Lecture 9

Memory and Call Stacks

Announcements for Today

Assignment 1

- We have started grading!
  - Should have your grade tomorrow morning
  - Resubmit until correct
- If you were **close**…
  - Will get feedback in CMS
  - Fix your assignment
- If you were very **wrong**…
  - Will be contacted tonight!
  - Will hold one-on-ones Fri

Reading

- Reread Chapter 3
- No reading for Tuesday

More Assignments

- A2 due next week (Tues)
- A3 posted this Thursday
  - Due 2 weeks from Fri
  - Before leave for Fall Break

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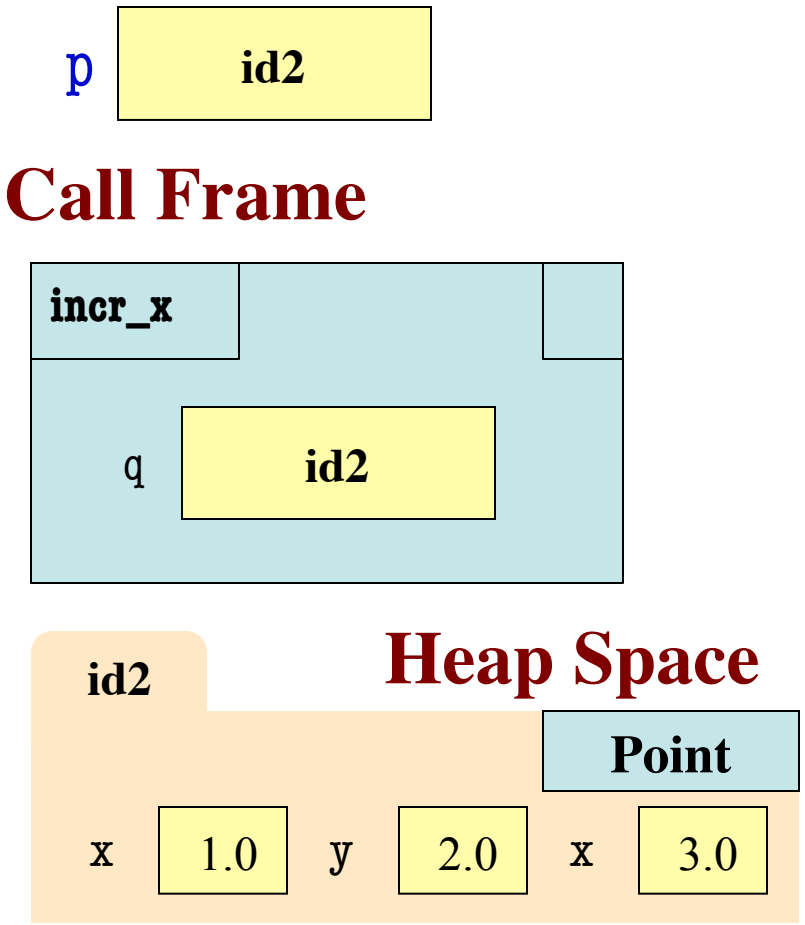
Complete the Survey on Assignment 1!

Modeling Storage in Python

- **Global Space**
  - What you "start with"
  - Stores global variables
  - Also **modules & functions!**
  - Lasts until you quit Python
- **Call Frame**
  - Variables in function call
  - Deleted when call done
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly



