

# Chapter 8

## Lists

### 8.1 A list is a sequence

Like a string, a *list* is a sequence of values. In a string, the values are characters; in a list, they can be any type. The values in list are called *elements* or sometimes *items*.

There are several ways to create a new list; the simplest is to enclose the elements in square brackets (“[” and “]”):

```
[10, 20, 30, 40]
['crunchy frog', 'ram bladder', 'lark vomit']
```

The first example is a list of four integers. The second is a list of three strings. The elements of a list don’t have to be the same type. The following list contains a string, a float, an integer, and (lo!) another list:

```
['spam', 2.0, 5, [10, 20]]
```

A list within another list is *nested*.

A list that contains no elements is called an empty list; you can create one with empty brackets, [].

As you might expect, you can assign list values to variables:

```
>>> cheeses = ['Cheddar', 'Edam', 'Gouda']
>>> numbers = [17, 123]
>>> empty = []
>>> print(cheeses, numbers, empty)
['Cheddar', 'Edam', 'Gouda'] [17, 123] []
```

## 8.2 Lists are mutable

The syntax for accessing the elements of a list is the same as for accessing the characters of a string: the bracket operator. The expression inside the brackets specifies the index. Remember that the indices start at 0:

```
>>> print(cheeses[0])
Cheddar
```

Unlike strings, lists are mutable because you can change the order of items in a list or reassign an item in a list. When the bracket operator appears on the left side of an assignment, it identifies the element of the list that will be assigned.

```
>>> numbers = [17, 123]
>>> numbers[1] = 5
>>> print(numbers)
[17, 5]
```

The one-th element of `numbers`, which used to be 123, is now 5.

You can think of a list as a relationship between indices and elements. This relationship is called a *mapping*; each index “maps to” one of the elements.

List indices work the same way as string indices:

- Any integer expression can be used as an index.
- If you try to read or write an element that does not exist, you get an `IndexError`.
- If an index has a negative value, it counts backward from the end of the list.

The `in` operator also works on lists.

```
>>> cheeses = ['Cheddar', 'Edam', 'Gouda']
>>> 'Edam' in cheeses
True
>>> 'Brie' in cheeses
False
```

## 8.3 Traversing a list

The most common way to traverse the elements of a list is with a `for` loop. The syntax is the same as for strings:

```
for cheese in cheeses:
    print(cheese)
```

This works well if you only need to read the elements of the list. But if you want to write or update the elements, you need the indices. A common way to do that is to combine the functions `range` and `len`:

```
for i in range(len(numbers)):
    numbers[i] = numbers[i] * 2
```

This loop traverses the list and updates each element. `len` returns the number of elements in the list. `range` returns a list of indices from 0 to  $n - 1$ , where  $n$  is the length of the list. Each time through the loop, `i` gets the index of the next element. The assignment statement in the body uses `i` to read the old value of the element and to assign the new value.

A `for` loop over an empty list never executes the body:

```
for x in empty:
    print('This never happens.')
```

Although a list can contain another list, the nested list still counts as a single element. The length of this list is four:

```
['spam', 1, ['Brie', 'Roquefort', 'Pol le Veq'], [1, 2, 3]]
```

## 8.4 List operations

The `+` operator concatenates lists:

```
>>> a = [1, 2, 3]
>>> b = [4, 5, 6]
>>> c = a + b
>>> print(c)
[1, 2, 3, 4, 5, 6]
```

Similarly, the `*` operator repeats a list a given number of times:

```
>>> [0] * 4
[0, 0, 0, 0]
>>> [1, 2, 3] * 3
[1, 2, 3, 1, 2, 3, 1, 2, 3]
```

The first example repeats four times. The second example repeats the list three times.

## 8.5 List slices

The slice operator also works on lists:

```
>>> t = ['a', 'b', 'c', 'd', 'e', 'f']
>>> t[1:3]
['b', 'c']
>>> t[:4]
['a', 'b', 'c', 'd']
>>> t[3:]
['d', 'e', 'f']
```

If you omit the first index, the slice starts at the beginning. If you omit the second, the slice goes to the end. So if you omit both, the slice is a copy of the whole list.

```
>>> t[:]
['a', 'b', 'c', 'd', 'e', 'f']
```

Since lists are mutable, it is often useful to make a copy before performing operations that fold, spindle, or mutilate lists.

