Lecture #5: Exercising Environments

Announcements:

- Discussion orientation attendance is a bit low. Tutorials aren't intended to present reviews of material, and they assume that you have attended orientation.
- As of Thursday, CS10 had additional seats. If you find you are not ready for CS61A, consider switching to CS10.
- Please see Piazza message @318 for test times and for the form requesting alternative times in the case of time conflicts.
- Ask questions on the Piazza thread for today's lecture (@346).

Today

- In this lecture, there is nothing new!
- We'll just look at illustrations of the rules set down previously.

Example I: Which Definition?

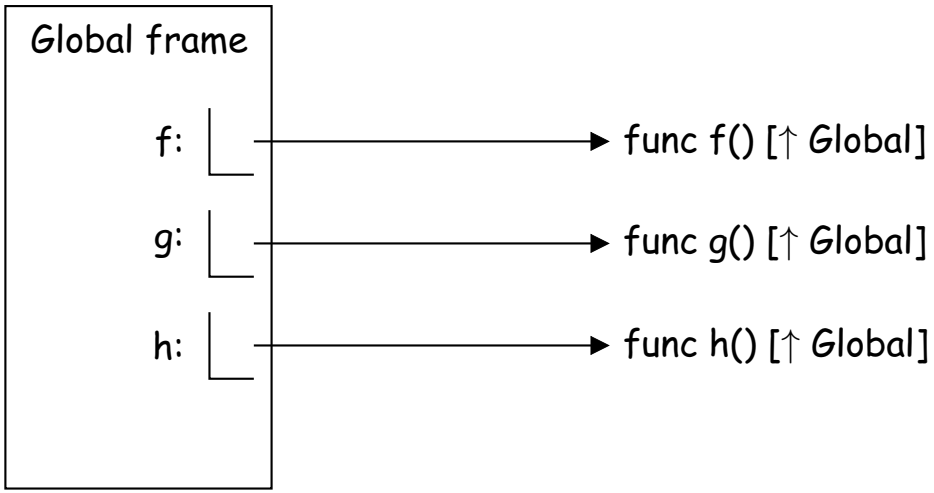
What is printed (0, 1, or error) and why?

```
def f():
    return 0

def g():
    print(f())

def h():
    def f():
        return 1
    g()

h()
```

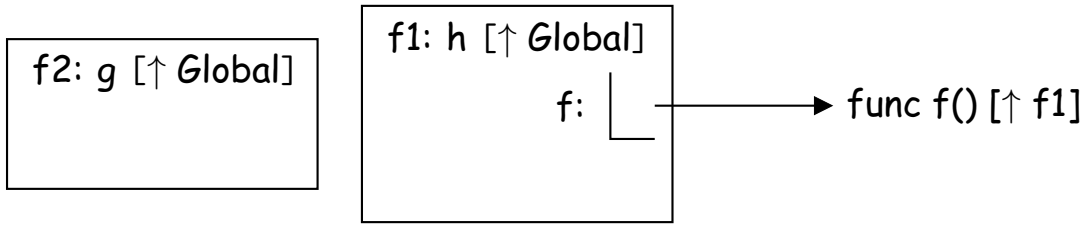
[Python Tutor]

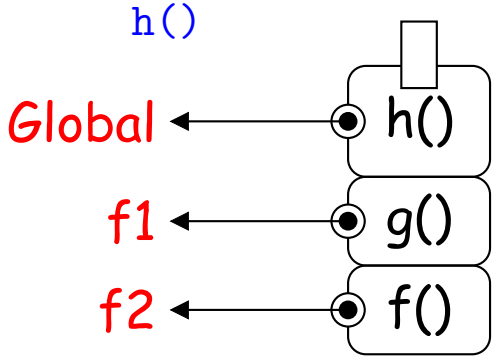
Answer I

The program prints `0`. At the point that `f` is called, we are in the situation shown below:




```
def f():
    return 0
def g():
    print(f())
def h():
    def f():
        return 1
    g()
h()
```





So we evaluate f in an environment (f2) where it is bound to a function that returns 0.

