(1) Ordering of Functions
(2) Scope of Variables in Programs with Functions

FEB 16-18, 2015

Ordering functions in your code

- Will the following code work? Here the function is defined after the main program that is calling it.

```
print foo()
def foo():
        return "hello"
```

- Will this work? Here functions are defined before the main program. But, `foo2()` is called before it is defined by `foo1`.

```
def foo1():
        return foo2()
def foo2():
        return "hello"
print(foo1())
```

How does Python process code with functions?

```
def foo1():
        return foo2()
def foo2():
        return “hello”
print(foo1())
```

1. Python starts scanning the code from the beginning of the file.
2. It notes down names of functions as it encounters their *definitions*. Note that the functions are not executed at this time.
3. It reaches the first executable statement (`print foo1()`) and since `foo1` is known to Python, control is transferred to `foo1`.
4. In `foo1`, Python encounters a call to `foo2`. Function `foo2` is also known to Python and so control is transferred to `foo2`.

Lesson of this example?

- Define *all* functions before the main program.
- And then don’t worry about the order in which the functions themselves are defined.

Variables revisited

- To better understand how information gets passed between a function call and a function, let us develop a “mental model” of how variables in Python work.

- We will use a “sticky note” model for Python variables.

“Sticky note” model

- What happens when the following code is executed?

```
x = 10
y = x
x = x + 1
```

- A memory cell with value 10 is created and a “sticky note” with x on it is attached to this memory cell.
- A new “sticky note” with y on it is also attached to the same memory cell.
- A new memory cell with 11 is created and the “sticky note” x is moved from the old cell (with 10) to the new cell (with 11).

Note y continues to have value 10.

Terminology: Arguments vs Parameters

```
def foo1(n):
    return n * foo2(n*n)

def foo2(m):
    return m * "hello”

print(foo1(2))
```

- When `foo1` is called from the *main program*, 2 is sent in as an *argument*. The *parameter* n acquires the value 2.

- When `foo2` is called from `foo1`, the value of `n*n` is sent in as *argument*. The parameter `m` acquires the value of `n*n`.

“Sticky note” model for parameter passing

```
def foo(x):
    x = x + 1
    return 5

y = 10
print(foo(y))
print(y)
```

- y is a “sticky note” attached to 10
- When foo is called from the main program, x is a “sticky note” attached to the same memory cell as y.
- The “sticky note” x is moved to a memory cell containing 11 when the line x = x + 1 is executed. Note that this does not change the value of y.

Scope of a variable

- The *scope* of a variable refers to the “where” and “when” a variable is available for use.
- Things were simple when we did not have functions.
- If we only had a main program: the scope of a variable extends from the point where the variable is first defined till the end of the program.

Scope of variables inside functions

- Parameters and variables defined inside a function are “local” to that function.

```
def foo():
    var1 = “hello”
    return var1 + var1

# main program
print(foo())
if var1 == “hellohello”:
    print(foo())
```

var1 is a variable that is local to foo(). It comes into existence when the first line of foo() is executed and it “dies” when we exit the function.

var1 is not defined and this usage will cause an error.

Function parameters are also local

```
def foo(x):
    var1 = “hello”
    return var1 + x

# main program
print(foo(“bye”))
if x == “hellohello”:
    print(foo())
```

