61A LECTURE 3 – CONTROL, HOF

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June 26, 2013

Announcements

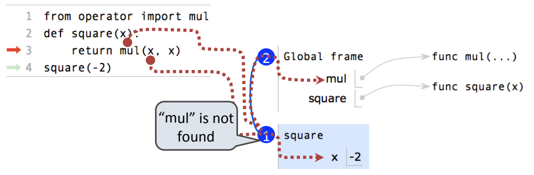
- hw1 is due tomorrow at 11:59PM
  - Have to submit through your account
  - Your TA will go over homework submission in lab
- Project1 is out! Find a partner if you haven't already.
  - Will have all the tools you need to complete the project by the end of lecture today

Let's recap...

Looking up names

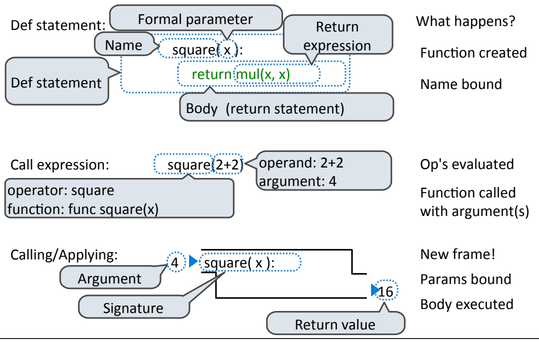
Procedure for looking up a name from inside a function (v. 1):

1. Look it up in the local frame
2. If not in local frame, look it up in the global frame
3. If in neither frame, generate error



```
from operator import mul
def square(x):
    return mul(x, x)
square(-2)
```

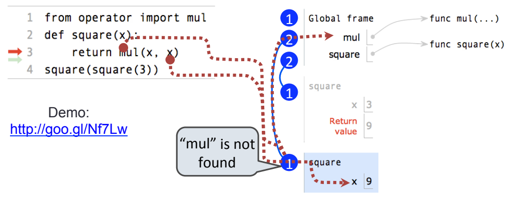
Life cycle of a user-defined function



Multiple environments in one diagram

Every expression is evaluated in the context of an environment.

mul(x, x)



```
from operator import mul
def square(x):
    return mul(x, x)
square(square(3))
```

Demo:
http://goo.gl/Nf7Lw

Python Feature Demonstration

Multiple Assignment

Multiple Return Values

Docstrings

Doctests

Default Arguments

Boolean Contexts

George Boole

```
def absolute_value(x):
    """Return the absolute value of x."""
    if x > 0:
        return x
    elif x == 0:
        return 0
    else:
        return -x
```

Two boolean contexts

False values in Python: False, 0, "", None (more to come)

True values in Python: Anything else (True)

Read Section 1.5.4!

Keywords: “and” “or”

- The keywords “and” and “or” are useful for combining values in a boolean context
- and returns a true value if all expressions are true in a boolean context
  - (5 > 3) and (1 + 1 == 2) will return True
- or returns a true value if any expression is true in a boolean context
  - (1 > 5) or (400 < 10) or (2 == 4 – 2) will return True
- But it’s not quite that simple...

“Short-circuiting”

- The keyword “and” will return the first expression that is False in a boolean context
  - If there are no expressions that are False, then the last value in the statement is returned
- The keyword “or” will return the first expression that is True in a boolean context
  - If there are no expressions that are True, then the last value in hte statement is returned

```
>>> True and 5
5
>>> True or (5 / 0)
True
```

Interpreter session

Break

Statements

A *statement* is executed by the interpreter to perform an action

Types of statements we have seen so far

- An assignment

```
    radius = 10
```

- A function definition

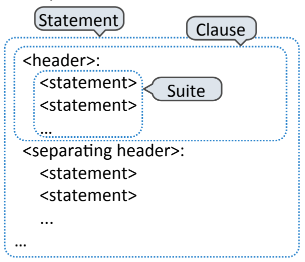
```
    def square(x):
        return x * x
```

