References

Simple values and collections

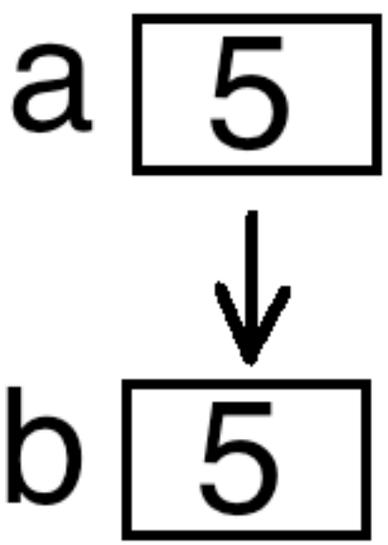
- ```
  >>> a = 5
  >>> b = a
  >>> a = a + 1
  >>> b
  5
  ```

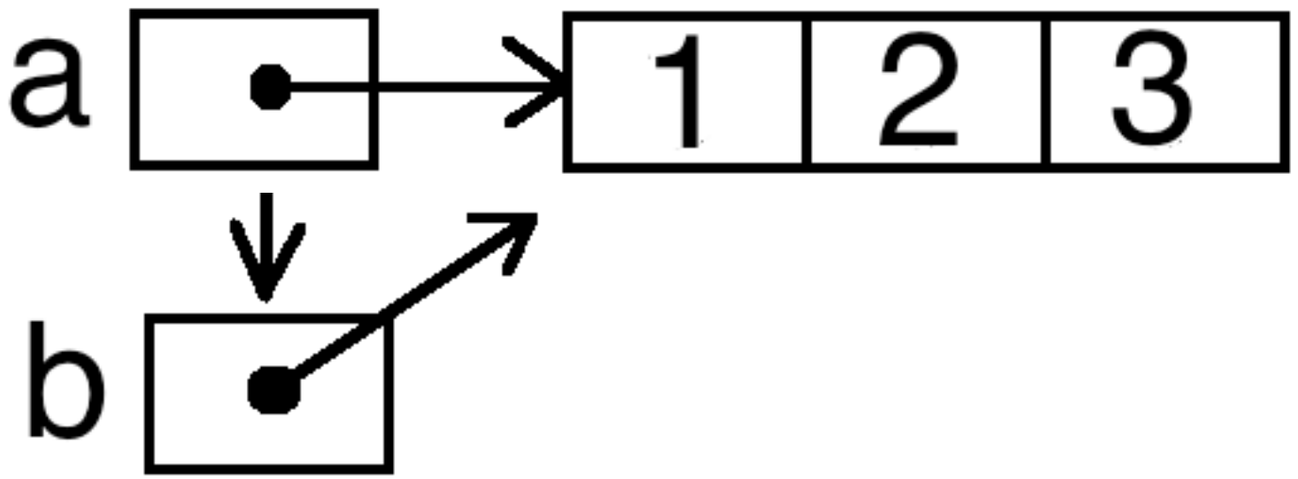
- ```
  >>> a = [1, 2, 3]
  >>> b = a
  >>> a[1] = 5
  >>> b
  [1, 5, 3]
  ```

- What's going on?

Variable contents

- Think of a variable as a "box" that can hold a *small* amount of information
- In the case of a simple value (number or boolean), the value can fit in the box
- In the case of a larger value, such as a list, what is put in the box is a ***reference*** to the value
- What we copy to another variable is what is in the box





Call by value

- When we call a function, the arguments in the call are evaluated, and the values are put into the parameters
- If the parameters are changed within the function (which isn't good style), the changes are *not* put back into the arguments
  - Besides, the arguments are not necessarily simple variables; they could be literal numbers, or expressions
-
```
>>> a = 5
>>> def alter(x):
 x = x + 1


>>> alter(a)
>>> print(a)
5
```
- We refer to this as ***call by value***
- What is in **a** is a *value*, and that is what is passed to the function

Call by reference

- When a function is called with something other than a number or boolean, the same rules apply, but something different happens
- ```
  >>> b = [1, 2, 3]
  >>> def alter(x):
      x[1] = 99          # changes contents of b
      x = [4, 5, 6]      # does not affect b
  ```

```
>>> alter(b)
>>> print(b)
[1, 99, 3]
```

- This is ***call by reference***
- What is in **`b`** is a *reference*, and that is what is passed to the function
- In this example **`b`** continues to refer to the same list (the assignment to **`x`** does not change that), but the list has been altered
```

Collections as parameters

- A variable is a "box" that can hold a *small* amount of information
  - Four bytes of actual data, but there is associated information to describe the *type* of the data
- Dictionaries and sets are ***mutable***: You can change the values in them
  - Dictionaries and sets are not small, so like lists, a variable whose value *appears to be* a dictionary or set, is actually a ***reference*** to that dictionary or set
  - Python keeps this straight, so you don't (usually) have to
- **Bottom line:** Dictionaries and sets are like lists; when you pass one into a function,
  - You can change the *values* in the dictionary or set, but
  - You can't change it to be a different dictionary or set

Strings as parameters

- Are strings passed to functions by value or by reference?
- ```
  >>> c = "abcde"
  >>> def alter(s):
      s = s + "123"
  >>> d = alter(c)
  >>> print(c)
  abcde
  >>> print(d)
  None
  ```
- **Answer:** Strings are passed by reference, but since they are immutable, nothing you do in the function will change the original string
  ```

