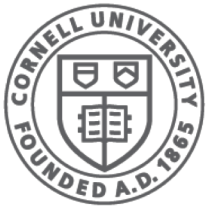
http://www.cs.cornell.edu/courses/cs1110/2019sp

Lecture 9: Memory in Python

CS 1110

Introduction to Computing Using Python

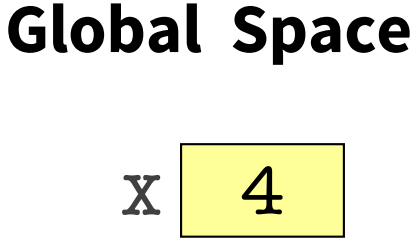


Cornell CIS
COMPUTING AND INFORMATION SCIENCE

[E. Andersen, A. Bracy, D. Gries, L. Lee, S. Marschner, C. Van Loan, W. White]

Global Space

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

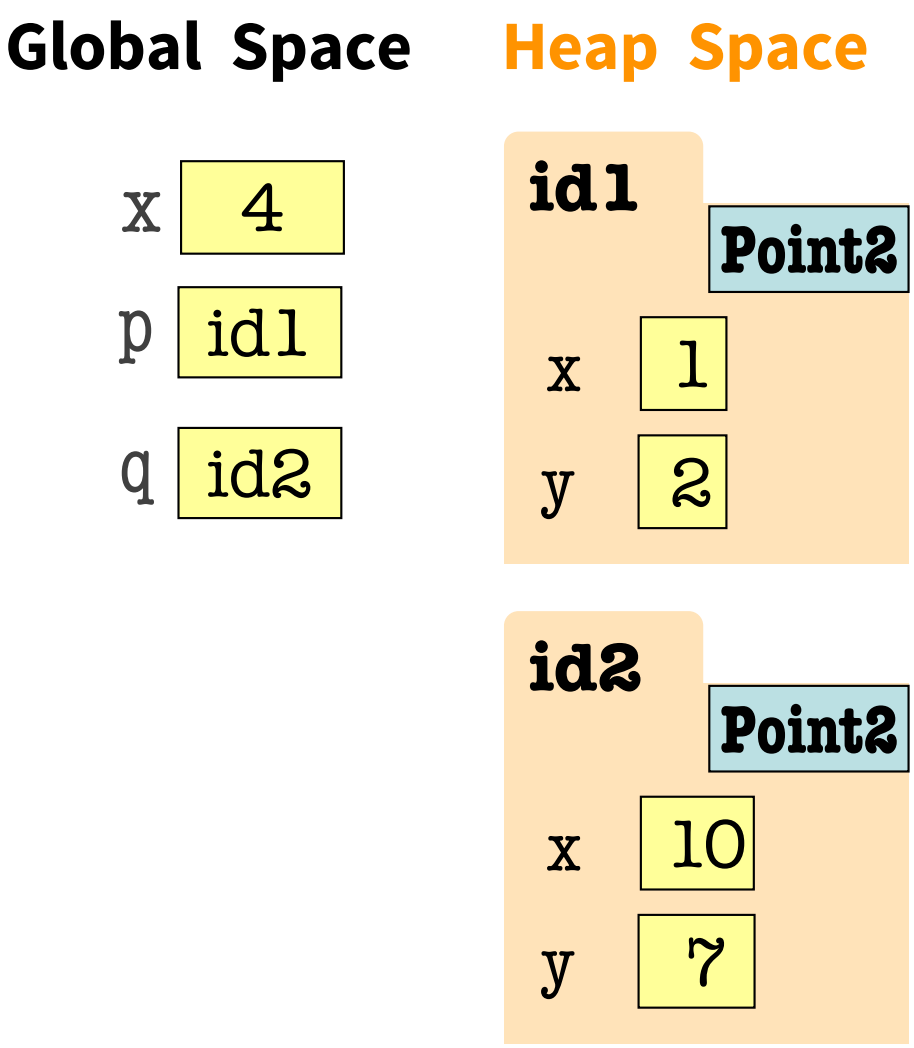



```
x = 4
```

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)
```



