_names + boy_names Enter
>>> print(all_names) Enter
['Joanne', 'Karen', 'Lori', 'Chris', 'Jerry', 'Will']
```

You can also use the += augmented assignment operator to concatenate one list to another. Here is an example:

```
list1 = [1, 2, 3, 4]
list2 = [5, 6, 7, 8]
list1 += list2
```

The last statement appends `list2` to `list1`. After this code executes, `list2` remains unchanged, but `list1` references the following list:

```
[1, 2, 3, 4, 5, 6, 7, 8]
```

The following interactive mode session also demonstrates the += operator used for list concatenation:

```
>>> girl_names = ['Joanne', 'Karen', 'Lori'] Enter
>>> girl_names += ['Jenny', 'Kelly'] Enter
>>> print(girl_names) Enter
['Joanne', 'Karen', 'Lori', 'Jenny', 'Kelly']
>>>
```

NOTE: Keep in mind that you can concatenate lists only with other lists. If you try to concatenate a list with something that is not a list, an exception will be raised.

Checkpoint

7.1 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
numbers[2] = 99
print(numbers)
```

7.2 What will the following code display?

```
numbers = list(range(3))
print(numbers)
```

7.3 What will the following code display?

```
numbers = [10] * 5
print(numbers)
```

7.4 What will the following code display?

```
numbers = list(range(1, 10, 2))
for n in numbers:
    print(n)
```

7.5 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
print(numbers[-2])
```

7.6 How do you find the number of elements in a list?

7.7 What will the following code display?

```
numbers1 = [1, 2, 3]
numbers2 = [10, 20, 30]
numbers3 = numbers1 + numbers2
print(numbers1)
print(numbers2)
print(numbers3)
```

7.8 What will the following code display?

```
numbers1 = [1, 2, 3]
numbers2 = [10, 20, 30]
numbers2 += numbers1
print(numbers1)
print(numbers2)
```

7.3 List Slicing

CONCEPT: A slicing expression selects a range of elements from a sequence.

You have seen how indexing allows you to select a specific element in a sequence. Sometimes you want to select more than one element from a sequence. In Python, you can write expressions that select subsections of a sequence, known as slices.

VideoNote
List Slicing

A *slice* is a span of items that are taken from a sequence. When you take a slice from a list, you get a span of elements from within the list. To get a slice of a list, you write an expression in the following general format:

```
list_name[start : end]
```

In the general format, *start* is the index of the first element in the slice, and *end* is the index marking the end of the slice. The expression returns a list containing a copy of the elements from *start* up to (but not including) *end*. For example, suppose we create the following list:

```
days = ['Sunday', 'Monday', 'Tuesday', 'Wednesday',
        'Thursday', 'Friday', 'Saturday']
```

The following statement uses a slicing expression to get the elements from indexes 2 up to, but not including, 5:

```
mid_days = days[2:5]
```

After this statement executes, the `mid_days` variable references the following list:

```
['Tuesday', 'Wednesday', 'Thursday']
```

You can quickly use the interactive mode interpreter to see how slicing works. For example, look at the following session. (We have added line numbers for easier reference.)

```
1  >>> numbers = [1, 2, 3, 4, 5] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5]
```

```
4  >>> print(numbers[1:3]) Enter
5  [2, 3]
6  >>>
```

Here is a summary of each line:

- In line 1 we created the list and `[1, 2, 3, 4, 5]` and assigned it to the `numbers` variable.
- In line 2 we passed `numbers` as an argument to the `print` function. The `print` function displayed the list in line 3.
- In line 4 we sent the slice `numbers[1:3]` as an argument to the `print` function. The `print` function displayed the slice in line 5.

If you leave out the *`start`* index in a slicing expression, Python uses 0 as the starting index. The following interactive mode session shows an example:

```
1  >>> numbers = [1, 2, 3, 4, 5] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5]
4  >>> print(numbers[:3]) Enter
5  [1, 2, 3]
6  >>>
```

Notice that line 4 sends the slice `numbers[:3]` as an argument to the `print` function. Because the starting index was omitted, the slice contains the elements from index 0 up to 3.

If you leave out the *`end`* index in a slicing expression, Python uses the length of the list as the *`end`* index. The following interactive mode session shows an example:

```
1  >>> numbers = [1, 2, 3, 4, 5] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5]
4  >>> print(numbers[2:]) Enter
5  [3, 4, 5]
6  >>>
```

Notice that line 4 sends the slice `numbers[2:]` as an argument to the `print` function. Because the ending index was omitted, the slice contains the elements from index 2 through the end of the list.

If you leave out both the start and end index in a slicing expression, you get a copy of the entire list. The following interactive mode session shows an example:

```
1  >>> numbers = [1, 2, 3, 4, 5] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5]
4  >>> print(numbers[:])Enter
5  [1, 2, 3, 4, 5]
6  >>>
```

The slicing examples we have seen so far get slices of consecutive elements from lists. Slicing expressions can also have step value, which can cause elements to be skipped in the list. The following interactive mode session shows an example of a slicing expression with a step value:

```
1  >>> numbers = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
4  >>> print(numbers[1:8:2]) Enter
5  [2, 4, 6, 8]
6  >>>
```

In the slicing expression in line 4, the third number inside the brackets is the step value. A step value of 2, as used in this example, causes the slice to contain every second element from the specified range in the list.

You can also use negative numbers as indexes in slicing expressions to reference positions relative to the end of the list. Python adds a negative index to the length of a list to get the position referenced by that index. The following interactive mode session shows an example:

```
1  >>> numbers = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10] Enter
2  >>> print(numbers) Enter
3  [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
4  >>> print(numbers[-5:]) Enter
5  [6, 7, 8, 9, 10]
6  >>>
```

NOTE: Invalid indexes do not cause slicing expressions to raise an exception. For example:

- If the *end* index specifies a position beyond the end of the list, Python will use the length of the list instead.
- If the *start* index specifies a position before the beginning of the list, Python will use 0 instead.
- If the *start* index is greater than the *end* index, the slicing expression will return an empty list.

Checkpoint

7.9 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
my_list = numbers[1:3]
print(my_list)
```

7.10 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
my_list = numbers[1:]
print(my_list)
```

7.11 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
my_list = numbers[:1]
print(my_list)
```

7.12 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
my_list = numbers[:]
print(my_list)
```

7.13 What will the following code display?

```
numbers = [1, 2, 3, 4, 5]
my_list = numbers[-3:]
print(my_list)
```

7.4 Finding Items in Lists with the in Operator

CONCEPT: You can search for an item in a list using the in operator.

In Python you can use the in operator to determine whether an item is contained in a list. Here is the general format of an expression written with the in operator to search for an item in a list:

```
item in list
```

In the general format, *item* is the item for which you are searching, and *list* is a list. The expression returns true if *item* is found in the *list* or false otherwise. Program 7-2 shows an example.

Program 7-2 (in_list.py)

```
# This program demonstrates the in operator
# used with a list.

def main():
    # Create a list of product numbers.
    prod_nums = ['V475', 'F987', 'Q143', 'R688']

    # Get a product number to search for.
    search = input('Enter a product number: ')

    # Determine whether the product number is in the list.
    if search in prod_nums:
        print(search, 'was found in the list.')
    else:
        print(search, 'was not found in the list.')

