Lecture 9: Memory in Python

CS 1110

Introduction to Computing Using Python

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Announcements

- Last day to inform us of your Prelim 1 conflict!
- Previous Exams located on the website
- A1 revision process: A1 closed now on CMS for grading. Set your CMS notifications to "receive email when …" When feedback is released, expected on late Thursday, Feb 24 afternoon, read *re*submission instructions
- A2 to be released today

Global Space

Global Space

- What you "start with"
- Stores global variables
- Lasts until you quit Python

Global Space

x | 4

```
x = 4
```

Enter Heap Space

Global Space

- What you "start with"
- Stores global variables
- Lasts until you quit Python

Heap Space

- Where "folders" are stored
- Have to access indirectly

```
x = 4
p = shape.Point2(1,2)
q = shape.Point2(10,7)
```

Global Space

x | 4
p | id1
q | id2

Heap Space

id1 Point2
x | 1
y | 2

id2 Point2
x | 10
y | 7

p & **q** live in Global Space. Their folders live on the Heap.

Calling a Function Creates a Call Frame (1)

What's in a Call Frame?

- Boxes for parameters **at the start of the function**
- Boxes for variables local to the function **as they are created**

```
def adjust_x(pt, n):
    pt.x = pt.x + n

x = 4
p = shape.Point2(1,2)
adjust_x(p, x)
```

Global Space

x | 4
p | id1

Heap Space

id1 Point2
x | 1
y | 2

Call Stack

adjust_x | 1
id1 | pt
4 | n

Calling a Function Creates a Call Frame (2)

What's in a Call Frame?

- Boxes for parameters **at the start of the function**
- Boxes for variables local to the function **as they are created**

```
def adjust_x(pt, n):
    pt.x = pt.x + n

x = 4
p = shape.Point2(1,2)
adjust_x(p, x)
```

Global Space

x | 4
p | id1

Heap Space

id1 Point2
x | ~~1~~ 5
y | 2

Call Stack

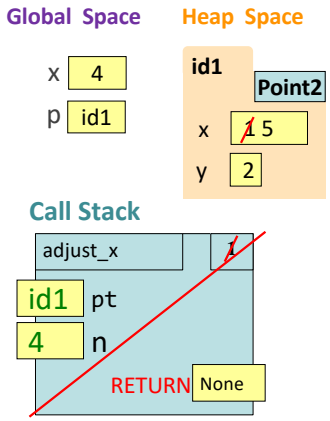
adjust_x | ~~1~~
id1 | pt
4 | n
RETURN | None

Calling a Function Creates a Call Frame (3)

What's in a Call Frame?

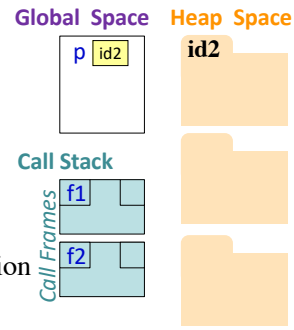
- Boxes for parameters **at the start of the function**
- Boxes for variables local to the function **as they are created**

```
def adjust_x(pt, n):
1    pt.x = pt.x + n

x = 4
p = shape.Point2(1,2)
adjust_x(p, x)
```



Putting it all together

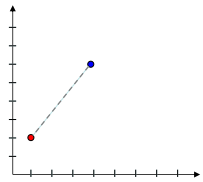
- **Global Space**
  - What you "start with"
  - Stores global variables
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly
- **Call Frames**
  - Parameters
  - Other variables local to function
  - Lasts until function returns



Two Points Make a Line

```
start = shape.Point2(0,0)
stop = shape.Point2(0,0)
print("Where does the line start?")
x = input("x: ")
start.x = int(x)
y = input("y: ")
start.y = int(y)
print("The line starts at ("+x+ ","+y+ ").")
print("Where does the line stop?")
x = input("x: ")
stop.x = int(x)
y = input("y: ")
stop.y = int(y)
print("The line stops at ("+x+ ","+y+ ").")
```

```
Where does the line start?
x: 1
y: 2
The line starts at (1,2).
Where does the line stop?
x: 4
y: 6
The line stops at (4,6).
```