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

Calling a Function Creates a Call Frame

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_coord(pt, n):
    pt.x = pt.x + n

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

1

Global Space

x	4
p	id1

Heap Space

id1 — Point2

x	1
y	2

Call Frame

adjust_x_coord — 1

pt	id1
n	4

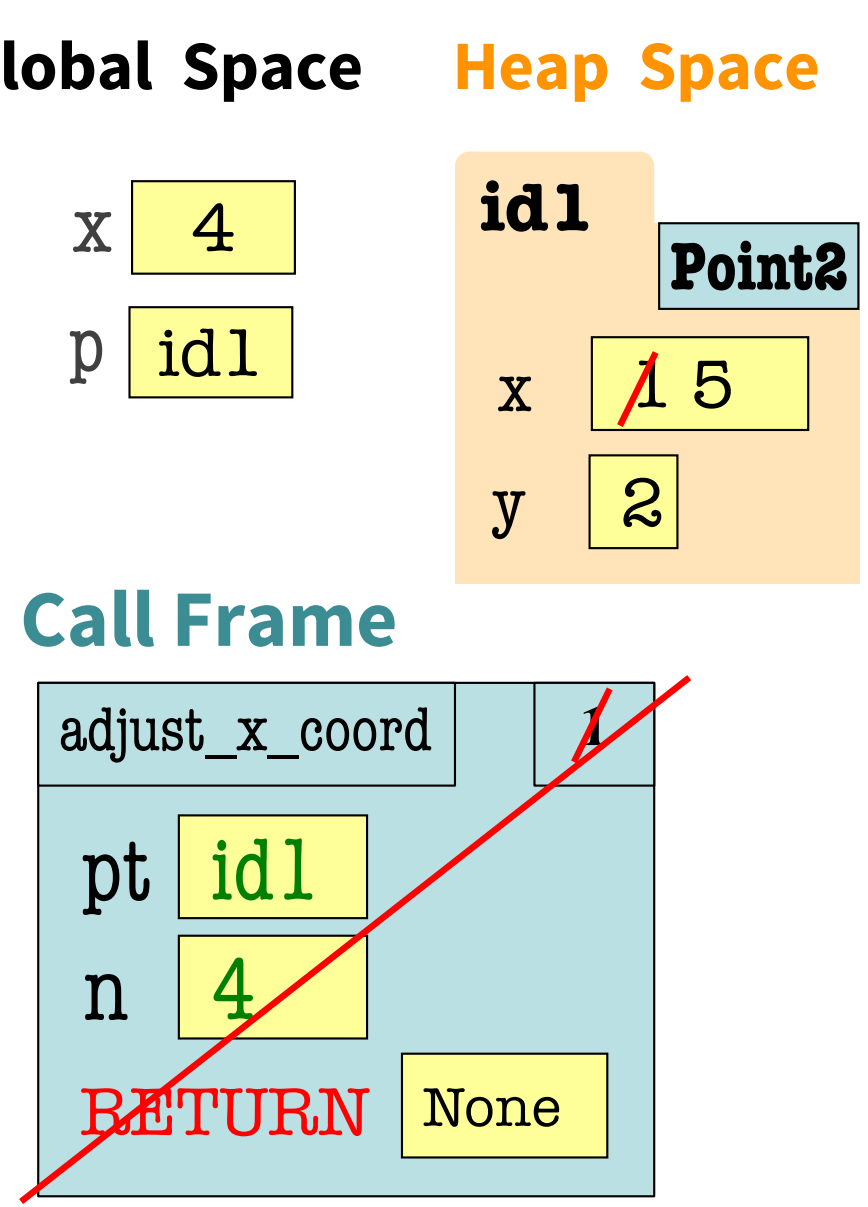
Calling a Function Creates a Call Frame

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**

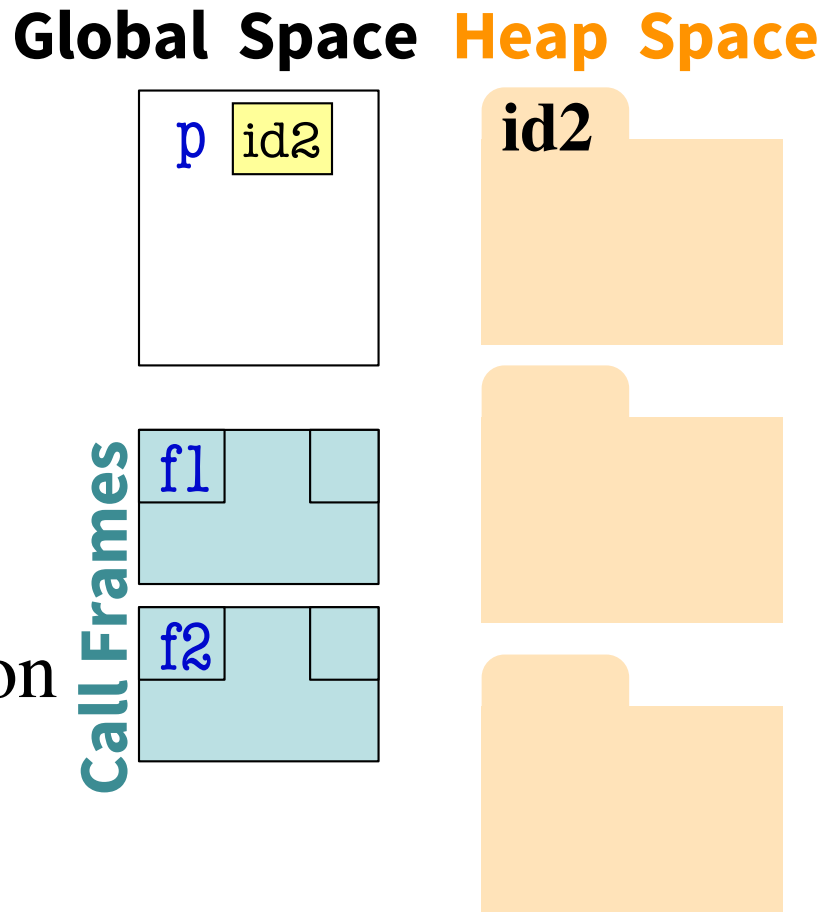
```
def adjust_x_coord(pt, n):
    pt.x = pt.x + n