# Call the main function.
main()
```

Program Output (with input shown in bold)

```
Enter a product number: Q143 Enter
Q143 was found in the list.
```

Program Output (with input shown in bold)

```
Enter a product number: B000 Enter
B000 was not found in the list.
```

The program gets a product number from the user in line 9 and assigns it to the `search` variable. The `if` statement in line 12 determines whether `search` is in the `prod_nums` list.

You can use the `not in` operator to determine whether an item is *not* in a list. Here is an example:

```
if search not in prod_nums:
    print(search, 'was not found in the list.')
else:
    print(search, 'was found in the list.')
```

Checkpoint

7.14 What will the following code display?

```
names = ['Jim', 'Jill', 'John', 'Jasmine']
if 'Jasmine' not in names:
    print('Cannot find Jasmine.')
else:
    print("Jasmine's family:")
    print(names)
```

7.5 List Methods and Useful Built-in Functions

CONCEPT: Lists have numerous methods that allow you to work with the elements that they contain. Python also provides some built-in functions that are useful for working with lists.

Lists have numerous methods that allow you to add elements, remove elements, change the ordering of elements, and so forth. We will look at a few of these methods,[1] which are listed in Table 7-1.

The `append` Method

The `append` method is commonly used to add items to a list. The item that is passed as an argument is appended to the end of the list's existing elements. Program 7-3 shows an example.

[1] We do not cover all of the list methods in this book. For a description of all of the list methods, see the Python documentation at www.python.org.

Table 7-1 A few of the list methods

Method	Description
`append(item)`	Adds *item* to the end of the list.
`index(item)`	Returns the index of the first element whose value is equal to item. A `ValueError` exception is raised if item is not found in the list.
`insert(index, item)`	Inserts *item* into the list at the specified *index*. When an item is inserted into a list, the list is expanded in size to accommodate the new item. The item that was previously at the specified index, and all the items after it, are shifted by one position toward the end of the list. No exceptions will occur if you specify an invalid index. If you specify an index beyond the end of the list, the item will be added to the end of the list. If you use a negative index that specifies an invalid position, the item will be inserted at the beginning of the list.
`sort()`	Sorts the items in the list so they appear in ascending order (from the lowest value to the highest value).
`remove(item)`	Removes the first occurrence of *item* from the list. A `ValueError` exception is raised if item is not found in the list.
`reverse()`	Reverses the order of the items in the list.

Program 7-3 (list_append.py)

```python
# This program demonstrates how the append
# method can be used to add items to a list.

def main():
    # First, create an empty list.
    name_list = []

    # Create a variable to control the loop.
    again = 'y'

    # Add some names to the list.
    while again == 'y':
        # Get a name from the user.
        name = input('Enter a name: ')

        # Append the name to the list.
        name_list.append(name)

        # Add another one?
        print('Do you want to add another name?')
        again = input('y = yes, anything else = no: ')
        print()

```

```
24      # Display the names that were entered.
25      print('Here are the names you entered.')
26
27      for name in name_list:
28          print(name)
29
30  # Call the main function.
31  main()
```

Program Output (with input shown in bold)

```
Enter a name: Kathryn Enter
Do you want to add another name?
y = yes, anything else = no: y Enter

Enter a name: Chris Enter
Do you want to add another name?
y = yes, anything else = no: y Enter

Enter a name: Kenny Enter
Do you want to add another name?
y = yes, anything else = no: y Enter

Enter a name: Renee Enter
Do you want to add another name?
y = yes, anything else = no: n Enter

Here are the names you entered.
Kathryn
Chris
Kenny
Renee
```

Notice the statement in line 6:

```
name_list = []
```

This statement creates an empty list (a list with no elements) and assigns it to the `name_list` variable. Inside the loop, the `append` method is called to build the list. The first time the method is called, the argument passed to it will become element 0. The second time the method is called, the argument passed to it will become element 1. This continues until the user exits the loop.

The `index` Method

Earlier you saw how the `in` operator can be used to determine whether an item is in a list. Sometimes you need to know not only whether an item is in a list, but where it is located. The `index` method is useful in these cases. You pass an argument to the `index` method, and it returns the index of the first element in the list containing that item. If the item is not found in the list, the method raises a `ValueError` exception. Program 7-4 demonstrates the `index` method.

Program 7-4 (index_list.py)

```python
 1  # This program demonstrates how to get the
 2  # index of an item in a list and then replace
 3  # that item with a new item.
 4
 5  def main():
 6      # Create a list with some items.
 7      food = ['Pizza', 'Burgers', 'Chips']
 8
 9      # Display the list.
10      print('Here are the items in the food list:')
11      print(food)
12
13      # Get the item to change.
14      item = input('Which item should I change? ')
15
16      try:
17          # Get the item's index in the list.
18          item_index = food.index(item)
19
20          # Get the value to replace it with.
21          new_item = input('Enter the new value: ')
22
23          # Replace the old item with the new item.
24          food[item_index] = new_item
25
26          # Display the list.
27          print('Here is the revised list:')
28          print(food)
29      except ValueError:
30          print('That item was not found in the list.')
31
32  # Call the main function.
33  main()
```

Program Output (with input shown in bold)

```
Here are the items in the food list:
['Pizza', 'Burgers', 'Chips']
Which item should I change? Burgers Enter
Enter the new value: Pickles Enter
Here is the revised list:
['Pizza', 'Pickles', 'Chips']
```

The elements of the `food` list are displayed in line 11, and in line 14 the user is asked which item he or she wants to change. Line 18 calls the `index` method to get the index of the item.

Line 21 gets the new value from the user, and line 24 assigns the new value to the element holding the old value.

The `insert` Method

The `insert` method allows you to insert an item into a list at a specific position. You pass two arguments to the `insert` method: an index specifying where the item should be inserted and the item that you want to insert. Program 7-5 shows an example.

Program 7-5 (insert_list.py)

```
# This program demonstrates the insert method.

def main():
    # Create a list with some names.
    names = ['James', 'Kathryn', 'Bill']

    # Display the list.
    print('The list before the insert:')
    print(names)

    # Insert a new name at element 0.
    names.insert(0, 'Joe')

    # Display the list again.
    print('The list after the insert:')
    print(names)

# Call the main function.
main()
```

Program Output

```
The list before the insert:
['James', 'Kathryn', 'Bill']
The list after the insert:
['Joe', 'James', 'Kathryn', 'Bill']
```

The `sort` Method

The `sort` method rearranges the elements of a list so they appear in ascending order (from the lowest value to the highest value). Here is an example:

```
my_list = [9, 1, 0, 2, 8, 6, 7, 4, 5, 3]
print('Original order:', my_list)
my_list.sort()
print('Sorted order:', my_list)
```

When this code runs it will display the following:

```
Original order: [9, 1, 0, 2, 8, 6, 7, 4, 5, 3]
Sorted order: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

Here is another example:

```
my_list = ['beta', 'alpha', 'delta', 'gamma']
print('Original order:', my_list)
my_list.sort()
print('Sorted order:', my_list)
```

When this code runs it will display the following:

```
Original order: ['beta', 'alpha', 'delta', 'gamma']
Sorted order: ['alpha', 'beta', 'delta', 'gamma']
```

The `remove` Method

The `remove` method removes an item from the list. You pass an item to the method as an argument, and the first element containing that item is removed. This reduces the size of the list by one element. All of the elements after the removed element are shifted one position toward the beginning of the list. A `ValueError` exception is raised if the item is not found in the list. Program 7-6 demonstrates the method.