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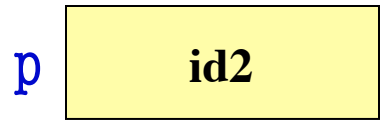
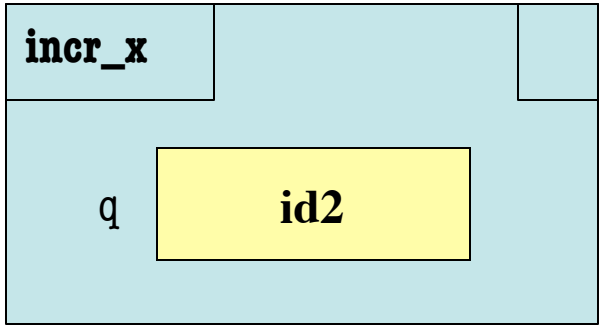
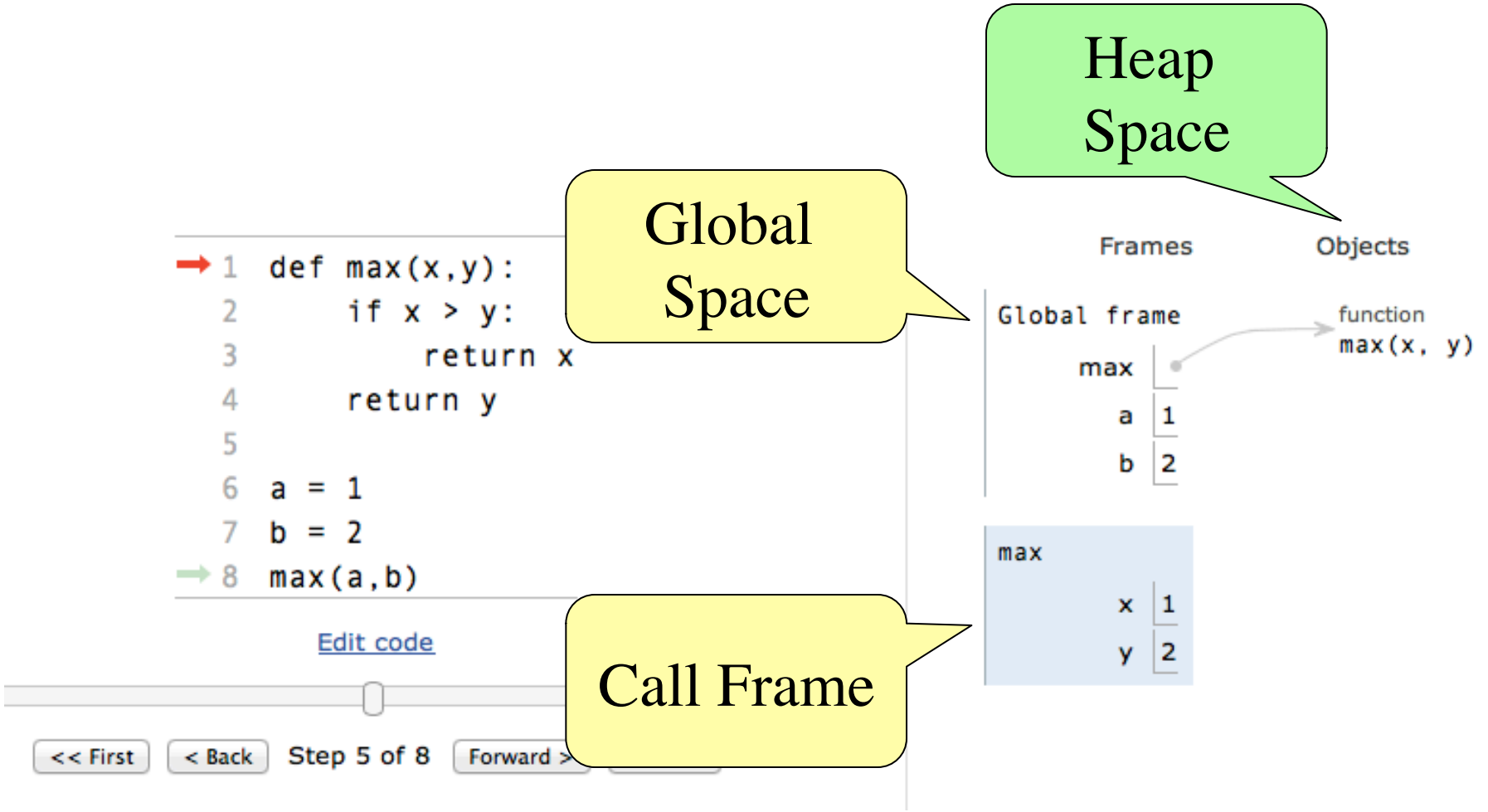
Global Space



Call Frame



Memory and the Python Tutor



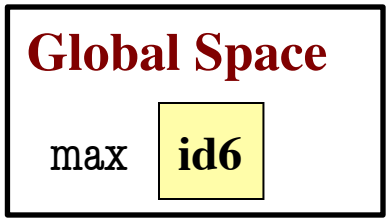
Functions and Global Space

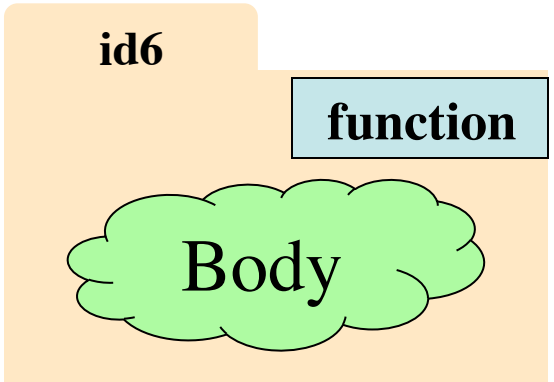
- A function definition…
  - Creates a global variable (same name as function)
  - Creates a **folder** for body
  - Puts folder id in variable
- Variable vs. Call

```
>>> max
<fun max at 0x100498de8>
>>> max(1,2)
2
```

```
def max(x,y):
    if x > y:
        return x
    return y
```

