# Discussion 02

## Environment Diagrams, Higher-Order Functions

Aditya Balasubramanian
aditbala [at] berkeley [dot] edu

Slides available at `teaching.aditbala.com`

# Announcements

- First Project (Hog) released !!!
  - Checkpoint due 7/1 (1pt)
  - Project due 7/6
  - Extra Credit (1pt, due 7/5)
- First Homework released (HW01)
  - Getting started videos
  - Due Thursday (6/30)
- Quick note
  - 61a is 2x speed
  - Make sure to use resources
  - Tutoring Sections have opened!

# Boolean Expressions Clarification

- `True and not False or not True and False`
- `(True and (not False)) or ((not True) and False)` -> `True`
- `False or 1 and 4`
- `False or (1 and 4)` -> `4`

# Environment Diagrams

# Enviroment Diagrams

- What are they?
  - A way to model how our program runs line by line
  - Keep track of variables, function calls and what they return, etc.
- Why use them?
  - Can help us understand where there is a bug in program (debugging)
  - Useful for other questions (WWPD, coding)
  - Exam points!

# Important Concepts

- Expressions
  - Evaluate to values
  - `1 + 1` -> `2`
- Statements
  - Bind **names** to **values**
  - **Names**
    - `def` statements, assignment statements, variable names
  - **Values**
    - numbers, strings, functions, or other objects
  - `x = 2`
  - doesn't return anything

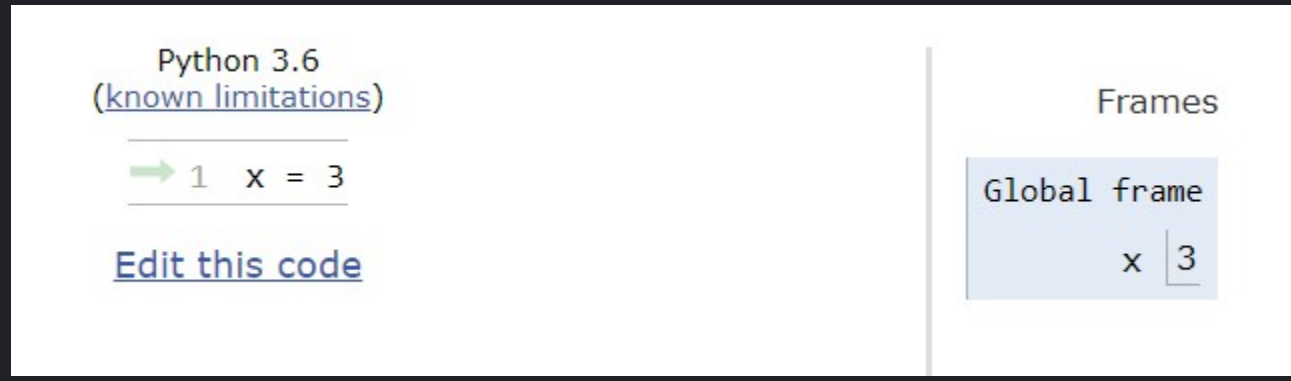
# Frames

- What are they?
  - Frames list the bindings of variables and their corresponding value
- What are they used for?
  - Used to look up the value of a variable
- `Global Frame` always exists

# Assignment Statements

- Assignment statements (denoted by =) creates new binding in frame
- Evaluate right side **completely** before binding to left side
- Example

```
x = 11 % 4
y = x
x **= 2
```



# Def statements

- `def` statements are used to bind **function objects** to a **variable**
- Binding name is function name
- Parent of the function is frame where function is defined
- Keep track of *name*, *parameters*, *parent frame*
- Example

```
x = 3
def square(x):
    return x ** 3
square(x)
```

# Def statements

- Only bind, **NO** execution until function is called
  - `def foo():` -> define function called `foo` with no parameters
  - `foo()` -> execute foo

# Call Expressions

- Syntax: `function_name(arg1, arg2, ...)`
- `sum(square(2), 2 + 2)`
- Create new frame for call expression
- Steps for evaluating:
  1. Evaluate operator (function)
     - See if it exists
       - `square(2) -> 4` squares number
       - `sum` adds two numbers
  2. Evaluate operands (args)
     - simplify args
       - `2 + 2` -> `4`
  3. Apply operator to the operands
     - `sum(4, 4) -> 8`

# Creating New Frames

- Give frame with unique index ( `f1` , `f2` , `f3` )
- Label frame with name of function object
  - not always the variable name
- Label function's parent (frame in which it is defined in)
- Every function has return value
  - Return value can be `None`

# Variable Lookup

- Start in current frame
- If variable does not exist, search parent frame
- If variable still does not exist, continue looking in parent frames
- If variable does not exist, program errors