Program 7-6 (remove_item.py)

```
# This program demonstrates how to use the remove
# method to remove an item from a list.

def main():
    # Create a list with some items.
    food = ['Pizza', 'Burgers', 'Chips']

    # Display the list.
    print('Here are the items in the food list:')
    print(food)

    # Get the item to change.
    item = input('Which item should I remove? ')

    try:
        # Remove the item.
        food.remove(item)

        # Display the list.
        print('Here is the revised list:')
        print(food)

    except ValueError:
            print('That item was not found in the list.')

# Call the main function.
main()
```

Program Output (with input shown in bold)

```
Here are the items in the food list:
['Pizza', 'Burgers', 'Chips']
Which item should I remove? **Burgers** Enter
Here is the revised list:
['Pizza', 'Chips']
```

The `reverse` Method

The `reverse` method simply reverses the order of the items in the list. Here is an example:

```
my_list = [1, 2, 3, 4, 5]
print('Original order:', my_list)
my_list.reverse()
print('Reversed:', my_list)
```

This code will display the following:

```
Original order: [1, 2, 3, 4, 5]
Reversed: [5, 4, 3, 2, 1]
```

The `del` Statement

The `remove` method that you saw earlier removes a specific item from a list, if that item is in the list. Some situations might require that you remove an element from a specific index, regardless of the item that is stored at that index. This can be accomplished with the `del` statement. Here is an example of how to use the `del` statement:

```
my_list = [1, 2, 3, 4, 5]
print('Before deletion:', my_list)
del my_list[2]
print('After deletion:', my_list)
```

This code will display the following:

```
Before deletion: [1, 2, 3, 4, 5]
After deletion: [1, 2, 4, 5]
```

The `min` and `max` Functions

Python has two built-in functions named `min` and `max` that work with sequences. The `min` function accepts a sequence, such as a list, as an argument and returns the item that has the lowest value in the sequence. Here is an example:

```
my_list = [5, 4, 3, 2, 50, 40, 30]
print('The lowest value is', min(my_list))
```

This code will display the following:

```
The lowest value is 2
```

The `max` function accepts a sequence, such as a list, as an argument and returns the item that has the highest value in the sequence. Here is an example:

```
my_list = [5, 4, 3, 2, 50, 40, 30]
print('The highest value is', max(my_list))
```

This code will display the following:

```
The highest value is 50
```

Checkpoint

7.15 What is the difference between calling a list's `remove` method and using the `del` statement to remove an element?

7.16 How do you find the lowest and highest values in a list?

7.17 Assume the following statement appears in a program:

```
names = []
```

Which of the following statements would you use to add the string 'Wendy' to the list at index 0? Why would you select this statement instead of the other?

```
a. names[0] = 'Wendy'
b. names.append('Wendy')
```

7.18 Describe the following list methods:

```
a. index
b. insert
c. sort
d. reverse
```

7.6 Copying Lists

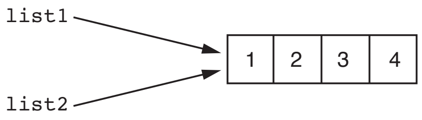
CONCEPT: To make a copy of a list, you must copy the list's elements.

Recall that in Python, assigning one variable to another variable simply makes both variables reference the same object in memory. For example, look at the following code:

```
# Create a list.
list1 = [1, 2, 3, 4]
# Assign the list to the list2 variable.
list2 = list1
```

After this code executes, both variables `list1` and `list2` will reference the same list in memory. This is shown in Figure 7-4.

Figure 7-4 `list1` and `list2` reference the same list



To demonstrate this, look at the following interactive session:

```
1   >>> list1 = [1, 2, 3, 4] Enter
2   >>> list2 = list1 Enter
3   >>> print(list1) Enter
4   [1, 2, 3, 4]
5   >>> print(list2) Enter
6   [1, 2, 3, 4]
7   >>> list1[0] = 99 Enter
8   >>> print(list1) Enter
9   [99, 2, 3, 4]
10  >>> print(list2) Enter
11  [99, 2, 3, 4]
12  >>>
```

Let's take a closer look at each line:

- In line 1 we create a list of integers and assign the list to the `list1` variable.
- In line 2 we assign `list1` to `list2`. After this, both `list1` and `list2` reference the same list in memory.
- In line 3 we print the list referenced by `list1`. The output of the `print` function is shown in line 4.
- In line 5 we print the list referenced by `list2`. The output of the `print` function is shown in line 6. Notice that it is the same as the output shown in line 4.
- In line 7 we change the value of `list[0]` to 99.
- In line 8 we print the list referenced by `list1`. The output of the `print` function is shown in line 9. Notice that the first element is now 99.
- In line 10 we print the list referenced by `list2`. The output of the `print` function is shown in line 11. Notice that the first element is 99.

In this interactive session, the `list1` and `list2` variables reference the same list in memory.

Suppose you wish to make a copy of the list, so that `list1` and `list2` reference two separate but identical lists. One way to do this is with a loop that copies each element of the list. Here is an example:

```
# Create a list with values.
list1 = [1, 2, 3, 4]
# Create an empty list.
list2 = []
# Copy the elements of list1 to list2.
for item in list1:
    list2.append(item)
```

After this code executes, `list1` and `list2` will reference two separate but identical lists. A simpler and more elegant way to accomplish the same task is to use the concatenation operator, as shown here:

```
# Create a list with values.
list1 = [1, 2, 3, 4]
# Create a copy of list1.
list2 = [] + list1
```

The last statement in this code concatenates an empty list with `list1` and assigns the resulting list to `list2`. As a result, `list1` and `list2` will reference two separate but identical lists.

7.7 Processing Lists

So far you've learned a wide variety of techniques for working with lists. Now we will look at a number of ways that programs can process the data held in a list. For example, the following *In the Spotlight* section shows how list elements can be used in calculations.

In the Spotlight:
Using List Elements in a Math Expression

Megan owns a small neighborhood coffee shop, and she has six employees who work as baristas (coffee bartenders). All of the employees have the same hourly pay rate. Megan has asked you to design a program that will allow her to enter the number of hours worked by each employee and then display the amounts of all the employees' gross pay. You determine that the program should perform the following steps:

1. For each employee: get the number of hours worked and store it in a list element.
2. For each list element: use the value stored in the element to calculate an employee's gross pay. Display the amount of the gross pay.

Program 7-7 shows the code for the program.

Program 7-7 (barista_pay.py)

```
# This program calculates the gross pay for
# each of Megan's baristas.

# NUM_EMPLOYEES is used as a constant for the
# size of the list.
NUM_EMPLOYEES = 6

```

```
 8  def main():
 9      # Create a list to hold employee hours.
10      hours = [0] * NUM_EMPLOYEES
11
12      # Get each employee's hours worked.
13      for index in range(NUM_EMPLOYEES):
14          print('Enter the hours worked by employee ', \
15                index + 1, ': ', sep='', end='')
16          hours[index] = float(input())
17
18      # Get the hourly pay rate.
19      pay_rate = float(input('Enter the hourly pay rate: '))
20
21      # Display each employee's gross pay.
22      for index in range(NUM_EMPLOYEES):
23          gross_pay = hours[index] * pay_rate
24          print('Gross pay for employee ', index + 1, ': $', \
25                format(gross_pay, ',.2f'), sep='')
26
27  # Call the main function.
28  main()
```

Program Output (with input shown in bold)

```
Enter the hours worked by employee 1: 10 Enter
Enter the hours worked by employee 2: 20 Enter
Enter the hours worked by employee 3: 15 Enter
Enter the hours worked by employee 4: 40 Enter
Enter the hours worked by employee 5: 20 Enter
Enter the hours worked by employee 6: 18 Enter
Enter the hourly pay rate: 12.75 Enter
Gross pay for employee 1: $127.50
Gross pay for employee 2: $255.00
Gross pay for employee 3: $191.25
Gross pay for employee 4: $510.00
Gross pay for employee 5: $255.00
Gross pay for employee 6: $229.50
```

NOTE: Suppose Megan's business increases and she hires two additional baristas. This would require you to change the program so it processes eight employees instead of six. Because you used a constant for the list size, this is a simple modification—you just change the statement in line 6 to read:

```
NUM_EMPLOYEES = 8
```

(continued)

Because the `NUM_EMPLOYEES` constant is used in line 10 to create the list, the size of the `hours` list will automatically become eight. Also, because you used the `NUM_EMPLOYEES` constant to control the loop iterations in lines 13 and 22, the loops will automatically iterate eight times, once for each employee.