Making lists

- You can enter a list directly:
  - `>>> [1, 2, 3]`
    `[1, 2, 3]`
- You can give a sequence to the **`list`** function:
  - `>>> list(range(1, 4))`
    `[1, 2, 3]`
  - `>>> list({'one', 'two', 'three'})`
    `['two', 'three', ‘one']`
  - `>>> list({'one': 1, 'two':2})`
    `['two', ‘one']`
- You can “multiply” a list:
  - `>>> ['A'] * 3`
    `['A', 'A', ‘A']`
  - `>>> ['a', 'b', 'c'] * 2`
    `['a', 'b', 'c', 'a', 'b', 'c']`

List multiplication gone wrong

- ```
  >>> m = [['a', 'b', 'c']] * 3
  >>> m
  [['a', 'b', 'c'], ['a', 'b', 'c'], ['a', 'b',
  'c']]
  ```
- ```
  >>> m[1][2] = '*'
  >>> m
  [['a', 'b', '*'], ['a', 'b', '*'], ['a', 'b',
  '*']]
  ```

- **Explanation:**
  1. In the first line above, the list contains a *reference* to a list
  2. The `*3` made copies of the reference, not copies of the list itself
  3. This gets assigned to `m`, which has three copies of the same reference
  4. The second assignment above changes the *one* referenced list

It’s all about memory

- Variables always hold *small* values--integers, floats, booleans, and references
  - Small values are cheap to copy and pass around
- All other kinds of values are larger (some of which can grow and shrink, like lists), and these larger values are kept in a special part of memory called the ***heap***
  - Larger values are expensive (in both time and memory) to copy, so it doesn’t happen automatically
- Two ways to copy:
  - A ***shallow copy*** of an object makes a copy of an object that includes all the small values (including references) in the original object
  - A ***deep copy*** of an object makes a copy of that object that includes deep copies of all the referenced objects in the original object

List comprehensions I

- A ***list comprehension*** is special syntax for generating (creating) a list
- **Simple syntax:** `[`*expression* `for` *index* `in` *seq*`]`
  - *seq* can be a list or an expression that produces an iterator or list
- **Examples:**
  - `>>> [0 for i in range(1, 4)]`
    `[0, 0, 0]`
  - `>>> [i * i for i in [1, 2, 3, 4]]`
    `[1, 4, 9, 16]`

List comprehensions II

- You can have multiple **`for`** expressions:
  - **`>>> [(i, j) for i in range(1, 3) for j in range(10, 13)]`**
    `[(1, 10), (1, 11), (1, 12), (2, 10), (2, 11), (2, 12)]`
- You can have **`if`** expressions:
  - **`>>> [2 * i for i in range(1, 11) if i != 7]`**
    `[2, 4, 6, 8, 10, 12, 16, 18, 20]`
- And, of course, you can have multiple **`for`**s and **`if`**s:
  - **`>>> [[i, j] for i in range(1, 30) for j in range(1, 10)`**
    `if j * j == i]`
    `[[1, 1], [4, 2], [9, 3], [16, 4], [25, 5]]`
- The *expression* part can itself be a list comprehension:
  - **`>>> [[10 * i + j for j in range(2)] for i in range(3)]`**
    `[[0, 1], [10, 11], [20, 21]]`

copy and deepcopy

```
>>> import copy
>>> m = [1, [2, 3], 4]
>>> m2 = copy.copy(m)
>>> m3 = copy.deepcopy(m)
>>> m[1][1] = 99 # change to a sublist
>>> m.append(5)  # change to top level
```

- `>>> m`
  `[1, [2, 99], 4, 5]`
- `>>> m2`
  `[1, [2, 99], 4]`
- `>>> m3`
  `[1, [2, 3], 4]`

Slicing

- Slicing (with the `[i:j]` notation) produces *shallow* copies
- Using `[:]` copies the entire list
- ```
  >>> m = [0, 1, 2, 3, 4, 5]
  >>> m2 = m[2:5]
  >>> m3 = m[:]
  >>> m[3] = 99
  ```
- ```
  >>> m
  [0, 1, 2, 99, 4, 5]
  ```
- ```
  >>> m2
  [2, 3, 4]
  ```
- ```
  >>> m3
  [0, 1, 2, 3, 4, 5]
  ```

The End