Example II: Redefinition after Assignment

What is printed (0, 1, or error) and why?

```
def f():
    return 0

g = f

def f():
    return 1

print(g())
```

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Answer II

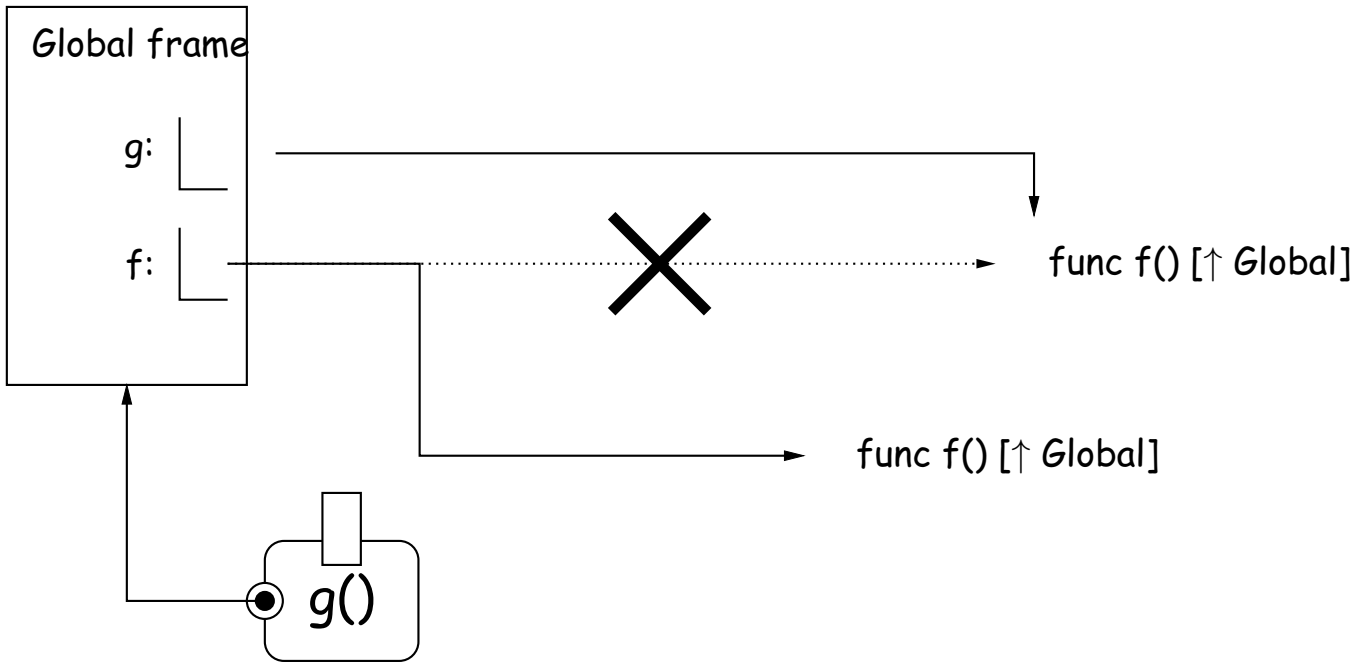
The program prints `0` again:

```
def f():
    return 0

g = f

def f():
    return 1

print(g())
```



At the time we evaluate `f` in the assignment to `g`, it has the value indicated by the crossed-out dotted line, so that is the value `g` gets. The fact that we change `f`'s value later is irrelevant, just as

```
x = 3; y = x; x = 4; print(y)
```

prints `3` even though `x` changes: `y` doesn't remember where its value came from.

Example III: Redefinition

What is printed (0, 1, or error) and why?

```
def f():
    return 0

def g():
    print(f())

def f():
    return 1

g()
```

[Python Tutor]

Answer III

This time, the program prints `1`. When `g` is executed, it evaluates the name 'f'. At the time that happens, f's value has been changed (by the third **def**), and that new value is therefore the one the program uses.

Example IV: Which Definition?

What is printed: (1, infinite loop, or error) and why?

```
def f(f):
    f(1)

def g(x):
    print(x)

f(g)
```

[Python Tutor]