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

1



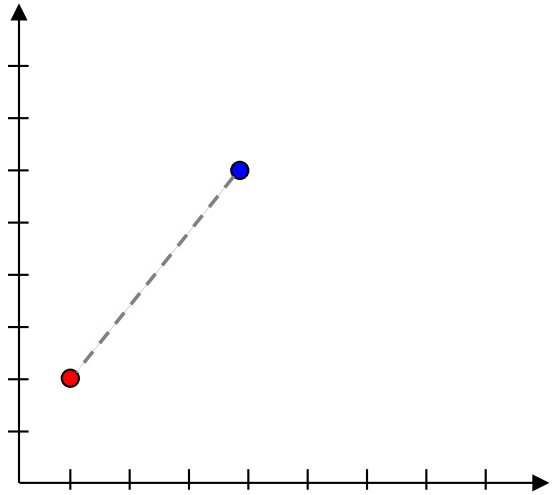
Putting it all together

- **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



2 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!

```
def configure(pt, role):
    print("Where does the line " + role + "?")
    x = input("x: ")
    pt.x = int(x)
    y = input("y: ")
    pt.y = int(y)
    print("The line " +role+ "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

```
def configure(pt, role):
    print("Where does the line " + role + "?")
    x = input("x: ")
    pt.x = int(x)
    y = input("y: ")
    pt.y = int(y)
    print("The line " +role+ "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 str(x)
```

int

← Actual bug I wrote in my code. Not staged!

Only have to fix 1 line. In the first version, I would have had to fix it in 4 places!

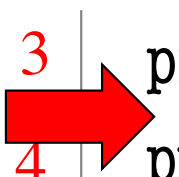
```
def configure(pt, role):
    print("Where does the line " + role + "?")
    pt.x = get_coord("x")
    pt.y = get_coord("y")
    print("The line " +role+ "s at ("+x+ ","+y+ ")." )

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

Frames and Helper Functions

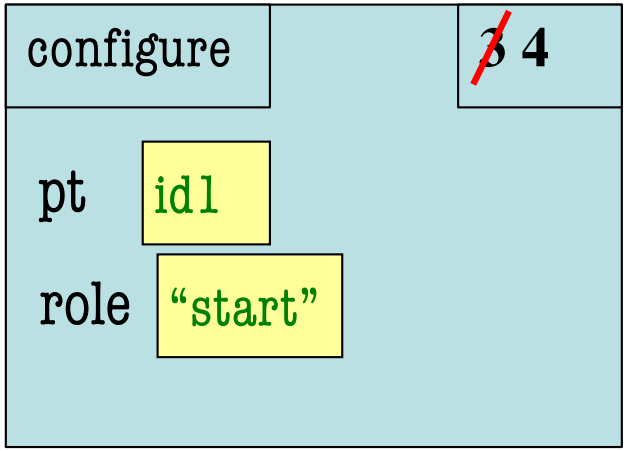
- Functions can call each other!
- Each call creates a *new call frame*
- Writing the same several lines of code in 2 places? Or code that accomplishes some conceptual sub-task? Or your function is getting too long? Write a **helper function!** Makes your code easier to:
  - **Read**
  - **Write**
 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

Drawing Frames for Helper Functions (1)

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

def configure(pt, role):
3     print("Where does the line " + role + "?")
4     pt.x = get_coord("x")
5     pt.y = get_coord("y")
6     print("The line " +role+ "s at ("+str(pt.x)+
              ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