- Returns, imports, assertions

Compound Statements

A function definition is a *compound statement*

Compound statements:



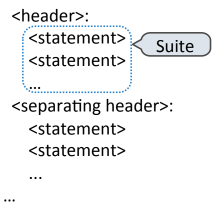
```
<header>:
    <statement>
    <statement>
    ...
<separating header>:
    <statement>
    <statement>
    ...
...
```

The first header determines a statement's type

The header of a clause "controls" the suite that follows

Compound Statements

Compound statements:



```
<header>:
    <statement>
    <statement>
    ...
<separating header>:
    <statement>
    <statement>
    ...
...
```

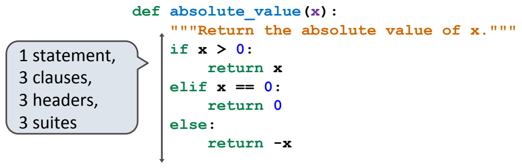
A suite is a sequence of statements

To "execute" a suite means to execute its sequence of statements, in order

Execution rule for a sequence of statements:

1. Execute the first
2. Unless directed otherwise, execute the rest

Conditional Statements



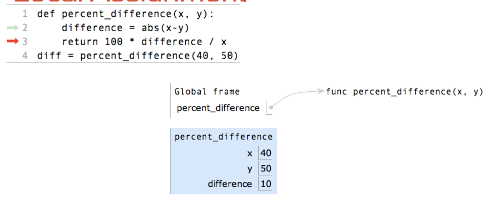
```
def absolute_value(x):
    """Return the absolute value of x."""
    if x > 0:
        return x
    elif x == 0:
        return 0
    else:
        return -x
```

Execution rule for conditional statements:

Each clause is considered in order.

1. Evaluate the header's expression.
2. If it is a true value,
   execute the suite & skip the remaining clauses.

Local Assignment

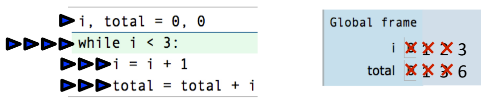


```
def percent_difference(x, y):
    difference = abs(x-y)
    return 100 * difference / x
diff = percent_difference(40, 50)
```

Execution rule for assignment statements:

1. Evaluate all expressions right of =, from left to right.
2. Bind the names on the left to the resulting values in the first frame of the current environment.

Iteration



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Execution rule for while statements:

1. Evaluate the header's expression.
2. If it is a true value,
   execute the (whole) suite,
   then return to step 1.

Example: http://goo.gl/mk7Sc

Break

Locally Defined Functions

Functions can be defined inside other functions

What happens when a def is executed?

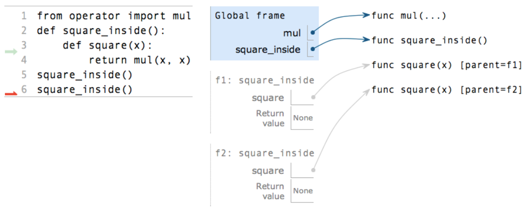
1. Create a function value with the given signature and body
2. Bind the given name to that value in the current frame

The name can then be used to call the function.

```
def sum_of_squares(n):
    """Sum of the squares of the integers 1 to n"""
    def square(x):
        return mul(x, x)
    total, k = 0, 1
    while k <= n:
        total, k = total + square(k), k + 1
    return total
```

Locally Defined Functions

The inner definition is executed each time the outer function is called



```
from operator import mul
def square_inside():
    def square(x):
        return mul(x, x)
square_inside()
square_inside()
```

Higher-Order Functions

Functions are first-class: they can be manipulated as values in Python

Higher-order function: a function that takes a function as an argument value or returns a function as a return value

Higher order functions:

- Express general methods of computation
- Remove repetition from programs
- Separate concerns among functions

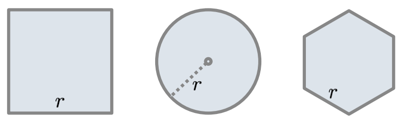
The Art of the Function

- Give each function exactly one job
- Don't reapeat yourself (DRY).
- Don't reapeat yourself (DRY).
- Define functions generally
- Proj1 has a composition score! Adhere to these guidelines

Generalizing Patterns with Parameters

Regular geometric shapes relate length and area.