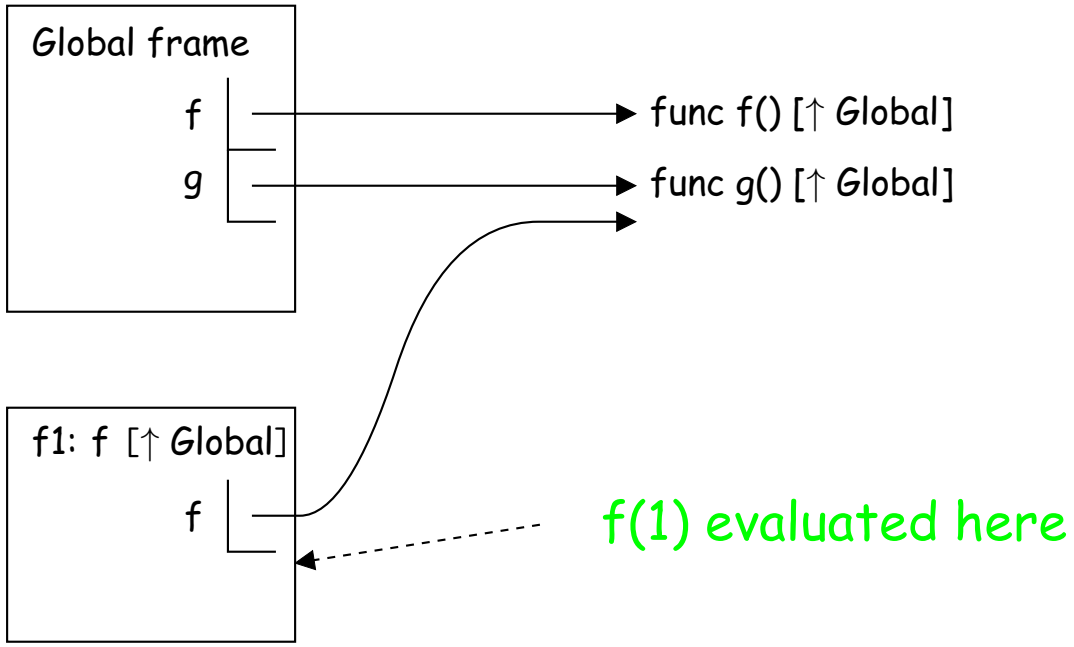
Answer IV

This prints 1. When we reach f(1) inside f, the call expression, and therefore the name f, is evaluated in the environment starting at frame f1, where the value of f is the global function bound to g:

```
def f(f):
    f(1)

def g(x):
    print(x)

f(g)
```



Example V: Which Definition?

What is printed: (0, 1, or error) and why?

```
def f():
    return 0

def g():
    return f()

def h(k):
    def f():
        return 1
    p = k
    return p()

print(h(g))
```

[Python Tutor]

Answer V

This prints 0. Function values are attached to current environments when they are first created (by lambda or def). Assignments (such as to p) don't themselves create new values, but only copy old ones, so that when p is evaluated, it is equal to k, which is equal to g, which is attached to the global environment.

Observation: Environments Reflect Nesting

- From what we've seen so far:

  Linking of environment frames $\Longleftrightarrow$ *Nesting of definitions.*

- For example, given

```
def f(x):
    def g(x):
        def h(x):
            print(x)
        ...
    ...
```

  The structure of the program tells you that the environment in which *print(x)* is evaluated will always be a chain of 4 frames:

  - A local frame for *h* linked to ...
  - A local frame for *g* linked to ...
  - A local frame for *f* linked to ...
  - The global frame.

- However, when there are multiple local frames for a particular function lying around, environment diagrams can help sort them out.

Example VI: Multiple Executions of Def

What is printed: (0, 1, or error) and why?

```
def f(p, k):
    def g():
        print(k)
    if k == 0:
        f(g, 1)
    else:
        p()
f(None, 0)
```