Body

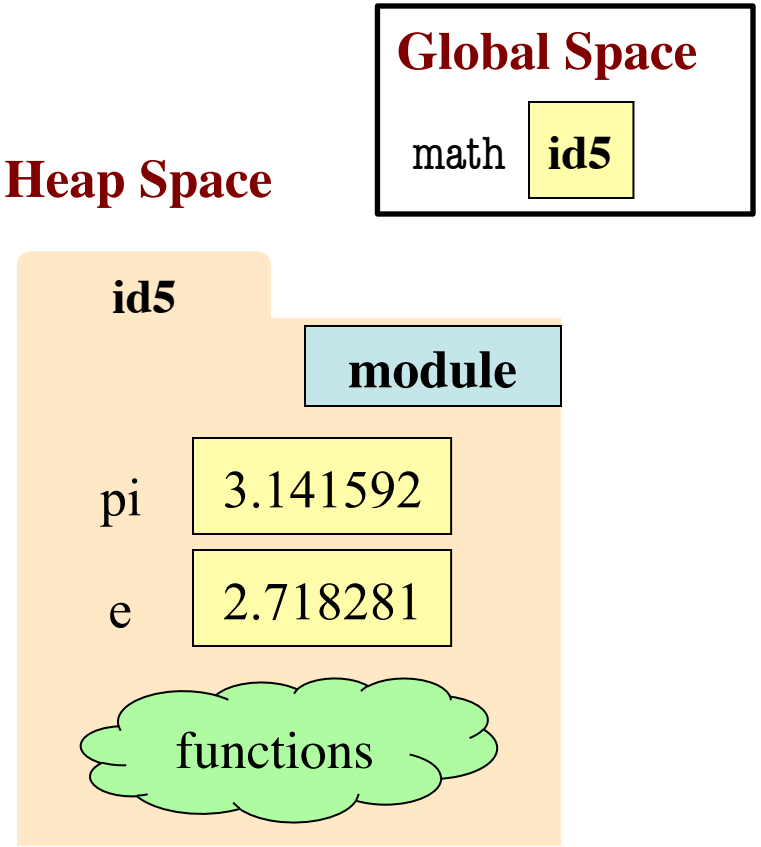




Modules and Global Space

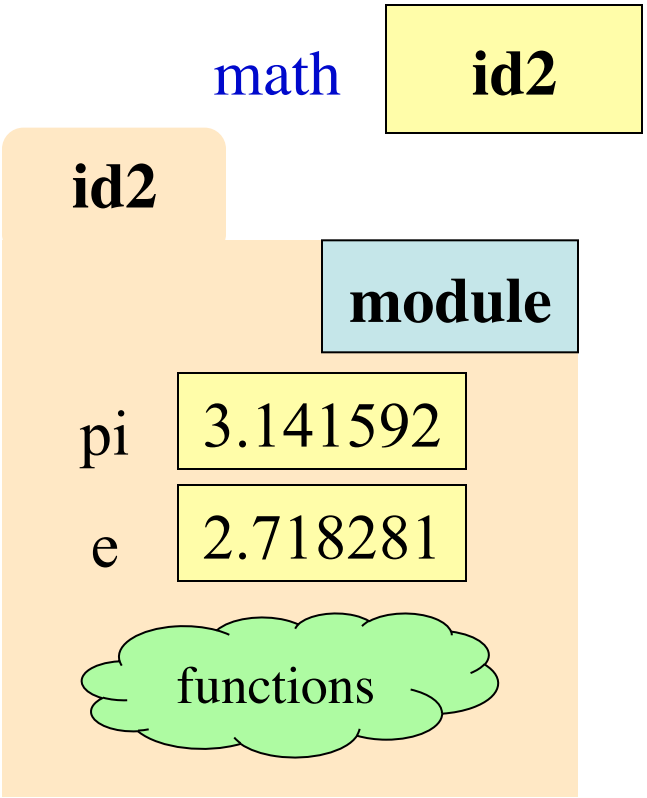
- Importing a module:
  - Creates a global variable (same name as module)
  - Puts contents in a **folder**
    - Module variables
    - Module functions
  - Puts folder id in variable
- **from** keyword dumps contents to global space

```
import math
```