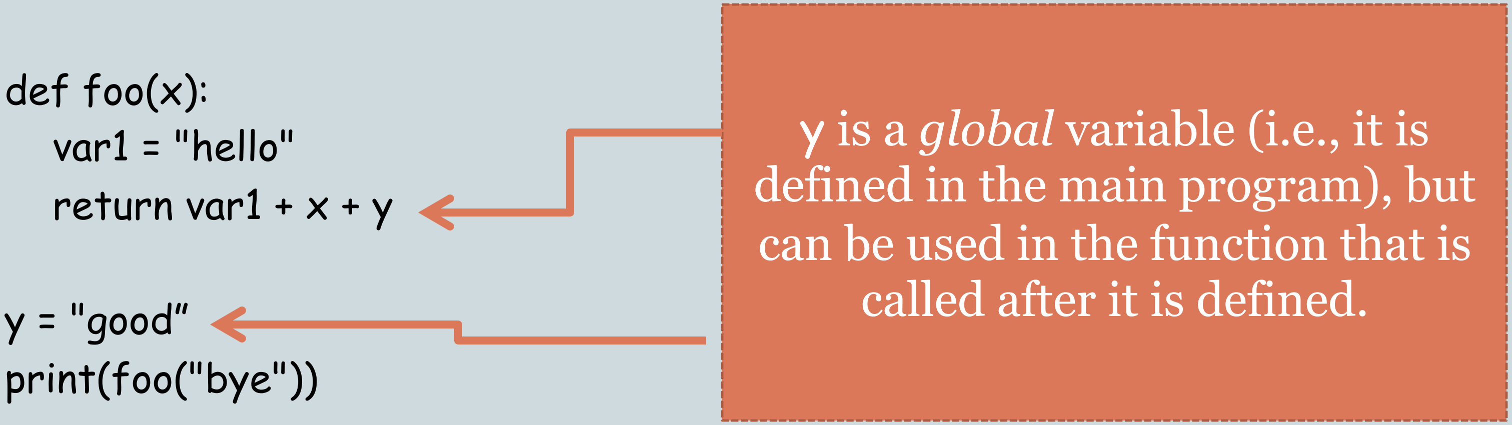
The variable x is undefined here because the parameter x lives only for the duration of the function

How does all this work?
Mental model: version 1.0

1. Python creates a dictionary of variable names when it starts evaluating the main program. It uses this dictionary to insert, look up, and update variable names.
2. When the function `foo` is executed, a new dictionary of variable names, specific to `foo` is created.
3. First the parameter `x` is inserted into this dictionary. Then variable `var1` is inserted.
4. Whenever we access a variable inside `foo`, `foo`’s dictionary is looked up.
5. When the execution of `foo` is over, `foo`’s dictionary is destroyed.

Global variables

- Mental model 1.0 explains why variables defined inside a function cannot be used in the main program.
- What about variables defined in the main program? Can they be used inside a function?



```
def foo(x):
    var1 = "hello"
    return var1 + x + y

y = "good”
print(foo("bye"))
```

y is a *global* variable (i.e., it is defined in the main program), but can be used in the function that is called after it is defined.

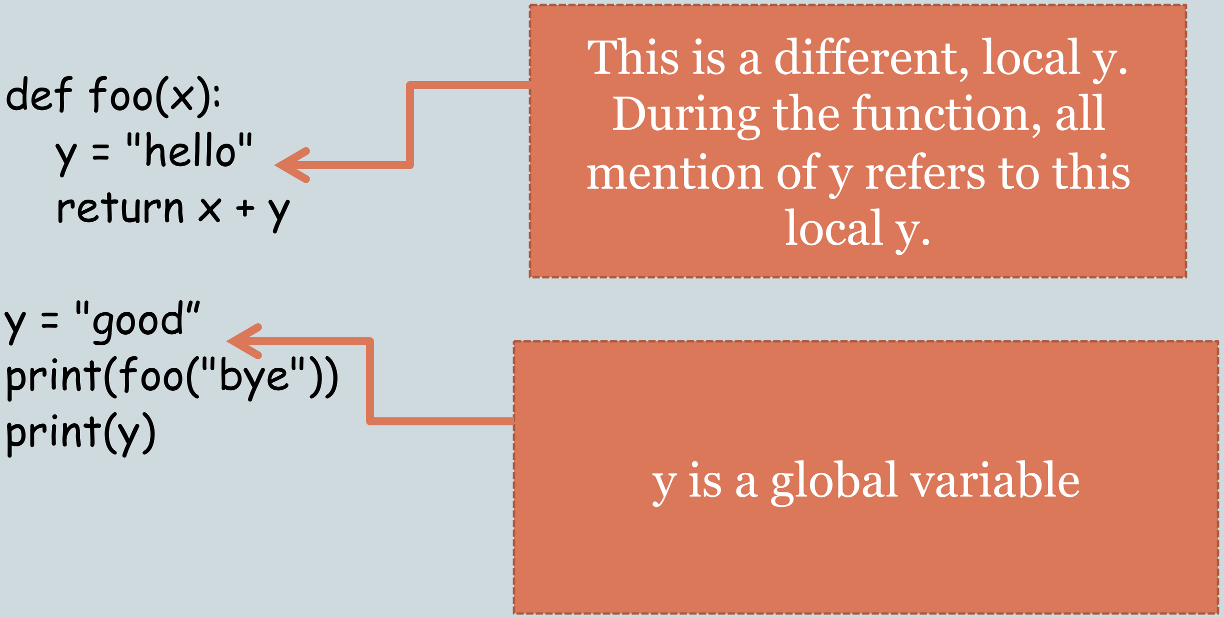
Mental model: version 1.1

- Here is a “more correct” version of item (4)

Whenever we access a variable inside `foo`, `foo`’s dictionary is looked up. If a variable is not found in `foo`’s dictionary, then Python looks up the dictionary of the main (calling) program.