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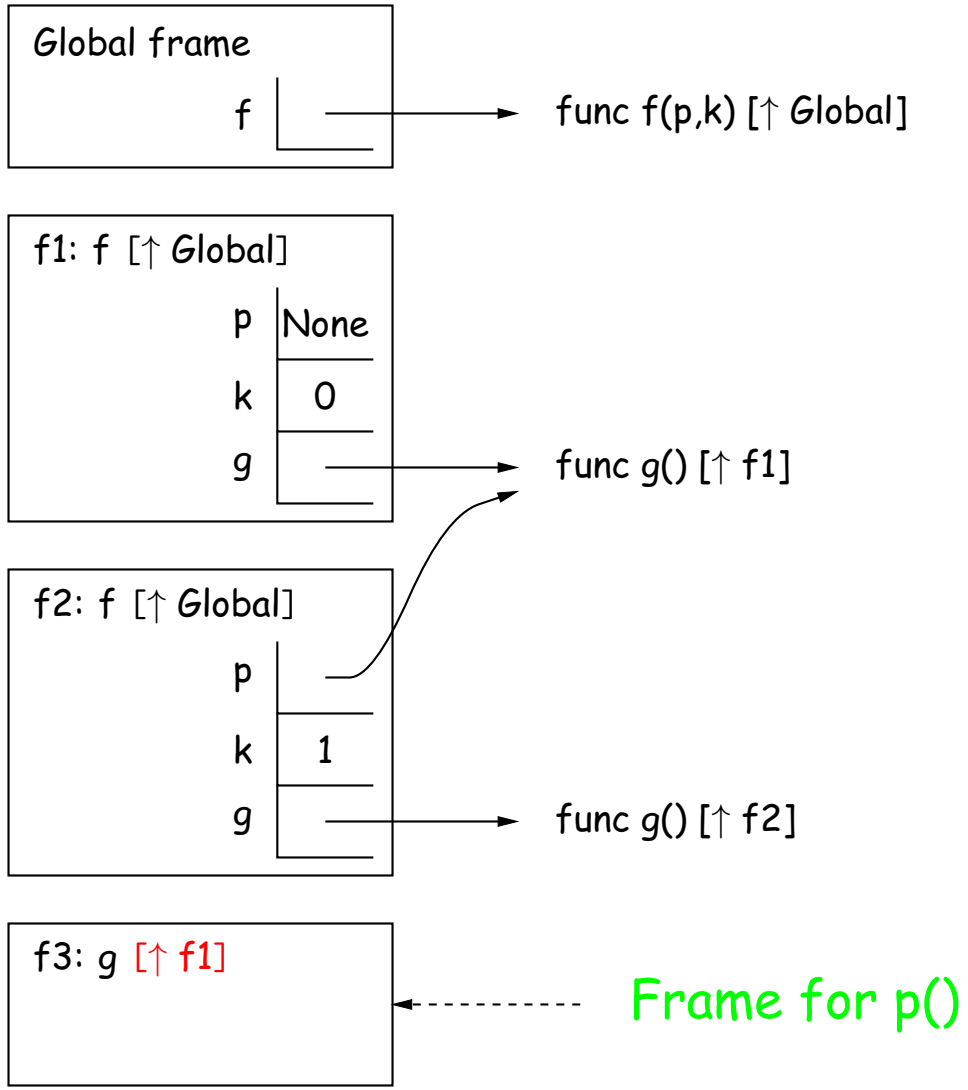
Answer VI

This prints 0. There are two local frames for f when p() is called (f1 and f2). The call to p() creates an instantiation of g whose parent is f1.

```
def f(p, k):
    def g():
        print(k)
    if k == 0:
        f(g, 1)
    else:
        p()
f(None, 0)
```



Example VII: Assign to Parameter

What is printed (4 2, 5 3, or 4 3) and why?

```
def f(x):
    x = x + 1

y = 4
f(y)
x = 2
f(x)
print(y, x)
```

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Answer VII

The program prints "4 2". During the execution of `f`, the formal parameter `x` resides in a new local frame. Anything done to it has no effect on any variables in other frames, such as in the global frame from which `f` is called.

Example VIII: Assign to Outer Parameter?

What is printed (3, 4, or error) and why?

```
def f(x):
    def g(y):
        x = y
    g(4)
    return x

print(f(3))
```

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Answer VIII

In the call to `g`, the assignment to `x` creates a new binding of `x` in the *local frame created by the call to* `g`. It is unrelated to the parameter of `f`, which is bound in a different local frame. Hence, the call to `g` has no effect and the argument to `f` is returned unchanged.

Example IX: Delayed Recursion

What does this print, and why?

```
def print_sums(n):
    print(n)
    def next_sum(k):
        return print_sums(n+k)
    return next_sum

print_sums(1)(3)(5)
```

[Python Tutor]

Answer IX

The call

```
print_sums(1)(3)(5)
```

produces the same result as

```
g1 = print_sums(1)
g2 = g1(3)
g2(5)
```

A call `print_sums(x)` returns a function that

- Prints `x` as a side-effect, and
- Returns a function that, when called with argument `y`, will do exactly the same thing, but with `x+y` instead of `x`.

So these calls will

- First print 1 and return `g1`,
- which when called with 3, will print 4 (= 1+3) and return g2,
- which when called with 5, will print 9 (= 4+5), and return....

Example X: Currying

- The term *currying* refers to converting a multi-argument function into one that takes one argument and returns a function that takes the next argument, and so on, until it finally produces the original function's result after consuming the last argument.
- The name comes from Haskell Curry, who did not invent it.
- In fact, to name it after its inventor, we'd have to say "Frege-ing" or perhaps "Schönfinkeling".
- We could define the process for two arguments like this:

```
def curry2(f):
    return lambda x: lambda y: f(x, y)

from operator import add
print(curry2(add)(30)(12))
print(curry2(add)(30))      # Prints a function value
```

[Python Tutor]