# Question 1 (5 minutes)

Let's put it all together! Draw an environment diagram for the following code. You may not have to use all of the blanks provided to you.

```
def double(x):
    return x * 2

hmmm = double
wow = double(3)
hmmm(wow)
```

# Question 2 (walkthrough)

Draw the environment diagram that results from executing the code below.
(note: evaluate, then assign)

```
def f(x):
    return x

def g(x, y):
    if x(y):
        return not y
    return y

x = 3
x = g(f, x)
f = g(f, 0)
```

# `lambda` Functions λ

# `lambda` Functions λ

- What are they?
  - A quicker and simpler way to define a function
  - Can also be used as the operator for a function
- Why use them?
  - Useful for scenarios in which you only want to use a function once and never again
- Syntax
  - written in 1 line
  - `lambda <args> : <body>`

# `lambda` Function Examples Pt. 1

```
def add_and_square(x, y, z):
    return (x + y + z) ** 2

lambda_add_and_square = lambda x, y, z : (x + y + z) ** 2
```

```
def error():
    return 1 + 2 / 0

lambda_error = lambda : 1 + 2 / 0
```

# `lambda` Examples Pt. 2

```
>>> lambda x : x // 3

>>> (lambda x : x // 3)(5)

>>> wow = lambda x: lambda y: lambda z: x * y * z
>>> wow(3)(7)(5)

>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

# `lambda` Examples Pt. 2

```
>>> lambda x : x // 3
Function
>>> (lambda x : x // 3)(5)

>>> wow = lambda x: lambda y: lambda z: x * y * z
>>> wow(3)(7)(5)

>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

# `lambda` Examples Pt. 2

```
>>> lambda x : x // 3
Function
>>> (lambda x : x // 3)(5)
1
>>> wow = lambda x: lambda y: lambda z: x * y * z
>>> wow(3)(7)(5)

>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

# `lambda` Examples Pt. 2

```
>>> lambda x : x // 3
Function
>>> (lambda x : x // 3)(5)
1
>>> wow = lambda x: lambda y: lambda z: x * y * z
>>> wow(3)(7)(5)
105
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

# `lambda` Examples Pt. 2

```
>>> lambda x : x // 3
Function
>>> (lambda x : x // 3)(5)
1
>>> wow = lambda x: lambda y: lambda z: x * y * z
>>> wow(3)(7)(5)
105
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
81
```

# Question 3 (10 minutes)

Draw the environment diagram for the following code and predict what Python will output.

```
a = lambda x: x * 2 + 1
def b(b, x):
    return b(x + a(x))
x = 3
x = b(a, x)
```

# Higher Order Functions 

# Higher Order Functions (HOF)

- What are they?
  - Functions that either return functions as output or take in other functions as inputs
- Why use them?
  - When you want to use a function within another function
  - Treat them as an object
- Important Note
  - Let's see we have function `foo()` that takes in zero parameters
  - `foo` refers to the function object and is **NOT** calling the function
  - `foo()` shows that we are actually calling the function

# HOF Function as Input Example

```
>>> def exec_func(func, a):
        return func(a)

>>> exec_func(lambda x : x * 4, 4)
16

>>> exec_func(lambda x : pow(x, 2), 2)
4
```

# HOF Function as Output Example

- PythonTutor

```
>>> def first(x):
        def square(y):
            def mod(z):
                return (x ** y) % z
            return mod
        return square

>>> a = first(2)
>>> b = a(4)
>>> b(3)
```

# HOF Function as Output Example

```
>>> def first(x):
        def square(y):
            def mod(z):
                return (x ** y) % z
            return h
        return g

>>> a = first(2)
>>> b = a(4)
>>> b(3)
1
```

# Question 4 (10 minutes)

Draw the environment diagram for the following code and predict what Python will output.

```
n = 9
def make_adder(n):
    return lambda k: k + n
add_ten = make_adder(n+1)
result = add_ten(n)
```

# Question 5 (10 min)

Write a function that takes in a number `n` and returns a function that can take in a single parameter `cond`. When we pass in some condition function `cond` into this returned function, it will print out numbers from 1 to `n` where calling cond on that number returns `True`.

```
def make_keeper(n):
    """Returns a function which takes one parameter cond and prints
    out all integers 1..i..n where calling cond(i) returns True.

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> make_keeper(5)(is_even)
    2
    4
    """
```

```
def make_keeper(n):
    """Returns a function which takes one parameter cond and prints
    out all integers 1..i..n where calling cond(i) returns True.

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> make_keeper(5)(is_even)
    2
    4
    """
     def keeper(cond):
      i = 1
      while (i <= n):
        if cond(i):
          print(i)
        i += 1
    return keeper # remember this line
```

# Thank you!

**Attendance Form -> https://tinyurl.com/adit-disc02**

**Anon Feedback -> https://tinyurl.com/adit-anon**

**Study Groups -> https://tinyurl.com/adit-study**