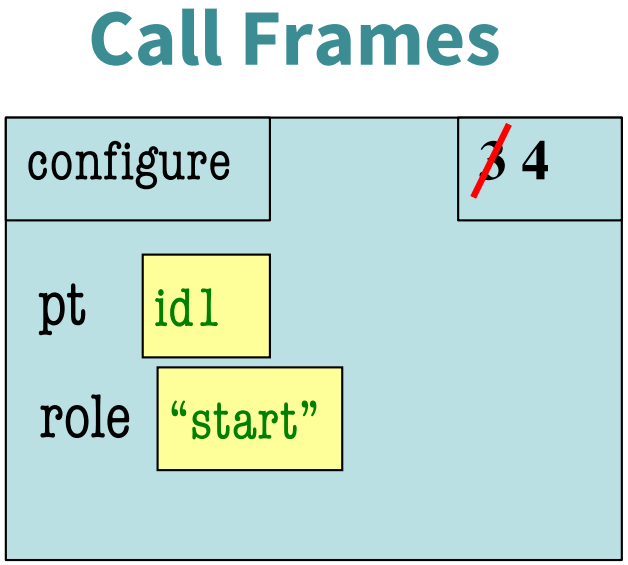


Call Frames

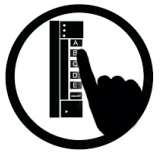


Q: what do you do next?

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

def configure(pt, role):
3     print("Where does the line " + role + "?")
4     pt.x = get_coord("x")
5     pt.y = get_coord("y")
6     print("The line " +role+ "s a
            ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```



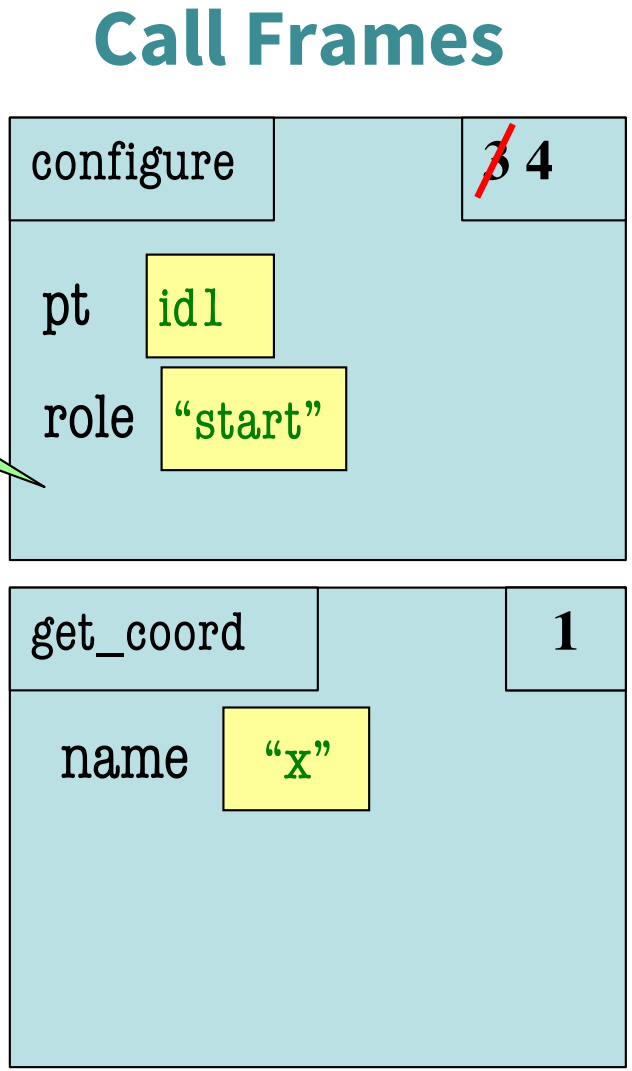
A: Cross out the configure call frame.
B: Create a get_coord call frame.
C: Cross out the 4 in the call frame.
D: A & B
E: B & C



Drawing Frames for Helper Functions (2)