- This allows a function access to “global” variables.

Local variables override global variables



```
def foo(x):
    y = "hello"
    return x + y

y = "good”
print(foo("bye"))
print(y)
```

This is a different, local y. During the function, all mention of y refers to this local y.

y is a global variable

- This mechanism also gives local variables precedence.
- In the above example, the variable `y` is found in `foo`’s dictionary and that is the variable that is accessed in `foo`.

Explicit global variables

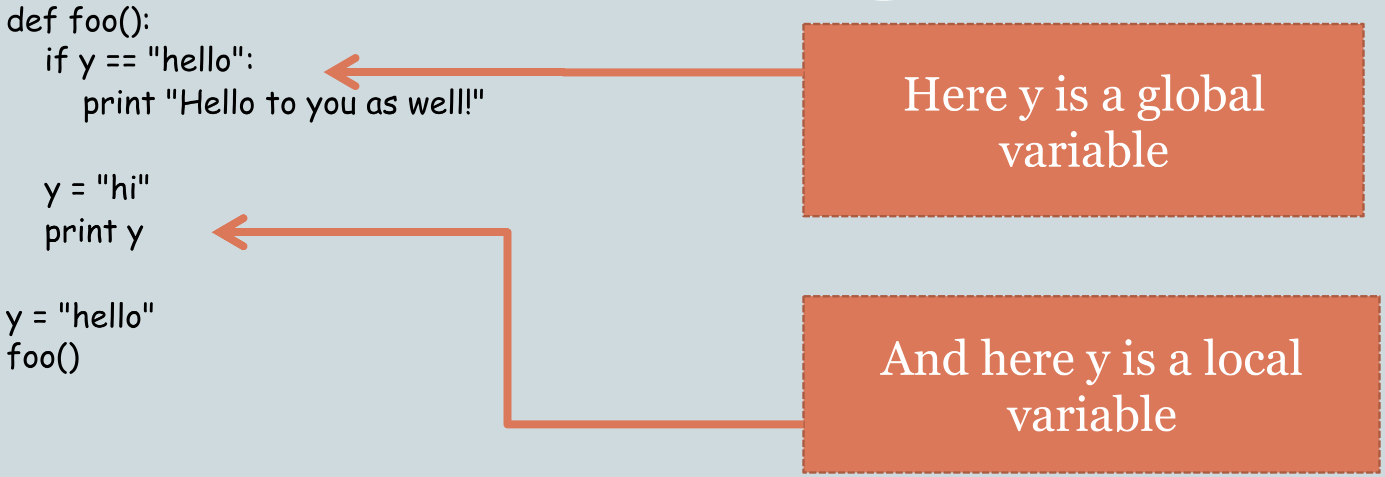
```
def foo(x):
    global y
    y = "hello"
    return x + y

y = "good”
print(foo("bye"))
print(y)
```

We are now explicitly declaring that the y we want to access inside foo() is the global variable y

- global is a Python keyword.
- If it were not for the global y statement, the variable y being mentioned inside foo would have been defined in foo’s dictionary and would be local to foo.

Explicit *global* variables avoid confusion like this



```
def foo():
    if y == "hello":
        print "Hello to you as well!"

    y = "hi"
    print y

y = "hello"
foo()
```

Here y is a global variable

And here y is a local variable

- This is an error in Python because Python sees the assignment `y = “hi”` inside `foo()` and assumes that all appearances of `y` inside `foo()` refer to this local variable.
- Therefore, in the first line of `foo()` we are accessing a variable not defined yet.

WARNING!!

- I would discourage the use of global variables, both implicit and explicit.
- Communication between functions or between the main program and a function should be explicit – via parameters/arguments and returned values.