A slice operator on the left side of an assignment can update multiple elements:

```
>>> t = ['a', 'b', 'c', 'd', 'e', 'f']
>>> t[1:3] = ['x', 'y']
>>> print(t)
['a', 'x', 'y', 'd', 'e', 'f']
```

## 8.6 List methods

Python provides methods that operate on lists. For example, `append` adds a new element to the end of a list:

```
>>> t = ['a', 'b', 'c']
>>> t.append('d')
>>> print(t)
['a', 'b', 'c', 'd']
```

`extend` takes a list as an argument and appends all of the elements:

```
>>> t1 = ['a', 'b', 'c']
>>> t2 = ['d', 'e']
>>> t1.extend(t2)
>>> print(t1)
['a', 'b', 'c', 'd', 'e']
```

This example leaves `t2` unmodified.

`sort` arranges the elements of the list from low to high:

## 8.11 Objects and values

If we execute these assignment statements:

```
a = 'banana'
b = 'banana'
```

we know that `a` and `b` both refer to a string, but we don't know whether they refer to the *same* string. There are two possible states:



Figure 8.1: Variables and Objects

In one case, `a` and `b` refer to two different objects that have the same value. In the second case, they refer to the same object.

To check whether two variables refer to the same object, you can use the `is` operator.

```
>>> a = 'banana'
>>> b = 'banana'
>>> a is b
True
```

In this example, Python only created one string object, and both `a` and `b` refer to it.

But when you create two lists, you get two objects:

```
>>> a = [1, 2, 3]
>>> b = [1, 2, 3]
>>> a is b
False
```

In this case we would say that the two lists are *equivalent*, because they have the same elements, but not *identical*, because they are not the same object. If two objects are identical, they are also equivalent, but if they are equivalent, they are not necessarily identical.

Until now, we have been using “object” and “value” interchangeably, but it is more precise to say that an object has a value. If you execute `a = [1, 2, 3]`, `a` refers to a list object whose value is a particular sequence of elements. If another list has the same elements, we would say it has the same value.

## 8.12 Aliasing

If `a` refers to an object and you assign `b = a`, then both variables refer to the same object:

```
>>> a = [1, 2, 3]
>>> b = a
>>> b is a
True
```

The association of a variable with an object is called a *reference*. In this example, there are two references to the same object.

An object with more than one reference has more than one name, so we say that the object is *aliased*.

If the aliased object is mutable, changes made with one alias affect the other:

```
>>> b[0] = 17
>>> print(a)
[17, 2, 3]
```

Although this behavior can be useful, it is error-prone. In general, it is safer to avoid aliasing when you are working with mutable objects.

For immutable objects like strings, aliasing is not as much of a problem. In this example:

```
a = 'banana'
b = 'banana'
```

it almost never makes a difference whether `a` and `b` refer to the same string or not.

## 8.13 List arguments

When you pass a list to a function, the function gets a reference to the list. If the function modifies a list parameter, the caller sees the change. For example, `delete_head` removes the first element from a list:

```
def delete_head(t):
    del t[0]
```

Here's how it is used:

```
>>> letters = ['a', 'b', 'c']
>>> delete_head(letters)
>>> print(letters)
['b', 'c']
```

The parameter `t` and the variable `letters` are aliases for the same object.

It is important to distinguish between operations that modify lists and operations that create new lists. For example, the `append` method modifies a list, but the `+` operator creates a new list:

```
>>> t1 = [1, 2]
>>> t2 = t1.append(3)
>>> print(t1)
[1, 2, 3]
>>> print(t2)
None

>>> t3 = t1 + [3]
>>> print(t3)
[1, 2, 3]
>>> t2 is t3
False
```

This difference is important when you write functions that are supposed to modify lists. For example, this function *does not* delete the head of a list:

```
def bad_delete_head(t):
    t = t[1:]                # WRONG!
```

The slice operator creates a new list and the assignment makes `t` refer to it, but none of that has any effect on the list that was passed as an argument.