Redundant Code is BAAAAD!

```
start = shape.Point2(0,0)
stop = shape.Point2(0,0)
print("Where does the line start?")
x = input("x: ")
start.x = int(x)
y = input("y: ")
start.y = int(y)
print("The line starts at ("+x+ ","+y+ ").")
print("Where does the line stop?")
x = input("x: ")
stop.x = int(x)
y = input("y: ")
stop.y = int(y)
print("The line stops at ("+x+ ","+y+ ").")
```


Let's make a function!

```
# pt is the point object to be initialized
# end type is "start" or "stop"
def configure(pt, end):
    print("Where does the line " + end + "?")
    x = input("x: ")
    pt.x = int(x)
    y = input("y: ")
    pt.y = int(y)
    print("The line " +end+ "s at ("+x+ ","+y+ ")."
)

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```


Still a bit of redundancy

```
# pt is the point object to be initialized
# end type is "start" or "stop"
def configure(pt, end):
    print("Where does the line " + end + "?")
    x = input("x: ")
    pt.x = int(x)
    y = input("y: ")
    pt.y = int(y)
    print("The line " +end+ "s at ("+x+ ","+y+ ")."
)

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```

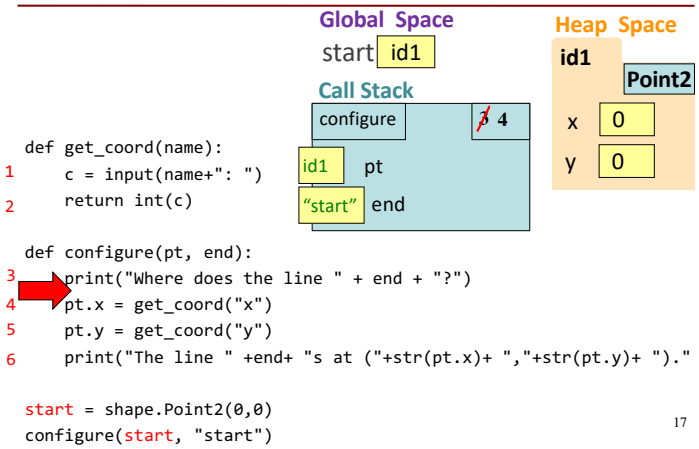
Yay, Helper Functions!

```
def get_coord(name):
    x = input(name+": ")
    return int(x)

def configure(pt, end):
    print("Where does the line " + end + "?")
    pt.x = get_coord("x")
    pt.y = get_coord("y")