Imagine how much more difficult this modification would be if you had not used a constant to determine the list size. You would have to change each individual statement in the program that refers to the list size. Not only would this require more work, but it would open the possibility for errors. If you overlooked any one of the statements that refer to the list size, a bug would occur.

Totaling the Values in a List

Assuming a list contains numeric values, to calculate the total of those values you use a loop with an accumulator variable. The loop steps through the list, adding the value of each element to the accumulator. Program 7-8 demonstrates the algorithm with a list named `numbers`.

Program 7-8 (total_list.py)

```
# This program calculates the total of the values
# in a list.

def main():
    # Create a list.
    numbers = [2, 4, 6, 8, 10]

    # Create a variable to use as an accumulator.
    total = 0

    # Calculate the total of the list elements.
    for value in numbers:
        total += value

    # Display the total of the list elements.
    print('The total of the elements is', total)

# Call the main function.
main()
```

Program Output

```
The total of the elements is 30
```

Averaging the Values in a List

The first step in calculating the average of the values in a list is to get the total of the values. You saw how to do that with a loop in the preceding section. The second step is to divide the total by the number of elements in the list. Program 7-9 demonstrates the algorithm.

Program 7-9 (average_list.py)

```
# This program calculates the average of the values
# in a list.

def main():
    # Create a list.
    scores = [2.5, 7.3, 6.5, 4.0, 5.2]

    # Create a variable to use as an accumulator.
    total = 0.0

    # Calculate the total of the list elements.
    for value in scores:
        total += value

    # Calculate the average of the elements.
    average = total / len(scores)

    # Display the total of the list elements.
    print('The average of the elements is', average)

# Call the main function.
main()
```

Program Output

```
The average of the elements is 5.3
```

Passing a List as an Argument to a Function

Recall from Chapter 5 that as a program grows larger and more complex, it should be broken down into functions that each performs a specific task. This makes the program easier to understand and to maintain.

You can easily pass a list as an argument to a function. This gives you the ability to put many of the operations that you perform on a list in their own functions. When you need to call these functions, you can pass the list as an argument.

Program 7-10 shows an example of a program that uses such a function. The function in this program accepts a list as an argument and returns the total of the list's elements.

Program 7-10 (total_function.py)

```
# This program uses a function to calculate the
# total of the values in a list.

def main():
    # Create a list.
    numbers = [2, 4, 6, 8, 10]

    # Display the total of the list elements.
    print('The total is', get_total(numbers))

# The get_total function accepts a list as an
# argument returns the total of the values in
# the list.
def get_total(value_list):
    # Create a variable to use as an accumulator.
    total = 0

    # Calculate the total of the list elements.
    for num in value_list:
        total += num

    # Return the total.
    return total

# Call the main function.
main()
```

Program Output

```
The total is 30
```

Returning a List from a Function

A function can return a reference to a list. This gives you the ability to write a function that creates a list and adds elements to it and then returns a reference to the list so other parts of the program can work with it. The code in Program 7-11 shows an example. It uses a function named `get_values` that gets a series of values from the user, stores them in a list, and then returns a reference to the list.

Program 7-11 (return_list.py)

```
# This program uses a function to create a list.
# The function returns a reference to the list.

```

```python
def main():
    # Get a list with values stored in it.
    numbers = get_values()

    # Display the values in the list.
    print('The numbers in the list are:')
    print(numbers)

# The get_values function gets a series of numbers
# from the user and stores them in a list. The
# function returns a reference to the list.
def get_values():
    # Create an empty list.
    values = []

    # Create a variable to control the loop.
    again = 'y'

    # Get values from the user and add them to
    # the list.
    while again == 'y':
        # Get a number and add it to the list.
        num = int(input('Enter a number: '))
        values.append(num)

        # Want to do this again?
        print('Do you want to add another number?')
        again = input('y = yes, anything else = no: ')
        print()

    # Return the list.
    return values

# Call the main function.
main()
```

Program Output (with input shown in bold)

```
Enter a number: 1 Enter
Do you want to add another number?
y = yes, anything else = no: y Enter

Enter a number: 2 Enter
Do you want to add another number?
y = yes, anything else = no: y Enter

Enter a number: 3 Enter
Do you want to add another number?
y = yes, anything else = no: y Enter
```

(program output continues)

Program Output *(continued)*

```
Enter a number: 4 Enter
Do you want to add another number?
y = yes, anything else = no: y Enter

Enter a number: 5 Enter
Do you want to add another number?
y = yes, anything else = no: n Enter
The numbers in the list are:
[1, 2, 3, 4, 5]
```

In the Spotlight:

Processing a List

Dr. LaClaire gives a series of exams during the semester in her chemistry class. At the end of the semester she drops each student's lowest test score before averaging the scores. She has asked you to design a program that will read a student's test scores as input and calculate the average with the lowest score dropped. Here is the algorithm that you developed:

```
Get the student's test scores.
Calculate the total of the scores.
Find the lowest score.
Subtract the lowest score from the total. This gives the adjusted total.
Divide the adjusted total by 1 less than the number of test scores. This is the average.
Display the average.
```

Program 7-12 shows the code for the program, which is divided into three functions. Rather than presenting the entire program at once, let's first examine the `main` function and then each additional function separately. Here is the `main` function:

Program 7-12 drop_lowest_score.py: `main` function

```python
# This program gets a series of test scores and
# calculates the average of the scores with the
# lowest score dropped.

def main():
    # Get the test scores from the user.
    scores = get_scores()

    # Get the total of the test scores.
    total = get_total(scores)

    # Get the lowest test score.
```

```
13      lowest = min(scores)
14
15      # Subtract the lowest score from the total.
16      total -= lowest
17
18      # Calculate the average. Note that we divide
19      # by 1 less than the number of scores because
20      # the lowest score was dropped.
21      average = total / (len(scores) - 1)
22
23      # Display the average.
24      print('The average, with the lowest score dropped', \
25            'is:', average)
26
```

Line 7 calls the `get_scores` function. The function gets the test scores from the user and returns a reference to a list containing those scores. The list is assigned to the scores variable.

Line 10 calls the `get_total` function, passing the `scores` list as an argument. The function returns the total of the values in the list. This value is assigned to the `total` variable.

Line 13 calls the built-in `min` function, passing the `scores` list as an argument. The function returns the lowest value in the list. This value is assigned to the `lowest` variable.

Line 16 subtracts the lowest test score from the `total` variable. Then, line 21 calculates the average by dividing `total` by `len(scores)` − 1. (The program divides by `len (scores)` − 1 because the lowest test score was dropped.) Lines 24 and 25 display the average.