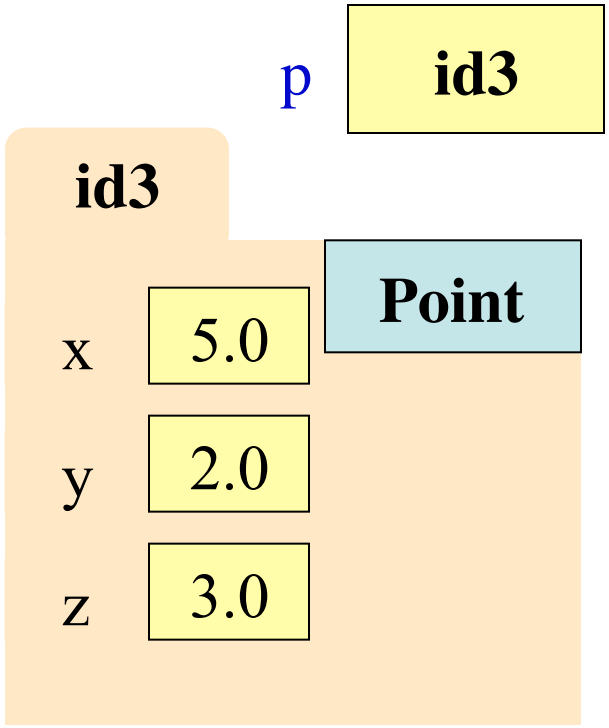


Modules vs Objects

Module



Object



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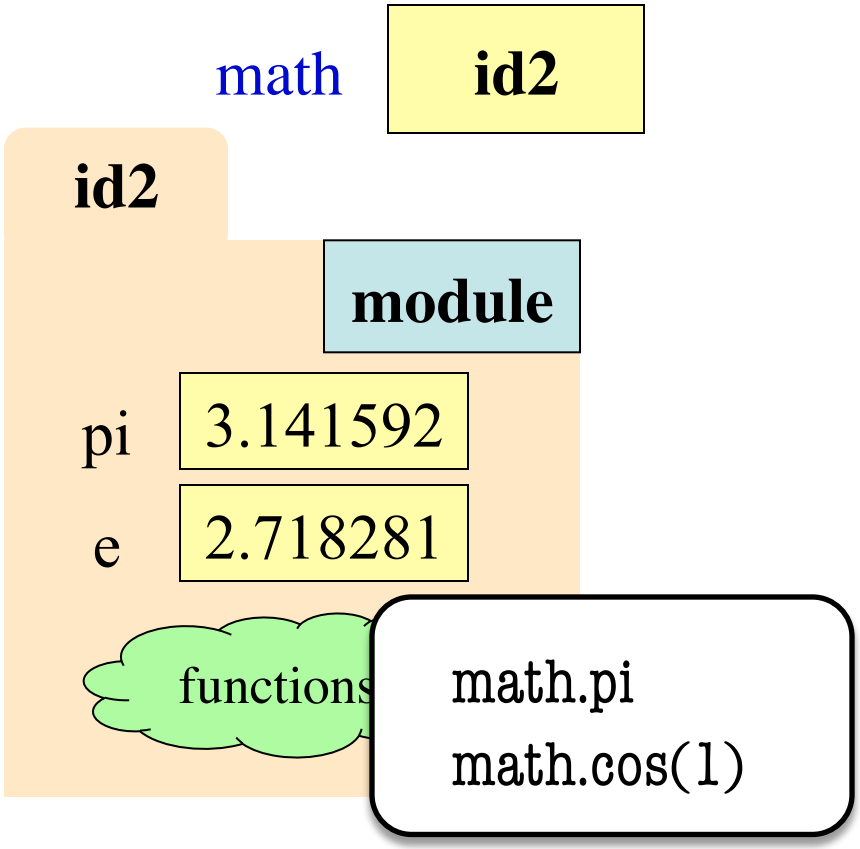