    print("The line " +end+ "s at ("+str(pt.x)+ ","+str(pt.y)+
")." )
)

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```

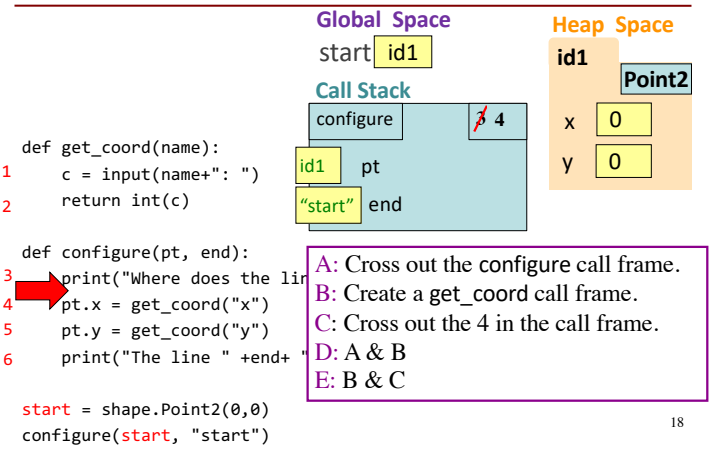

Frames and Helper Functions

- Functions can call each other!
- Each call creates a *new call frame*
- Writing the same several lines of code in 2 places? Or code that accomplishes some conceptual sub-task? Or your function is getting too long? Write a **helper function!** Makes your code easier to
  - **read**
  - **write**
  - **edit**
  - **debug**

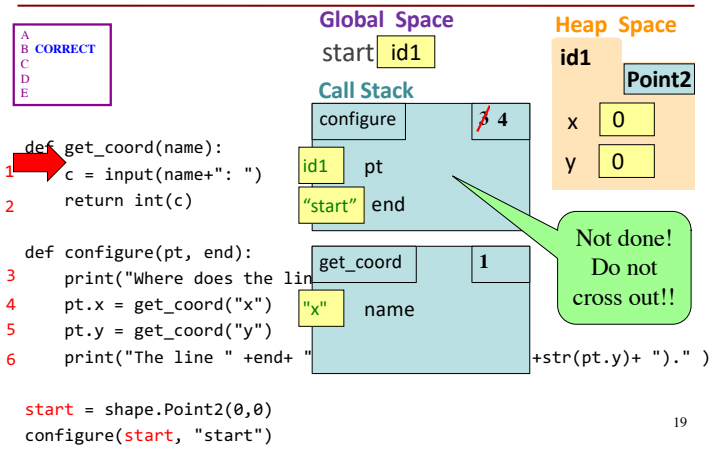
Drawing Frames for Helper Functions (1)



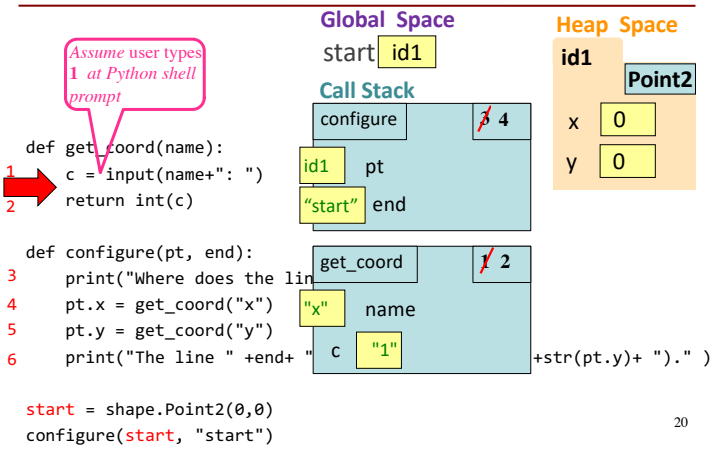
Q1: what do you do next?



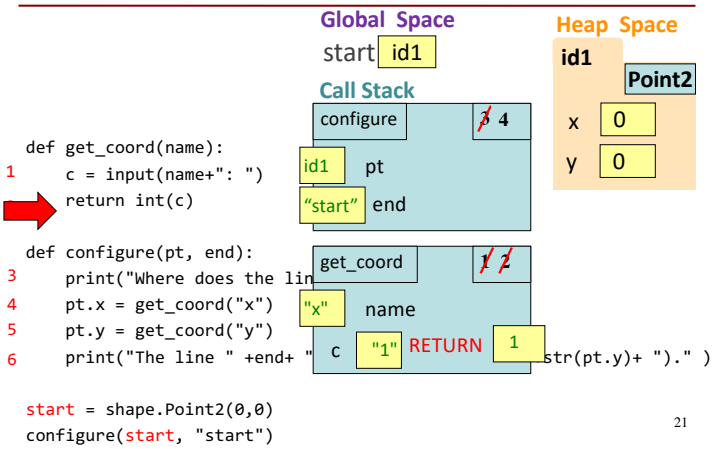
Drawing Frames for Helper Functions (2)



Drawing Frames for Helper Functions (3)

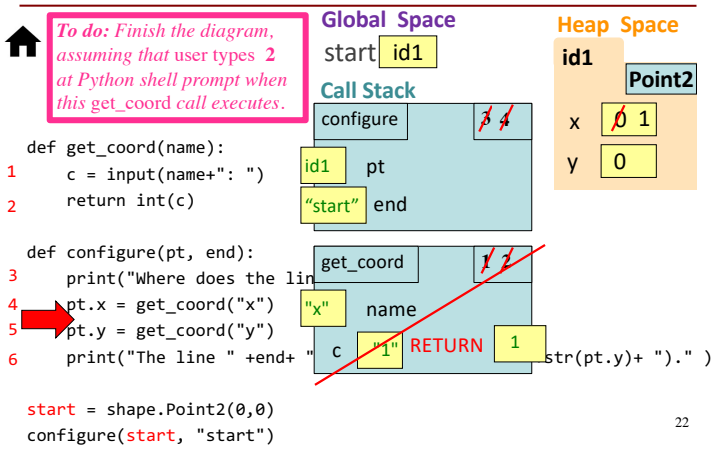


Drawing Frames for Helper Functions (4)



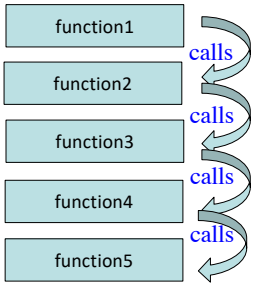
Drawing Frames for Helper Functions (5)

To do: Finish the diagram, assuming that user types 2 at Python shell prompt when this get_coord *call executes.*



The Call Stack

- The set of function frames drawn in call order
- Functions frames are "stacked"
  - Cannot remove one above w/o removing one below
- Python must keep the **entire stack** in memory
  - Error if it cannot hold stack ("stack overflow")



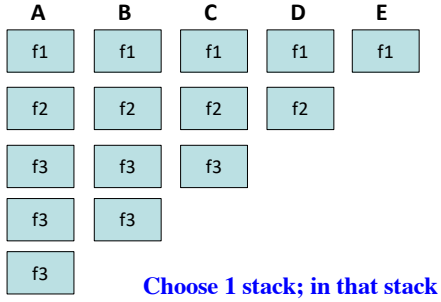
Errors and the Call Stack