Next is the `get_scores` function.

Program 7-12 drop_lowest_score.py: get_scores function

```
27  # The get_scores function gets a series of test
28  # scores from the user and stores them in a list.
29  # A reference to the list is returned.
30  def get_scores():
31      # Create an empty list.
32      test_scores = []
33
34      # Create a variable to control the loop.
35      again = 'y'
36
37      # Get the scores from the user and add them to
38      # the list.
39      while again == 'y':
40          # Get a score and add it to the list.
```

(program continues)

Program 7-12 *(continued)*

```
41          value = float(input('Enter a test score: '))
42          test_scores.append(value)
43
44          # Want to do this again?
45          print('Do you want to add another score?')
46          again = input('y = yes, anything else = no: ')
47          print()
48
49      # Return the list.
50      return test_scores
51
```

The `get_scores` function prompts the user to enter a series of test scores. As each score is entered it is appended to a list. The list is returned in line 50. Next is the `get_total` function.

Program 7-12 drop_lowest_score.py: get_total function

```
52  # The get_total function accepts a list as an
53  # argument returns the total of the values in
54  # the list.
55  def get_total(value_list):
56      # Create a variable to use as an accumulator.
57      total = 0.0
58
59      # Calculate the total of the list elements.
60      for num in value_list:
61          total += num
62
63      # Return the total.
64      return total
65
66  # Call the main function.
67  main()
```

This function accepts a list as an argument. It uses an accumulator and a loop to calculate the total of the values in the list. Line 64 returns the total.

Program Output (with input shown in bold)

```
Enter a test score: 92 Enter
Do you want to add another score?
Y = yes, anything else = no: y Enter

Enter a test score: 67 Enter
Do you want to add another score?
Y = yes, anything else = no: y Enter
```

```
Enter a test score: 75 Enter
Do you want to add another score?
Y = yes, anything else = no: y Enter

Enter a test score: 88 Enter
Do you want to add another score?
Y = yes, anything else = no: n Enter

The average, with the lowest score dropped is: 85.0
```

Working with Lists and Files

Some tasks may require you to save the contents of a list to a file so the data can be used at a later time. Likewise, some situations may require you to read the data from a file into a list. For example, suppose you have a file that contains a set of values that appear in random order and you want to sort the values. One technique for sorting the values in the file would be to read them into a list, call the list's `sort` method, and then write the values in the list back to the file.

Saving the contents of a list to a file is a straightforward procedure. In fact, Python file objects have a method named `writelines` that writes an entire list to a file. A drawback to the `writelines` method, however, is that it does not automatically write a newline (`'\n'`) at the end of each item. Consequently, each item is written to one long line in the file. Program 7-13 demonstrates the method.

Program 7-13 (writelines.py)

```python
# This program uses the writelines method to save
# a list of strings to a file.

def main():
    # Create a list of strings.
    cities = ['New York', 'Boston', 'Atlanta', 'Dallas']

    # Open a file for writing.
    outfile = open('cities.txt', 'w')

    # Write the list to the file.
    outfile.writelines(cities)

    # Close the file.
    outfile.close()

# Call the main function.
main()
```

After this program executes, the `cities.txt` file will contain the following line:

```
New YorkBostonAtlantaDallas
```

An alternative approach is to use the `for` loop to iterate through the list, writing each element with a terminating newline character. Program 7-14 shows an example.

Program 7-14 (write_list.py)

```python
# This program saves a list of strings to a file.

def main():
    # Create a list of strings.
    cities = ['New York', 'Boston', 'Atlanta', 'Dallas']

    # Open a file for writing.
    outfile = open('cities.txt', 'w')

    # Write the list to the file.
    for item in cities:
        outfile.write(item + '\n')

    # Close the file.
    outfile.close()

# Call the main function.
main()
```

After this program executes, the `cities.txt` file will contain the following lines:

```
New York
Boston
Atlanta
Dallas
```

File objects in Python have a method named `readlines` that returns a file's contents as a list of strings. Each line in the file will be an item in the list. The items in the list will include their terminating newline character, which in many cases you will want to strip. Program 7-15 shows an example. The statement in line 8 reads the files contents into a list, and the loop in lines 15 through 17 steps through the list, stripping the `'\n'` character from each element.

Program 7-15 (read_list.py)

```
1  # This program reads a file's contents into a list.
2
3  def main():
4      # Open a file for reading.
```

```
    infile = open('cities.txt', 'r')

    # Read the contents of the file into a list.
    cities = infile.readlines()

    # Close the file.
    infile.close()

    # Strip the \n from each element.
    index = 0
    while index < len(cities):
        cities[index] = cities[index].rstrip('\n')
        index += 1

    # Print the contents of the list.
    print(cities)

# Call the main function.
main()
```

Program Output

```
['New York', 'Boston', 'Atlanta', 'Dallas']
```

Program 7-16 shows another example of how a list can be written to a file. In this example, a list of numbers is written. Notice that in line 12, each item is converted to a string with the `str` function, and then a `'\n'` is concatenated to it.

Program 7-16 (write_number_list.py)

```
 1  # This program saves a list of numbers to a file.
 2
 3  def main():
 4      # Create a list of numbers.
 5      numbers = [1, 2, 3, 4, 5, 6, 7]
 6
 7      # Open a file for writing.
 8      outfile = open('numberlist.txt', 'w')
 9
10      # Write the list to the file.
11      for item in numbers:
12          outfile.write(str(item) + '\n')
13
14      # Close the file.
15      outfile.close()
16
17  # Call the main function.
18  main()
```

When you read numbers from a file into a list, the numbers will have to be converted from strings to a numeric type. Program 7-17 shows an example.

Program 7-17 (read_number_list.py)

```
# This program reads numbers from a file into a list.

def main():
    # Open a file for reading.
    infile = open('numberlist.txt', 'r')

    # Read the contents of the file into a list.
    numbers = infile.readlines()

    # Close the file.
    infile.close()

    # Convert each element to an int.
    index = 0
    while index < len(numbers):
        numbers[index] = int(numbers[index])
        index += 1

    # Print the contents of the list.
    print(numbers)

# Call the main function.
main()
```

Program Output

```
[1, 2, 3, 4, 5, 6, 7]
```

7.8 Two-Dimensional Lists

CONCEPT: A two-dimensional list is a list that has other lists as its elements.

The elements of a list can be virtually anything, including other lists. To demonstrate, look at the following interactive session:

```
>>> students = [['Joe', 'Kim'], ['Sam', 'Sue'], ['Kelly', 'Chris']] Enter
>>> print(students) Enter
[['Joe', 'Kim'], ['Sam', 'Sue'], ['Kelly', 'Chris']]
>>> print(students[0]) Enter
['Joe', 'Kim']
>>> print(students[1]) Enter
```

```
 7  ['Sam', 'Sue']
 8  >>> print(students[2]) Enter
 9  ['Kelly', 'Chris']
10  >>>
```

Let's take a closer look at each line.

- Line 1 creates a list and assigns it to the `students` variable. The list has three elements, and each element is also a list. The element at `students[0]` is

  `['Joe', 'Kim']`

  The element at `students[1]` is

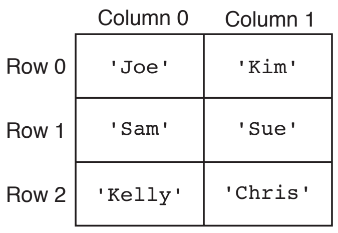
  `['Sam', 'Sue']`

  The element at `students[2]` is

  `['Kelly', 'Chris']`
- Line 2 prints the entire `students` list. The output of the `print` function is shown in line 3.
- Line 4 prints the `students[0]` element. The output of the `print` function is shown in line 5.
- Line 6 prints the `students[1]` element. The output of the `print` function is shown in line 7.
- Line 8 prints the `students[2]` element. The output of the `print` function is shown in line 9.