An alternative is to write a function that creates and returns a new list. For example, `tail` returns all but the first element of a list:

```
def tail(t):
    return t[1:]
```

This function leaves the original list unmodified. Here's how it is used:

```
>>> letters = ['a', 'b', 'c']
>>> rest = tail(letters)
>>> print(rest)
['b', 'c']
```

**Exercise 1:** Write a function called `chop` that takes a list and modifies it, removing the first and last elements, and returns `None`. Then write a function called `middle` that takes a list and returns a new list that contains all but the first and last elements.

## 8.14 Debugging

Careless use of lists (and other mutable objects) can lead to long hours of debugging. Here are some common pitfalls and ways to avoid them:

1. Don't forget that most list methods modify the argument and return `None`. This is the opposite of the string methods, which return a new string and leave the original alone.

If you are used to writing string code like this:

```
word = word.strip()
```

It is tempting to write list code like this:

```
t = t.sort()           # WRONG!
```

Because `sort` returns `None`, the next operation you perform with `t` is likely to fail.

Before using list methods and operators, you should read the documentation carefully and then test them in interactive mode. The methods and operators that lists share with other sequences (like strings) are documented at:

[docs.python.org/library/stdtypes.html#common-sequence-operations](https://docs.python.org/library/stdtypes.html#common-sequence-operations)

The methods and operators that only apply to mutable sequences are documented at:

[docs.python.org/library/stdtypes.html#mutable-sequence-types](https://docs.python.org/library/stdtypes.html#mutable-sequence-types)

2. Pick an idiom and stick with it.

Part of the problem with lists is that there are too many ways to do things. For example, to remove an element from a list, you can use `pop`, `remove`, `del`, or even a slice assignment.

To add an element, you can use the `append` method or the `+` operator. But don't forget that these are right:

```
t.append(x)
t = t + [x]
```

And these are wrong:

```
t.append([x])          # WRONG!
t = t.append(x)         # WRONG!
t + [x]                # WRONG!
t = t + x               # WRONG!
```

Try out each of these examples in interactive mode to make sure you understand what they do. Notice that only the last one causes a runtime error; the other three are legal, but they do the wrong thing.

3. Make copies to avoid aliasing.

If you want to use a method like `sort` that modifies the argument, but you need to keep the original list as well, you can make a copy.



```
orig = t[:]
t.sort()
```

In this example you could also use the built-in function `sorted`, which returns a new, sorted list and leaves the original alone. But in that case you should avoid using `sorted` as a variable name!

#### 4. Lists, `split`, and files

When we read and parse files, there are many opportunities to encounter input that can crash our program so it is a good idea to revisit the *guardian* pattern when it comes writing programs that read through a file and look for a “needle in the haystack”.

Let’s revisit our program that is looking for the day of the week on the from lines of our file:

```
From stephen.marquard@uct.ac.za Sat Jan 5 09:14:16 2008
```

Since we are breaking this line into words, we could dispense with the use of `startswith` and simply look at the first word of the line to determine if we are interested in the line at all. We can use `continue` to skip lines that don’t have “From” as the first word as follows:

```
fhand = open('mbox-short.txt')
for line in fhand:
    words = line.split()
    if words[0] != 'From' : continue
    print(words[2])
```

This looks much simpler and we don’t even need to do the `rstrip` to remove the newline at the end of the file. But is it better?

```
python search8.py
Sat
Traceback (most recent call last):
  File "search8.py", line 5, in <module>
    if words[0] != 'From' : continue
IndexError: list index out of range
```

It kind of works and we see the day from the first line (Sat), but then the program fails with a traceback error. What went wrong? What messed-up data caused our elegant, clever, and very Pythonic program to fail?

You could stare at it for a long time and puzzle through it or ask someone for help, but the quicker and smarter approach is to add a `print` statement. The best place to add the print statement is right before the line where the program failed and print out the data that seems to be causing the failure.

Now this approach may generate a lot of lines of output, but at least you will immediately have some clue as to the problem at hand. So we add a print of the variable `words` right before line five. We even add a prefix “Debug:” to the line so we can keep our regular output separate from our debug output.