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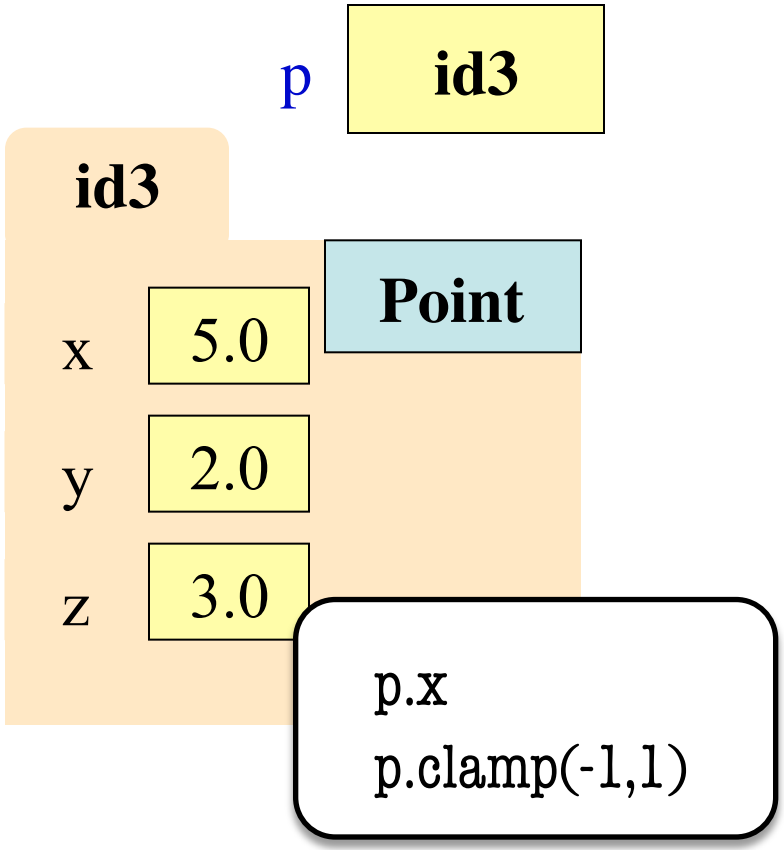


Modules vs Objects

Module

math | id2

id2

pi | 3.14159

e | 2.718281

functions

```
math.pi
math.cos(1)
```

Object

p | id3

y | 2.0

z | 3.0

```
p.x
p.clamp(-1,1)
```

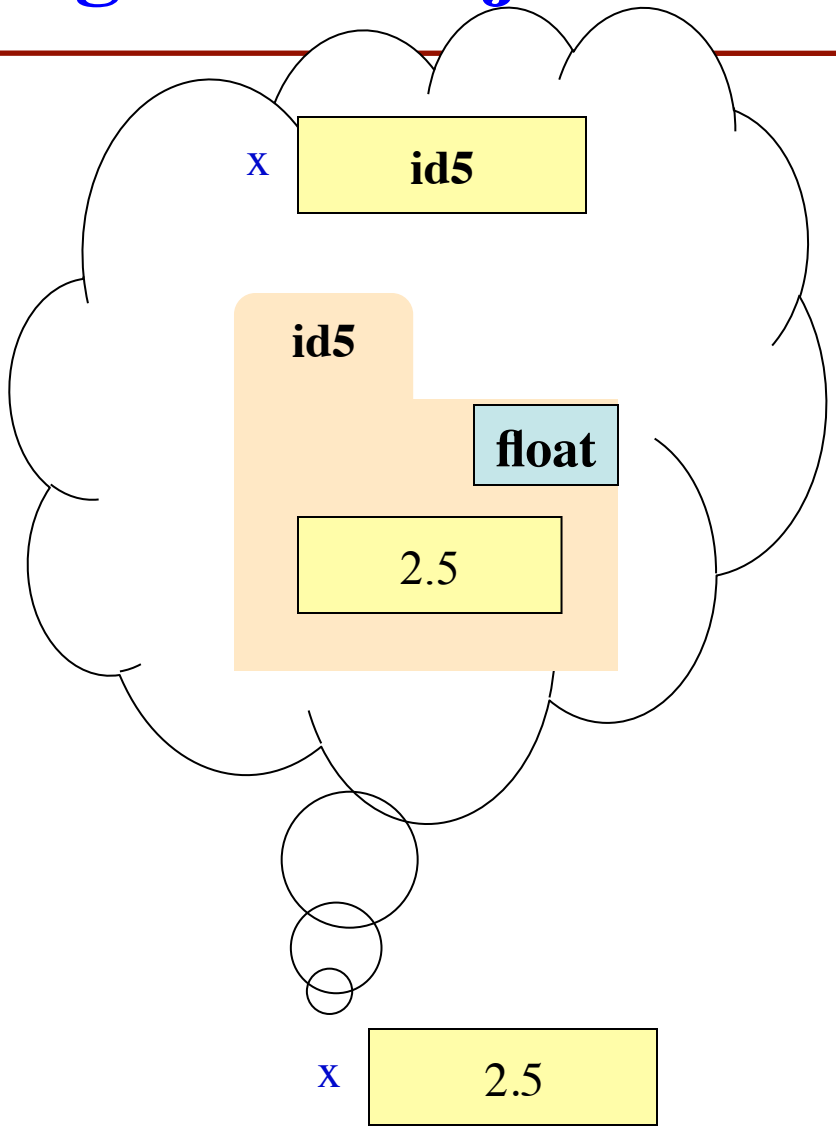
The period (.) means
"go inside of the folder"

Recall: Everything is an Object!