Lists of lists are also known as *nested lists,* or *two-dimensional lists*. It is common to think of a two-dimensional list as having rows and columns of elements, as shown in Figure 7-5. This figure shows the two-dimensional list that was created in the previous interactive session as having three rows and two columns. Notice that the rows are numbered 0, 1, and 2, and the columns are numbered 0 and 1. There is a total of six elements in the list.

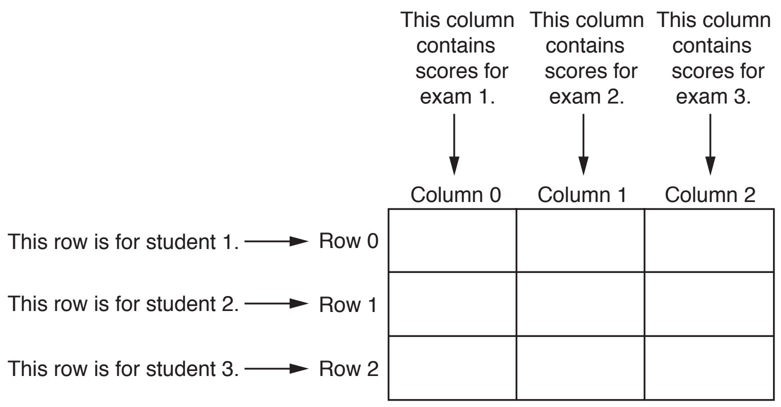
Figure 7-5 A two-dimensional list



	Column 0	Column 1
Row 0	'Joe'	'Kim'
Row 1	'Sam'	'Sue'
Row 2	'Kelly'	'Chris'

Two-dimensional lists are useful for working with multiple sets of data. For example, suppose you are writing a grade-averaging program for a teacher. The teacher has three students, and each student takes three exams during the semester. One approach would be to create three separate lists, one for each student. Each of these lists would have three elements, one for each exam score. This approach would be cumbersome, however, because you would have to separately process each of the lists. A better approach would be to use a two-dimensional list with three rows (one for each student) and three columns (one for each exam score), as shown in Figure 7-6.

Figure 7-6 Two-dimensional list with three rows and three columns


This column contains scores for exam 1.
This column contains scores for exam 2.
This column contains scores for exam 3.
Column 0
Column 1
Column 2
This row is for student 1.
Row 0
This row is for student 2.
Row 1
This row is for student 3.
Row 2

When processing the data in a two-dimensional list, you need two subscripts: one for the rows and one for the columns. For example, suppose we create a two-dimensional list with the following statement:

```
scores = [[0, 0, 0],
          [0, 0, 0],
          [0, 0, 0]]
```

The elements in row 0 are referenced as follows:

```
scores[0][0]
scores[0][1]
scores[0][2]
```

The elements in row 1 are referenced as follows:

```
scores[1][0]
scores[1][1]
scores[1][2]
```

And, the elements in row 2 are referenced as follows:

```
scores[2][0]
scores[2][1]
scores[2][2]
```

Figure 7-7 illustrates the two-dimensional list, with the subscripts shown for each element.

Figure 7-7 Subscripts for each element of the `scores` list

	Column 0	Column 1	Column 2
Row 0	scores[0][0]	scores[0][1]	scores[0][2]
Row 1	scores[1][0]	scores[1][1]	scores[1][2]
Row 2	scores[2][0]	scores[2][1]	scores[2][2]

Programs that process two-dimensional lists typically do so with nested loops. Let's look at an example. Program 7-18 creates a two-dimensional list and assigns random numbers to each of its elements.

Program 7-18 (random_numbers.py)

```
 1  # This program assigns random numbers to
 2  # a two-dimensional list.
 3  import random
 4
 5  # Constants for rows and columns
 6  ROWS = 3
 7  COLS = 4
 8
 9  def main():
10      # Create a two-dimensional list.
11      values = [[0, 0, 0, 0],
12                [0, 0, 0, 0],
13                [0, 0, 0, 0]]
14
15      # Fill the list with random numbers.
16      for r in range(ROWS):
17          for c in range(COLS):
18              values[r][c] = random.randint(1, 100)
19
20      # Display the random numbers.
21      print(values)
22
23  # Call the main function.
24  main()
```

Program Output

```
[[4, 17, 34, 24], [46, 21, 54, 10], [54, 92, 20, 100]]
```

Let's take a closer look at the program:

- Lines 6 and 7 create global constants for the number of rows and columns.
- Lines 11 through 13 create a two-dimensional list and assign it to the `values` variable. We can think of the list as having three rows and four columns. Each element is assigned the value 0.
- Lines 16 through 18 are a set of nested `for` loops. The outer loop iterates once for each row, and it assigns the variable `r` the values 0 through 2. The inner loop iterates once for each column, and it assigns the variable `c` the values 0 through 3. The statement in line 18 executes once for each element of the list, assigning it a random integer in the range of 1 through 100.
- Line 21 displays the list's contents.

Notice that the statement in line 21 passes the `values` list as an argument to the `print` function; as a result, the entire list is displayed on the screen. Suppose we do not like the way that the `print` function displays the list enclosed in brackets, with each nested list also enclosed in brackets. For example, suppose we want to display each list element on a line by itself, like this:

```
4
17
34
24
46
```
and so forth.

To accomplish that we can write a set of nested loops, such as

```
for r in range(ROWS):
    for c in range(COLS):
        print(values[r][c])
```

Checkpoint

7.19 Look at the following interactive session, in which a two-dimensional list is created. How many rows and how many columns are in the list?

```
numbers = [[1, 2], [10, 20], [100, 200], [1000, 2000]]
```

7.20 Write a statement that creates a two-dimensional list with three rows and four columns. Each element should be assigned the value 0.

7.21 Write a set of nested loops that display the contents of the `numbers` list shown in Checkpoint question 7.19.

7.9 Tuples

CONCEPT: A tuple is an immutable sequence, which means that its contents cannot be changed.

A *tuple* is a sequence, very much like a list. The primary difference between tuples and lists is that tuples are immutable. That means that once a tuple is created, it cannot be changed. When you create a tuple, you enclose its elements in a set of parentheses, as shown in the following interactive session:

```
>>> my_tuple = (1, 2, 3, 4, 5) Enter
>>> print(my_tuple) Enter
(1, 2, 3, 4, 5)
>>>
```

The first statement creates a tuple containing the elements 1, 2, 3, 4, and 5 and assigns it to the variable `my_tuple`. The second statement sends `my_tuple` as an argument to the `print` function, which displays its elements. The following session shows how a `for` loop can iterate over the elements in a tuple:

```
>>> names = ('Holly', 'Warren', 'Ashley') Enter
>>> for n in names: Enter
        print(n) Enter Enter
Holly
Warren
Ashley
>>>
```

Like lists, tuples support indexing, as shown in the following session:

```
>>> names = ('Holly', 'Warren', 'Ashley') Enter
>>> for i in range(len(names)): Enter
        print(names[i]) Enter Enter

Holly
Warren
Ashley
>>>
```

In fact, tuples support all the same operations as lists, except those that change the contents of the list. Tuples support the following:

- Subscript indexing (for retrieving element values only)
- Methods such as `index`
- Built-in functions such as `len`, `min`, and `max`
- Slicing expressions
- The `in` operator
- The `+` and `*` operators

Tuples do not support methods such as `append`, `remove`, `insert`, `reverse`, and `sort`.