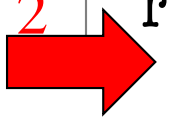
```
def get_coord(name):
1     x = input(name+": ")
2     return int(x)

def configure(pt, role):
3     print("Where does the line " + role + "?")
4     pt.x = get_coord("x")
5     pt.y = get_coord("y")
6     print("The line " +role+ "s at ("+str(pt.x)+
            ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

Not done!
Do not cross out!!

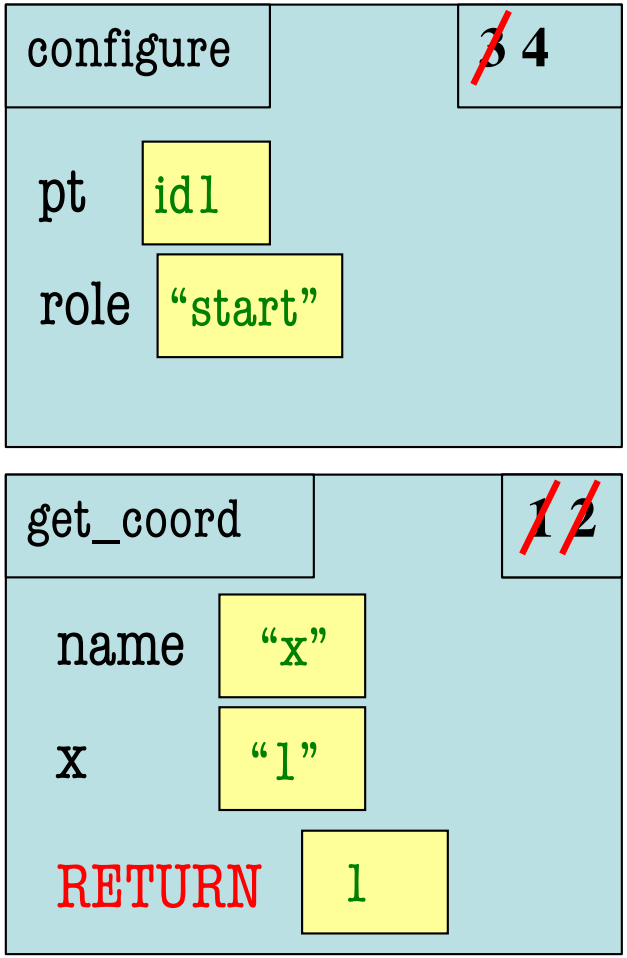


Drawing Frames for Helper Functions (3)

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

def configure(pt, role):
3       print("Where does the line " + role + "?")
4       pt.x = get_coord("x")
5       pt.y = get_coord("y")
6       print("The line " +role+ "s at ("+str(pt.x)+
                "," +str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

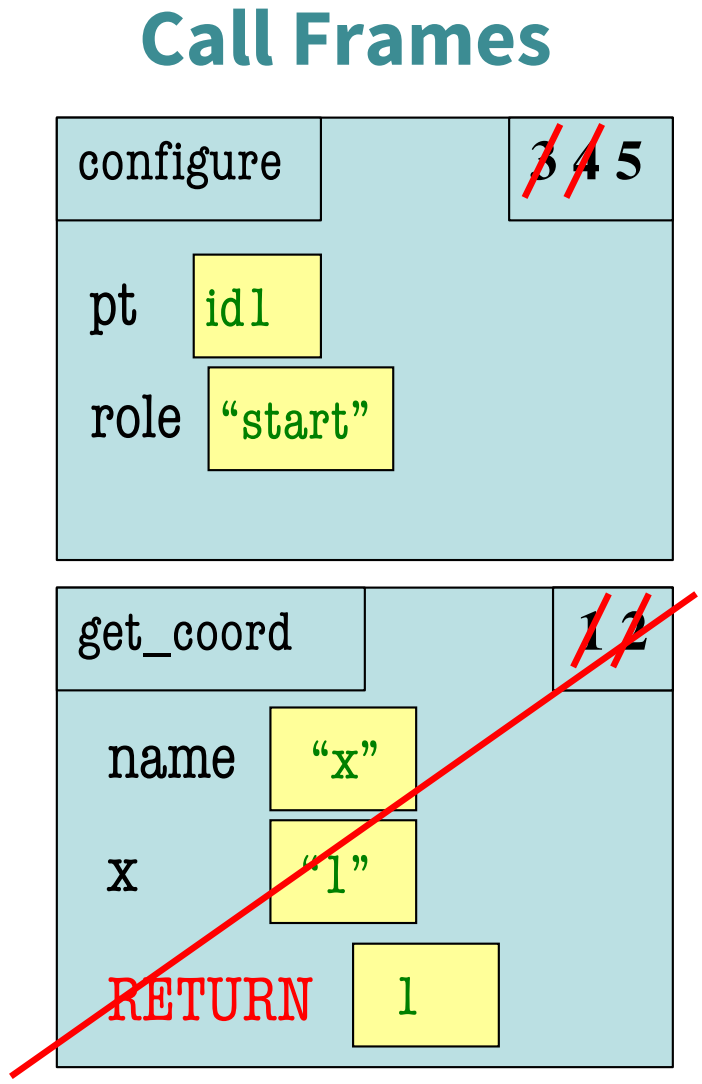


Call Frames