- Including *basic values*
  - int, float, bool, str
- **Example**:

```
>>> x = 2.5
>>> id(x)
```

- But basics are *immutable*
  - Contents cannot change
  - Distinction between *value* and *identity* is immaterial
  - So we can ignore the folder



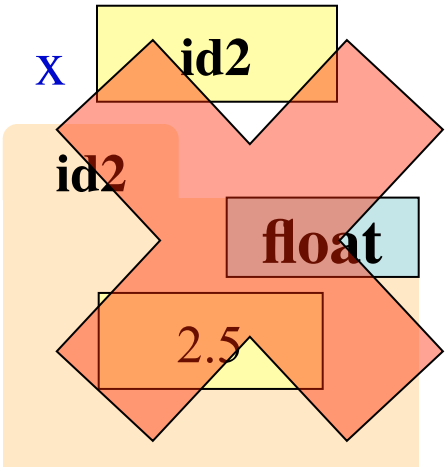
When Do We Need to Draw a Folder?

Yes

- Variable holds a
  - function
  - module
  - object
  - (more????)

No

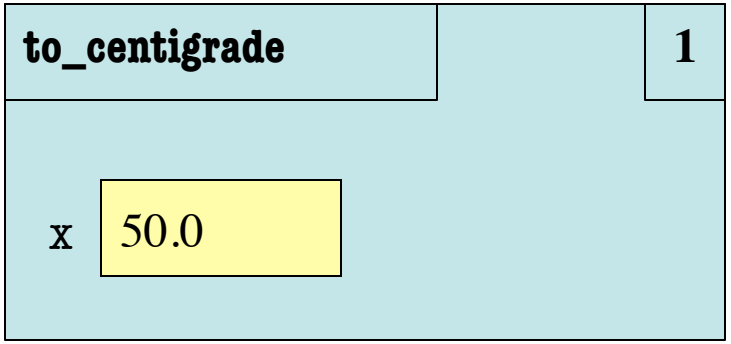
- Variable holds a
  - base type
  - bool, int, float, str



Review: Call Frames

1. Draw a frame for the call
2. Assign the argument value to the parameter (in frame)
3. Execute the function body
   - Look for variables in the frame
   - If not there, look for global variables with that name
4. Erase the frame for the call

Call: to_centigrade(50.0)



What is happening here?

Only at the End!

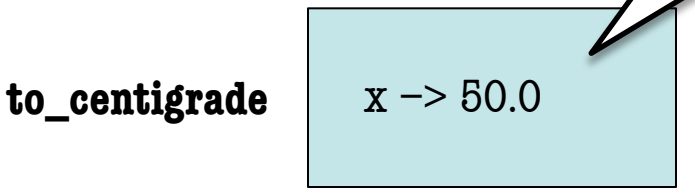
```
def to_centigrade(x):
    return 5*(x-32)/9.0
```

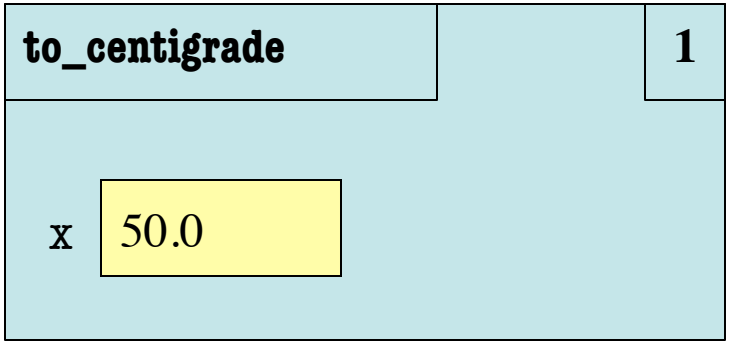
Text (Section 3.10) vs. Class

No instruction counter

Variables are not boxes

Textbook | **Class**





Definition:

```
def to_centigrade(x):
    return 5*(x-32)/9.0
```

Call: to_centigrade(50.0)

Aside: What Happens Each Frame Step?