NOTE: If you want to create a tuple with just one element, you must write a trailing comma after the element's value, as shown here:

```
my_tuple = (1,)    # Creates a tuple with one element.
```

If you omit the comma, you will not create a tuple. For example, the following statement simply assigns the integer value 1 to the `value` variable:

```
value = (1)        # Creates an integer.
```

What's the Point?

If the only difference between lists and tuples is immutability, you might wonder why tuples exist. One reason that tuples exist is performance. Processing a tuple is faster than processing a list, so tuples are good choices when you are processing lots of data and that data will not be modified. Another reason is that tuples are safe. Because you are not allowed to change the contents of a tuple, you can store data in one and rest assured that it will not be modified (accidentally or otherwise) by any code in your program.

Additionally, there are certain operations in Python that require the use of a tuple. As you learn more about Python, you will encounter tuples more frequently.

Converting Between Lists and Tuples

You can use the built-in `list()` function to convert a tuple to a list and the built-in `tuple()` function to convert a list to a tuple. The following interactive session demonstrates:

```
1  >>> number_tuple = (1, 2, 3) Enter
2  >>> number_list = list(number_tuple) Enter
3  >>> print(number_list) Enter
4  [1, 2, 3]
5  >>> str_list = ['one', 'two', 'three'] Enter
6  >>> str_tuple = tuple(str_list) Enter
7  >>> print(str_tuple) Enter
8  ('one', 'two', 'three')
9  >>>
```

Here's a summary of the statements:

- Line 1 creates a tuple and assigns it to the `number_tuple` variable.
- Line 2 passes `number_tuple` to the `list()` function. The function returns a list containing the same values as `number_tuple`, and it is assigned to the `number_list` variable.
- Line 3 passes `number_list` to the `print` function. The function's output is shown in line 4.
- Line 5 creates a list of strings and assigns it to the `str_list` variable.
- Line 6 passes `str_list` to the `tuple()` function. The function returns a tuple containing the same values as `str_list`, and it is assigned to `str_tuple`.
- Line 7 passes `str_tuple` to the `print` function. The function's output is shown in line 8.

Checkpoint

7.22 What is the primary difference between a list and a tuple?

7.23 Give two reasons why tuples exist.

7.24 Assume that `my_list` references a list. Write a statement that converts it to a tuple.

7.25 Assume that `my_tuple` references a tuple. Write a statement that converts it to a list.

Review Questions

Multiple Choice

1. This term refers to an individual item in a list.
   a. element
   b. bin
   c. cubbyhole
   d. slot
2. This is a number that identifies an item in a list.
   a. element
   b. index
   c. bookmark
   d. identifier
3. In Python, lists are
   a. mutable data structures
   b. static data structures
   c. dynamic data structures
   d. Both a. and c.
4. This is the last index in a list.
   a. 1
   b. 99
   c. 0
   d. The size of the list minus one
5. This will happen if you try to use an index that is out of range for a list.
   a. A `ValueError` exception will occur.
   b. An `IndexError` exception will occur.
   c. The list will be erased and the program will continue to run.
   d. Nothing—the invalid index will be ignored.
6. This built-in function returns the highest value in a list.
   a. `minimumOf()`
   b. `minimum()`
   c. `min()`
   d. `least()`
7. When the `*` operator's left operand is a list and its right operand is an integer, the operator becomes this.
   a. The multiplication operator
   b. The repetition operator
   c. The initialization operator
   d. Nothing—the operator does not support those types of operands.

8. This list method adds an item to the end of an existing list.
   a. `add`
   b. `add_to`
   c. `increase`
   d. `append`
9. Which of the following is not a property of tuples?
   a. Tuples are immutable data structures
   b. Tuples do not support functions like `len`, `min`, `max`
   c. Tuples can be accessed just like lists
   d. Processing tuples is faster than lists
10. Assume the following statement appears in a program:

    ```
    mylist = []
    ```

    Which of the following statements would you use to add the string `'Labrador'` to the list at index 0?
    a. `mylist[0] = 'Labrador'`
    b. `mylist.insert(0, 'Labrador')`
    c. `mylist.append('Labrador')`
    d. `mylist.insert('Labrador', 0)`
11. If you call the `index` method to locate an item in a list and the item is not found, this happens.
    a. A `ValueError` exception is raised.
    b. An `InvalidIndex` exception is raised.
    c. The method returns –1.
    d. Nothing happens. The program continues running at the next statement.
12. The method used to write an entire list to a file is known as
    a. `writelines`
    b. `writeline`
    c. `writelists`
    d. `writelist`
13. This file object method returns a list containing the file's contents.
    a. `to_list`
    b. `getlist`
    c. `readline`
    d. `readlines`
14. Which of the following statements creates a tuple?
    a. `values = [1, 2, 3, 4]`
    b. `values = {1, 2, 3, 4}`
    c. `values = (1)`
    d. `values = (1,)`

True or False

1. Lists in Python are immutable.
2. Tuples in Python are immutable.
3. The `del` statement deletes an item at a specified index in a list.
4. Assume `list1` references a list. After the following statement executes, `list1` and `list2` will reference two identical but separate lists in memory:

   ```
   list2 = list1
   ```
5. A file object's `writelines` method automatically writes a newline `('\n')` after writing each list item to the file.
6. Invalid indexes in slicing expressions can produce an 'out of bound' exception.
7. A list can be an element in another list.
8. In Python, the index of the first element of the list is 1.

Short Answer

1. What will the following code display?

   ```
   list1 = [4, 9, 6, 3, 8, 7, 5]
   print(list1[-2:6])
   ```
2. What does the following code display?

   ```
   list1 = ['text']*2
   list1 = list1+['end']
   print(list1)
   ```
3. Find the error in the following code:

   ```
   names = ('Alice','Bob','Melanie',’George’)
   names[2] = 'Melanie'
   print(names)
   ```
4. What will the following function return?

   ```
   list1 = [1, 2, 3]
   list1 = list1.append (list1)
   print(list1)
   ```
5. What does the following code display?

   ```
   numbers = [1, 2, 3, 4, 5, 6, 7, 8]
   print(numbers[-4:])
   ```
6. What does the following code display?

   ```
   values = [2] * 5
   print(values)
   ```

Algorithm Workbench

1. Write a statement that will print the first letter of each element of the following list: `list1 = ['Galileo','Oliver','Ostwald','Descartes'].`
2. Write a function that accepts a list as an argument and calculates the sum of each element of the list.
3. Assume the list `numbers1` has 100 elements and `numbers2` is an empty list. Write code that copies the values in `numbers1` to `numbers2`.
4. Draw a flowchart showing the general logic for totaling the values in a list.
5. Write a function that accepts a list as an argument (assume the list contains integers) and returns the total of the values in the list.
6. Assume the `names` variable references a list of strings. Write code that determines whether `'Ruby'` is in the names list. If it is, display the message `'Hello Ruby'`. Otherwise, display the message `'No Ruby'`.
7. What will the following code print?

```
list1 = [40, 50, 60]
list2 = [10, 20, 30]
list3 = list1 + list2
print(list3)
```

8. Write a statement that creates a two-dimensional list with 5 rows and 3 columns. Then write nested loops that get an integer value from the user for each element in the list.