Shape:



Area: $\boxed{1} \cdot r^2$ $\boxed{\pi} \cdot r^2$ $\boxed{\frac{3\sqrt{3}}{2}} \cdot r^2$

Finding common structure allows for shared implementation

Interpreter session

Generalizing Over Computational Processes

The common structure among functions may itself be a computational process, rather than a number.

$$\sum_{k=1}^{5} k = 1 + 2 + 3 + 4 + 5 = 15$$

$$\sum_{k=1}^{5} k^3 = 1^3 + 2^3 + 3^3 + 4^3 + 5^3 = 225$$

$$\sum_{k=1}^{5} \frac{8}{(4k-3)\cdot(4k-1)} = \frac{8}{3} + \frac{8}{35} + \frac{8}{99} + \frac{8}{195} + \frac{8}{323} = 3.04$$

Interpreter session

Functions as Arguments

Function values can be passed as arguments

```
def cube(k):
    return pow(k, 3)

def summation(n, term):
    """Sum the first n terms of a sequence.

    >>> summation(5, cube)
    225
    """
    total, k = 0, 1
    while k <= n:
        total, k = total + term(k), k + 1
    return total
```

Function of a single argument (not called term)

A formal parameter that will be bound to a function

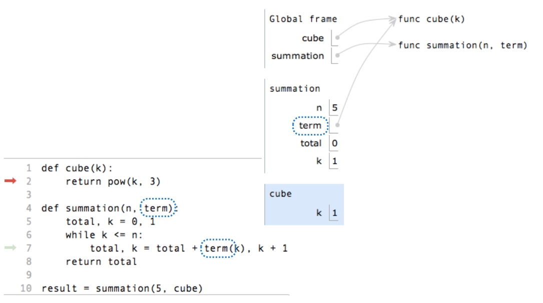
The cube function is passed as an argument value

$0 + 1^3 + 2^3 + 3^3 + 4^3 + 5^5$

The function bound to term gets called here

Function Values as Parameters

Parameters can be bound to function values

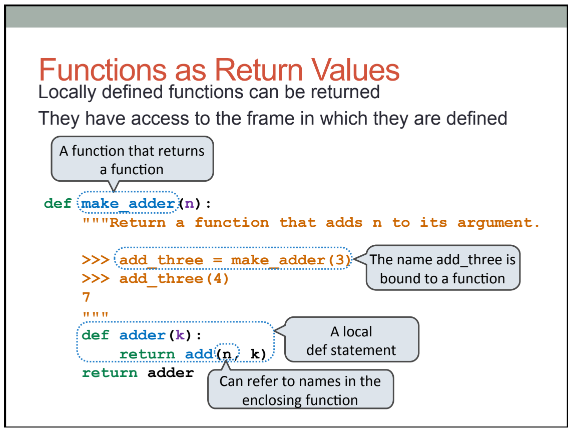


```
def cube(k):
    return pow(k, 3)

def summation(n, term):
    total, k = 0, 1
    while k <= n:
        total, k = total + term(k), k + 1
    return total

result = summation(5, cube)
```

Example: http://goo.gl/e4YBH

That's it for today

- This is all I wanted to get through for today, but if we have time left, we can go to the next slides