```
def get_coord(name):
9   c = input(name+": ")
10  return int(x)

def configure(pt, end):
13  print("Where does the line "
14  pt.x = get_coord("x")
15  pt.y = get_coord("y")
16  print("The line " +end+ "s at ("+x+ ","+y+ ")." )

18 start = shape.Point2(0,0)
19 configure(start, "start")
```

```
Where does the line start?
x: 1
Traceback (most recent call last):
  File "v3.py", line 19, in <module>
    configure(start, "start")
  File "v3.py", line 14, in configure
    pt.x = get_coord("x")
  File "v3.py", line 10, in get_coord
    return str(x)
NameError: name 'x' is not defined
```


Q2: what does the call stack look like at this point in the execution of the code?

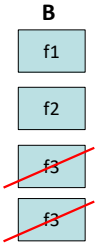
```
def f3():
    print("f3")

def f2():
    print("f2")
    f3()
    f3()
    f3()

def f1():
    print("f1")
    f2()

f1()
```



Choose 1 stack; in that stack cross out any frames that should have ended.

A2: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")

def f2():
    print("f2")
    f3()
    f3()
    f3()

def f1():
    print("f1")
    f2()

f1()
```

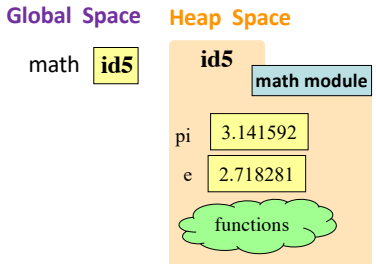


Choose 1 stack; in that stack cross out any frames that should have ended.

Modules and Global Space

Import

- Creates a global variable (same name as module)
- Puts variables, functions of module in a **folder**
- Puts folder id in the global variable