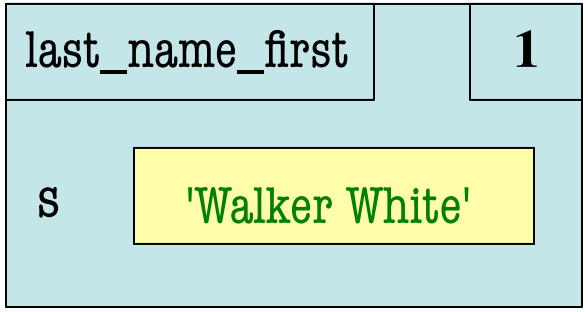
- The instruction counter **always** changes
- The contents only **change** if
  - You add a new variable
  - You change an existing variable
  - You delete a variable
- If a variable refers to a **mutable object**
  - The contents of the folder might change

Frames and Helper Functions

```
def last_name_first(s):
    """Precondition: s in the form
    <first-name> <last-name>"""
1   first = first_name(s)
2   last = last_name(s)
3   return last + ',' + first
```

```
def first_name(s):
    """Prec: see last_name_first"""
1   end = s.find(' ')
2   return s[0:end]
```

Call: last_name_first('Walker White'):



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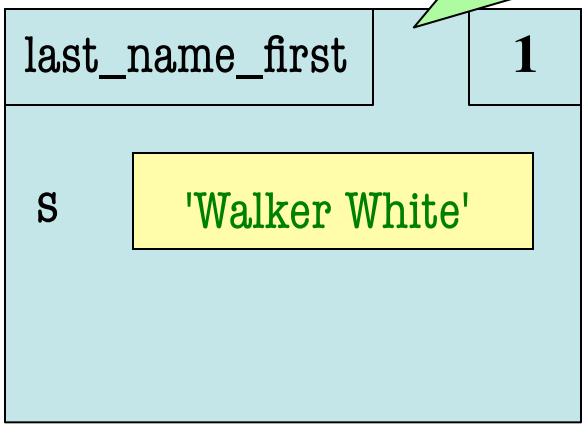
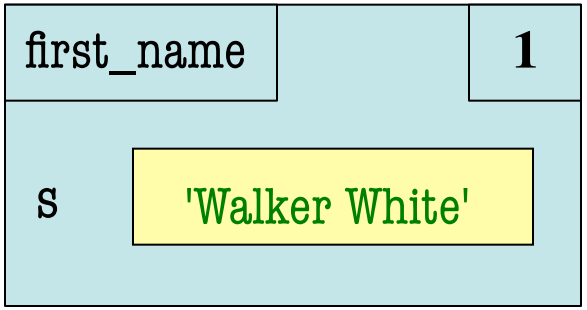
Call: last_

Not done. Do not erase!





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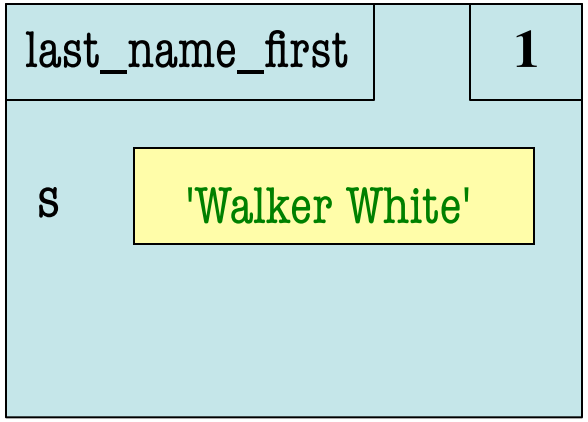