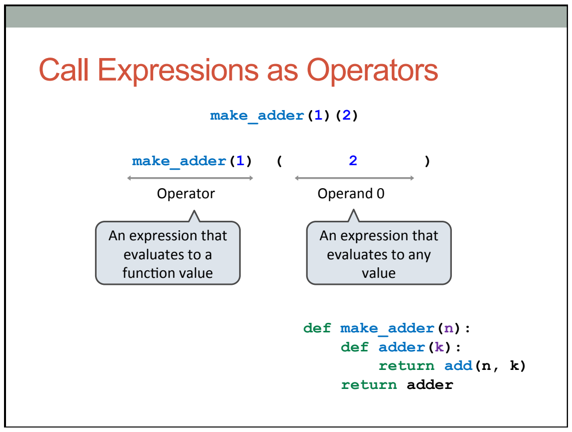
Functions as Return Values

Locally defined functions can be returned

They have access to the frame in which they are defined

```
def make_adder(n):
    """Return a function that adds n to its argument.

    >>> add_three = make_adder(3)
    >>> add_three(4)
    7
    """
    def adder(k):
        return add(n, k)
    return adder
```

A function that returns a function
The name add_three is bound to a function
A local def statement
Can refer to names in the enclosing function

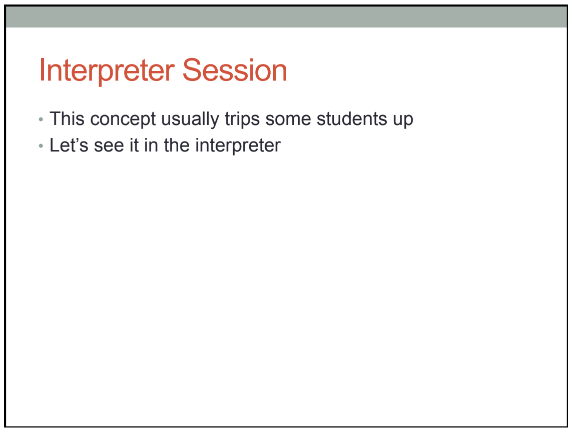


Call Expressions as Operators

```
make_adder(1)(2)

make_adder(1)   (     2     )
```

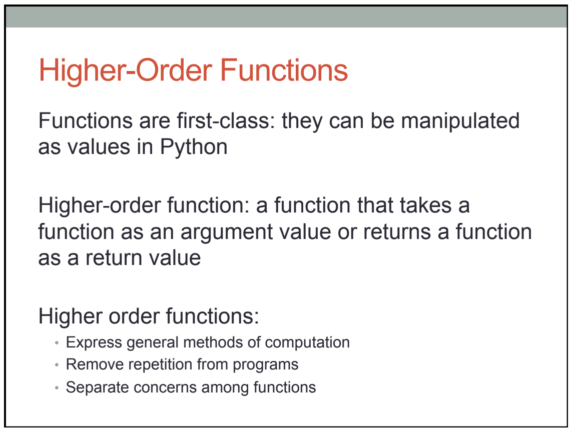
Operator
Operand 0
An expression that evaluates to a function value
An expression that evaluates to any value

```
def make_adder(n):
    def adder(k):
        return add(n, k)
    return adder
```



Interpreter Session

- This concept usually trips some students up
- Let's see it in the interpreter



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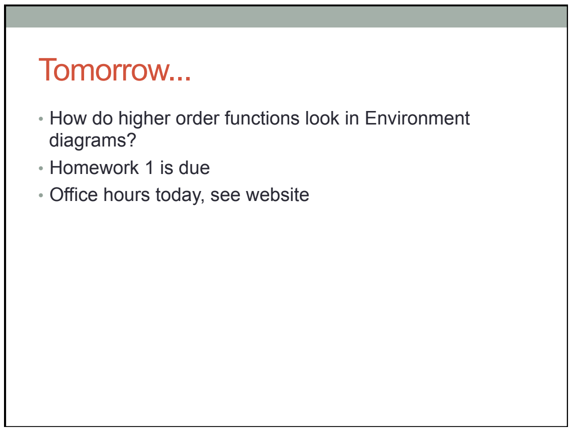

Tomorrow...

- How do higher order functions look in Environment diagrams?
- Homework 1 is due
- Office hours today, see website