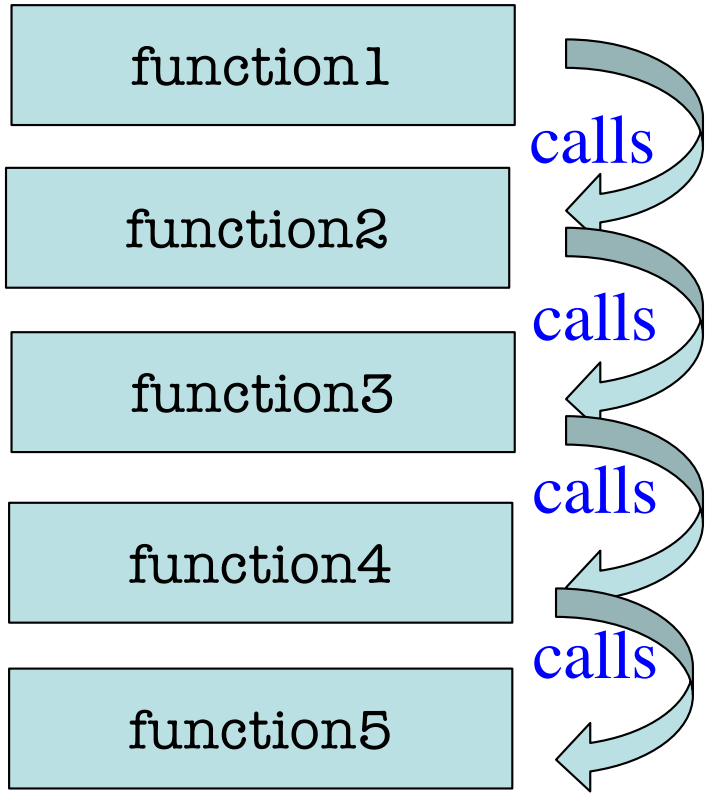
Drawing Frames for Helper Functions (4)

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

def configure(pt, role):
3       print("Where does the line " + role + "?")
4       pt.x = get_coord("x")
5       pt.y = get_coord("y")
6       print("The line " +role+ "s at ("+str(pt.x)+
                "," +str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```



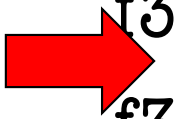
The Call Stack

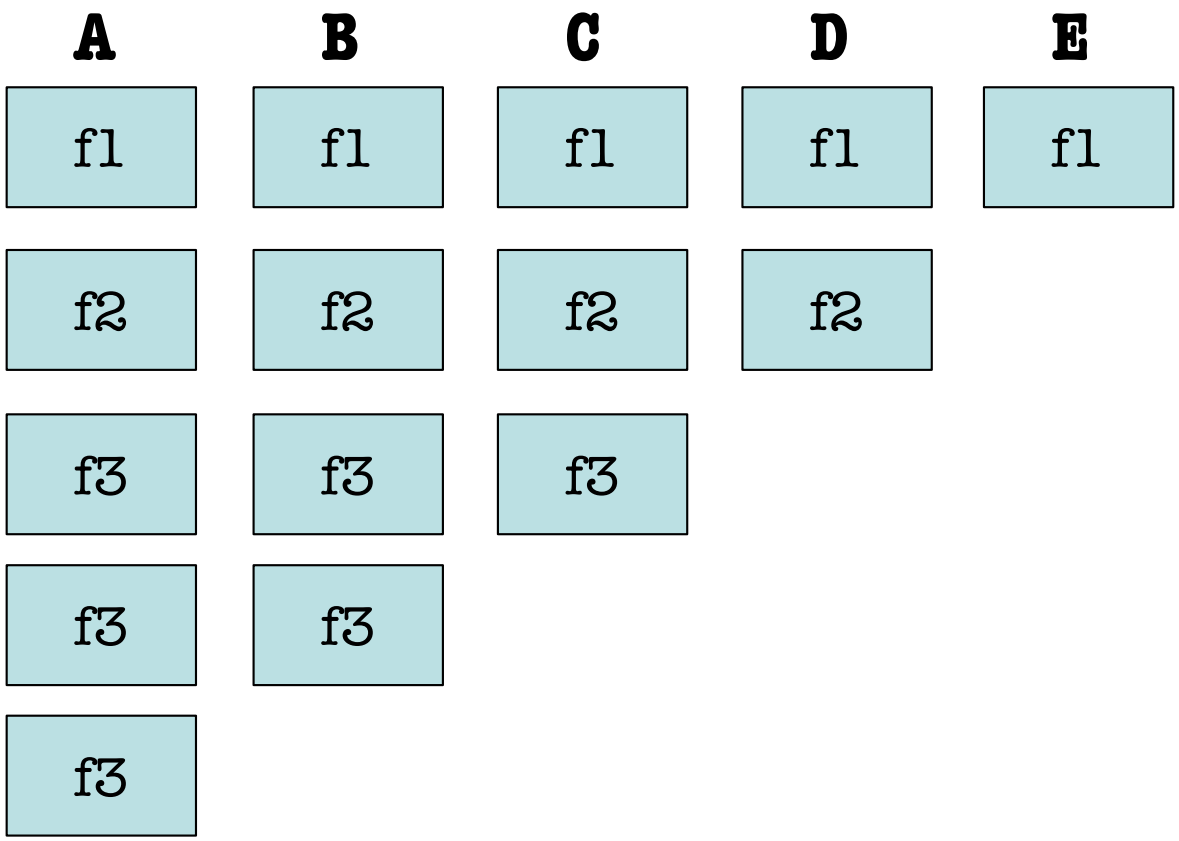
- Functions frames are "stacked"
  - Cannot remove one above w/o removing one below
- Python must keep the **entire stack** in memory
  - Error if it cannot hold stack ("stack overflow")

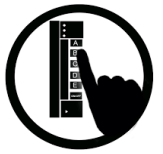


Q: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")
def f2():
    print("f2")
    f3()
    f3()
    f3()
def f1():
    print("f1")
    f2()
f1()
```