Programming Exercises

1. Total Sales

Design a program that asks the user to enter a store's sales for each day of the week. The amounts should be stored in a list. Use a loop to calculate the total sales for the week and display the result.

2. Lottery Number Generator

VideoNote
The Lottery Number Generator Problem

Design a program that generates a seven-digit lottery number. The program should generate seven random numbers, each in the range of 0 through 9, and assign each number to a list element. (Random numbers were discussed in Chapter 5.) Then write another loop that displays the contents of the list.

3. Rainfall Statistics

Design a program that lets the user enter the total rainfall for each of 12 months into a list. The program should calculate and display the total rainfall for the year, the average monthly rainfall, and the months with the highest and lowest amounts.

4. Number Analysis Program

Design a program that asks the user to enter a series of 20 numbers. The program should store the numbers in a list and then display the following data:

- The lowest number in the list
- The highest number in the list
- The total of the numbers in the list
- The average of the numbers in the list

5. Charge Account Validation

If you have downloaded the source code from this book's companion Web site, you will find a file named `charge_accounts.txt` in the *Chapter 07* folder. This file has a list of a company's valid charge account numbers. Each account number is a seven-digit number, such as `5658845`.

Write a program that reads the contents of the file into a list. The program should then ask the user to enter a charge account number. The program should determine whether the number is valid by searching for it in the list. If the number is in the list, the program should display a message indicating the number is valid. If the number is not in the list, the program should display a message indicating the number is invalid.

(You can access the book's companion Web site at www.pearsonglobaleditions.com/gaddis.)

6. Larger Than *n*

In a program, write a function that accepts two arguments: a list, and a number *n*. Assume that the list contains numbers. The function should display all of the numbers in the list that are greater than the number *n*.

7. Driver's License Exam

The local driver's license office has asked you to create an application that grades the written portion of the driver's license exam. The exam has 20 multiple-choice questions. Here are the correct answers:

1. A	6. B	11. A	16. C
2. C	7. C	12. D	17. B
3. A	8. A	13. C	18. B
4. A	9. C	14. A	19. D
5. D	10. B	15. D	20. A

Your program should store these correct answers in a list. The program should read the student's answers for each of the 20 questions from a text file and store the answers in another list. (Create your own text file to test the application.) After the student's answers have been read from the file, the program should display a message indicating whether the student passed or failed the exam. (A student must correctly answer 15 of the 20 questions to pass the exam.) It should then display the total number of correctly answered questions, the total number of incorrectly answered questions, and a list showing the question numbers of the incorrectly answered questions.

8. Name Search

If you have downloaded the source code from this book's companion Web site, you will find the following files in the *Chapter 07* folder:

- GirlNames.txt—This file contains a list of the 200 most popular names given to girls born in the United States from the year 2000 through 2009.
- BoyNames.txt—This file contains a list of the 200 most popular names given to boys born in the United States from the year 2000 through 2009.

Write a program that reads the contents of the two files into two separate lists. The user should be able to enter a boy's name, a girl's name, or both, and the application will display messages indicating whether the names were among the most popular.

(You can access the book's companion Web site at www.pearsonglobaleditions.com/gaddis.)

9. Population Data

If you have downloaded the source code from this book's companion Web site, you will find a file named USPopulation.txt in the *Chapter 07* folder. The file contains the midyear population of the United States, in thousands, during the years 1950 through 1990. The first line in the file contains the population for 1950, the second line contains the population for 1951, and so forth.

Write a program that reads the file's contents into a list. The program should display the following data:

- The average annual change in population during the time period
- The year with the greatest increase in population during the time period
- The year with the smallest increase in population during the time period

(You can access the book's companion Web site at www.pearsonglobaleditions.com/gaddis.)

10. World Series Champions

If you have downloaded the source code from this book's companion Web site, you will find a file named WorldSeriesWinners.txt in the *Chapter 07* folder. This file contains a chronological list of the World Series winning teams from 1903 through 2009. (The first line in the file is the name of the team that won in 1903, and the last line is the name of the team that won in 2009. Note that the World Series was not played in 1904 or 1994.)

Write a program that lets the user enter the name of a team and then displays the number of times that team has won the World Series in the time period from 1903 through 2009.

(You can access the book's companion Web site at www.pearsonglobaleditions.com/gaddis.)

TIP: Read the contents of the WorldSeriesWinners.txt file into a list. When the user enters the name of a team, the program should step through the list, counting the number of times the selected team appears.

11. Lo Shu Magic Square

The Lo Shu Magic Square is a grid with 3 rows and 3 columns, shown in Figure 7-8. The Lo Shu Magic Square has the following properties:

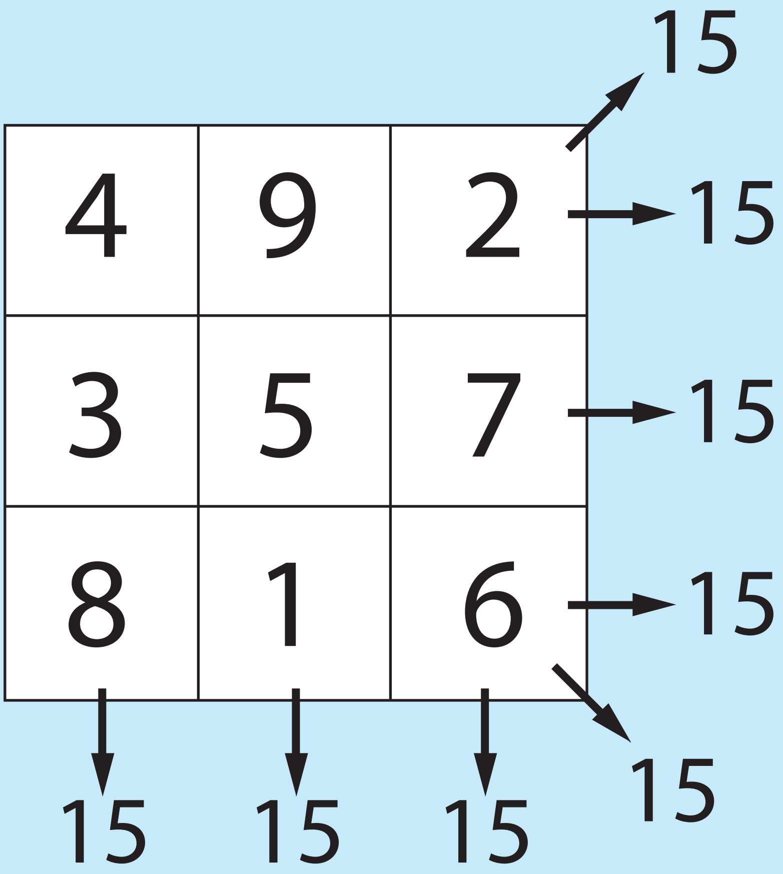
- The grid contains the numbers 1 through 9 exactly.
- The sum of each row, each column, and each diagonal all add up to the same number. This is shown in Figure 7-9.

In a program you can simulate a magic square using a two-dimensional list. Write a function that accepts a two-dimensional list as an argument and determines whether the list is a Lo Shu Magic Square. Test the function in a program.

Figure 7-8 The Lo Shu Magic Square

4	9	2
3	5	7
8	1	6

Figure 7-9 The sum of the rows, columns, and diagonals


15
4
9
2
15
3
5
7
15
8
1
6
15
15
15
15
15