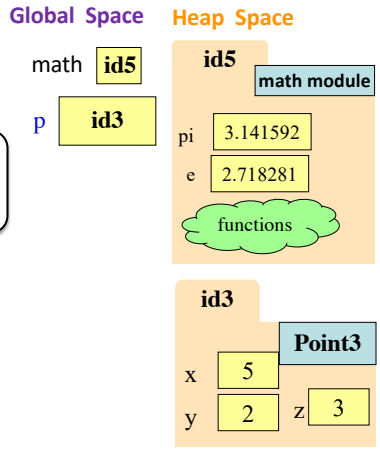



```
>>> import math
```


Modules vs Objects

```
>>> import math
>>> math.pi
```

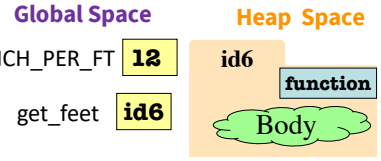
```
>>> p = shapes.Point3(5,2,3)
>>> p.x
```



Functions and Global Space

A function definition

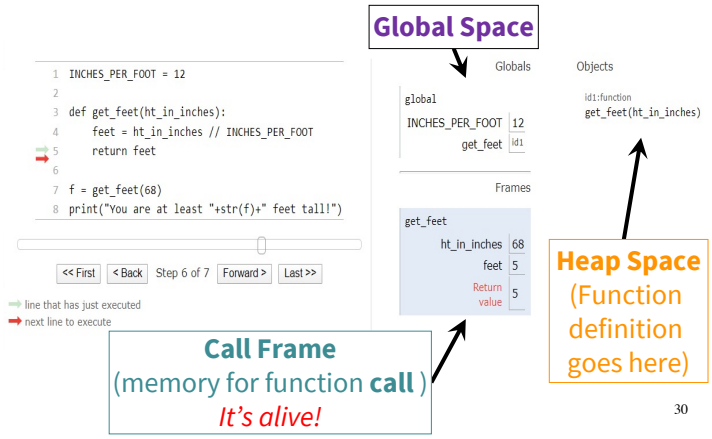
- Creates a global variable (same name as function)
- Creates a **folder** for body
- Puts folder id in the global variable




```
INCH_PER_FT = 12
def get_feet(ht_in_inches):
    return ht_in_inches // INCH_PER_FT
```

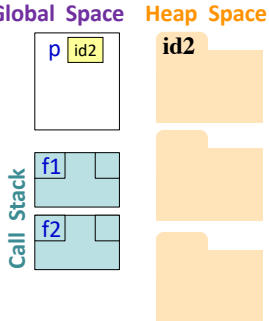
Body

Function Definition vs. Call Frame



Storage in Python

- **Global Space**
  - What you "start with"
  - Stores global variables, modules & functions
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly
- **Call Stack**
  - Where Call Frames live
  - Parameters
  - Other variables local to function
  - Lasts until function returns



Don't draw module folder, function folder

Folders that we do not require you to draw:

- Module folder is created upon import, for example,

  import math

- Function folder is created with def (the function header), for example,

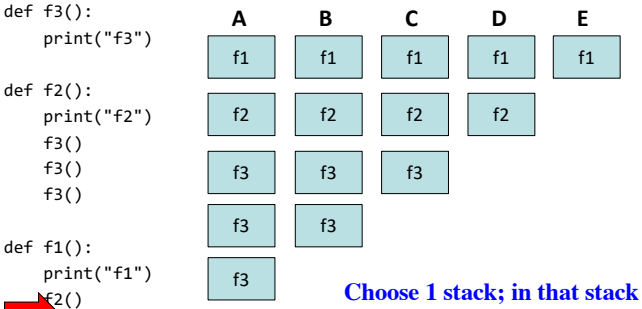
  def get_feet(height_in_inches):

Don't draw those folders and the variables that store their ids; we only explained those folders to explain what you see in Python Tutor.

Do not draw them.

Q3: what does the call stack look like at this point in the execution of the code?

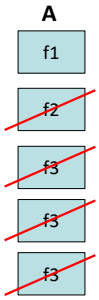
```
def f3():
    print("f3")

def f2():
    print("f2")
    f3()
    f3()
    f3()

def f1():
    print("f1")
    f2()

f1()
```



Choose 1 stack; in that stack cross out any frames that should have ended.

A3: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")

def f2():
    print("f2")
    f3()
    f3()
    f3()

def f1():
    print("f1")
    f2()

f1()
```



Choose 1 stack; in that stack cross out any frames that should have ended.