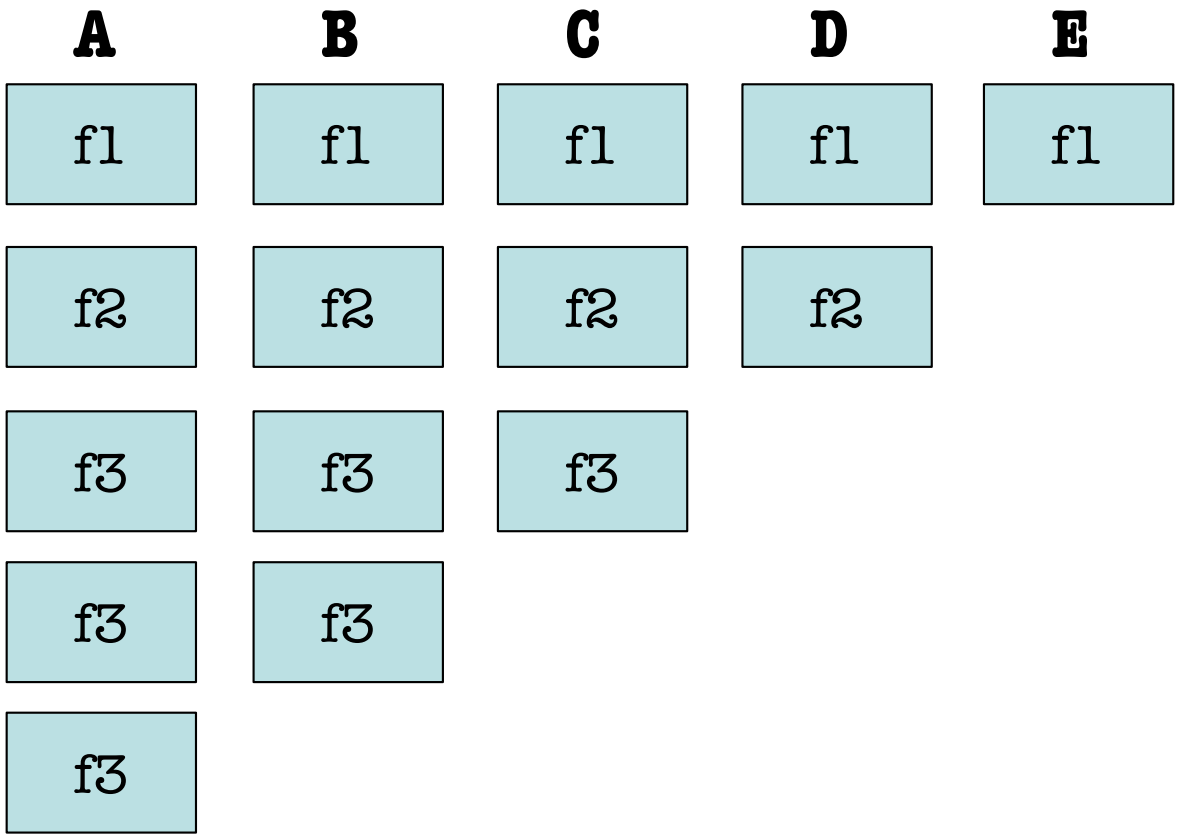


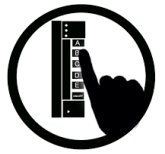




Q: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")
def f2():
    print("f2")
    f3()
    f3()
    f3()
def f1():
    print("f1")
    f2()
f1()
```





Errors and the Call Stack

```
def get_coord(name):
1     x = input(name+": ")
2     return int(x1)

def configure(pt, role):
3     print("Where does the line
4     pt.x = get_coord("x")
5     pt.y = get_coord("y")
6     print("The line " +role+ "s

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

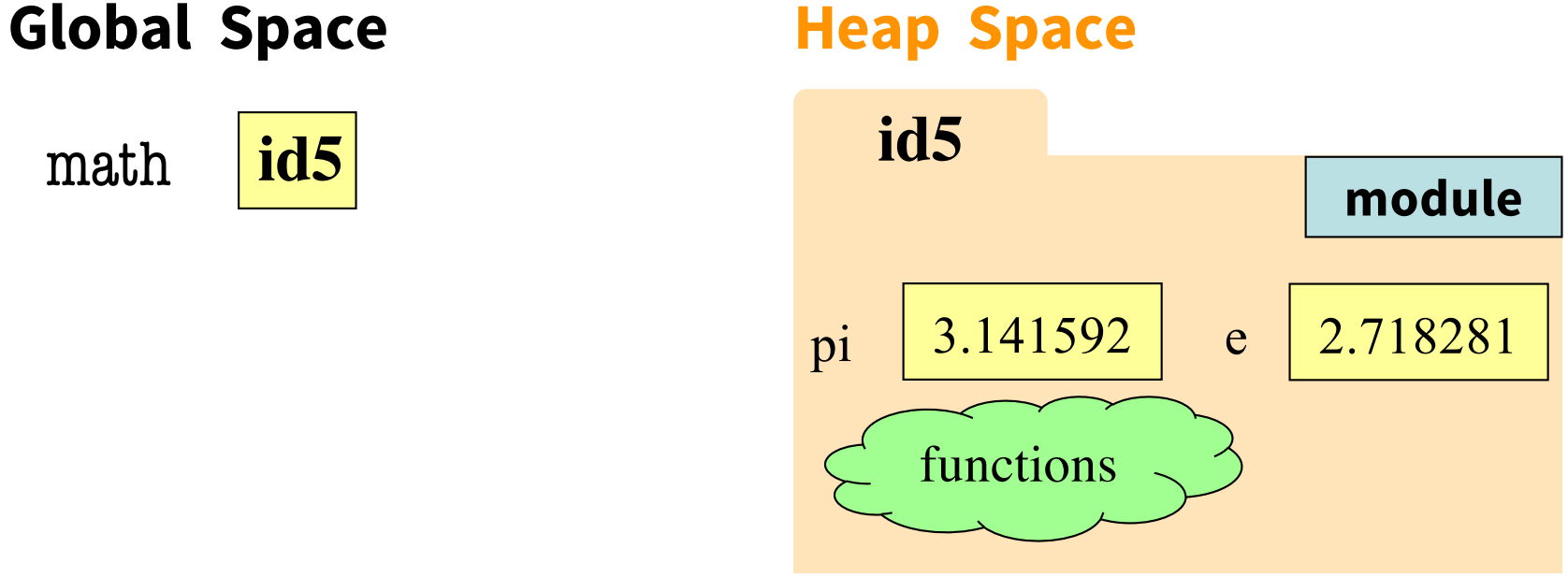
```
Where does the line start?
x: 1
Traceback (most recent call last):
  File "v3.py", line 15, in <module>
    configure(start, "start")
  File "v3.py", line 9, in configure
    pt.x = get_coord("x")
  File "v3.py", line 5, in get_coord
    return str(x1)
NameError: name 'x1' is not defined
```

Modules and Global Space

import

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

```
import math
```



Modules vs Objects

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

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

Global Space

math → **id5**

p → **id3**

Heap Space

id5 — **math**

pi: 3.141592

e: 2.718281

functions

id3 — **Point3**

x: 5

y: 2

z: 3

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 Frame Stack**
  - Parameters
  - Other variables local to function
  - Lasts until function returns