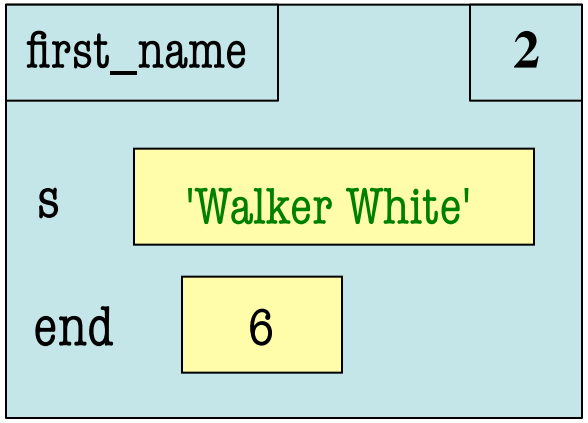

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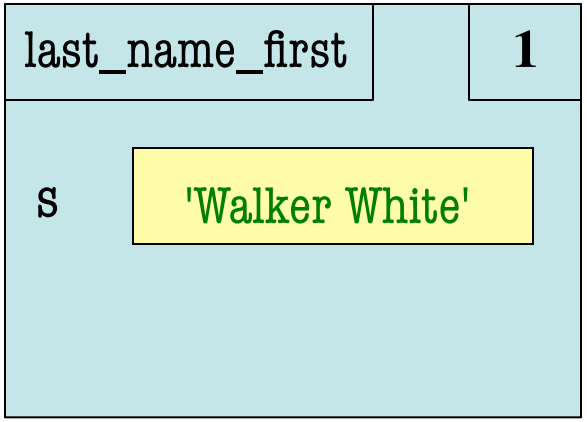

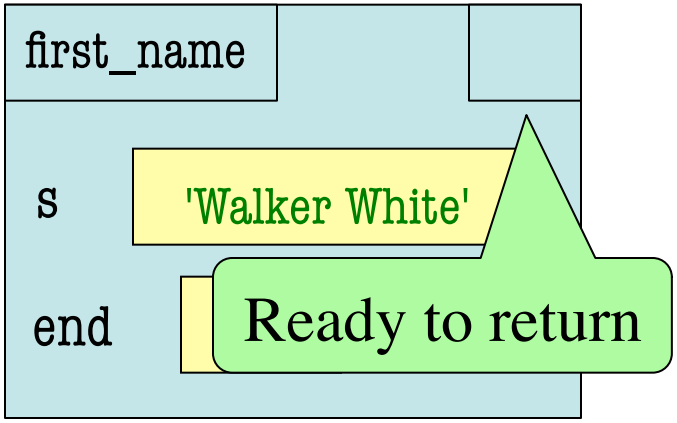

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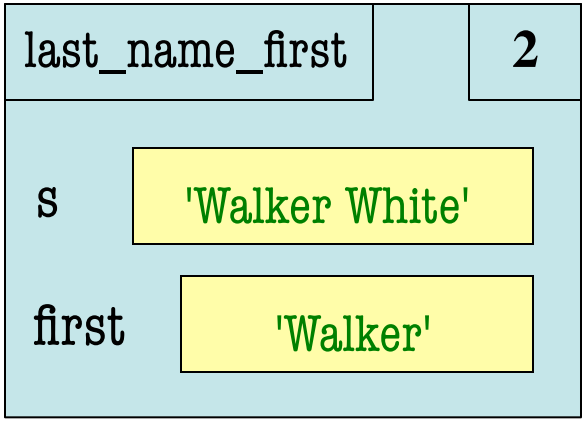


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ERASE WHOLE FRAME

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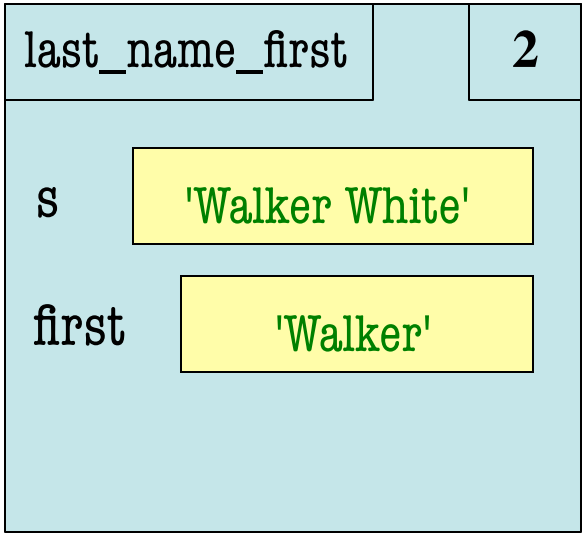
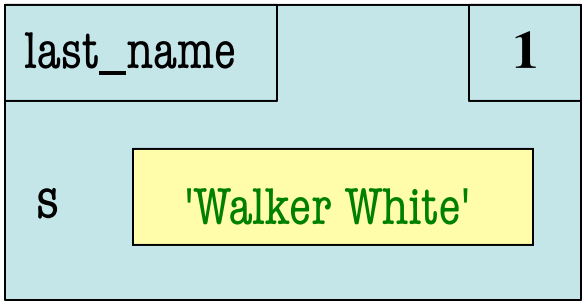
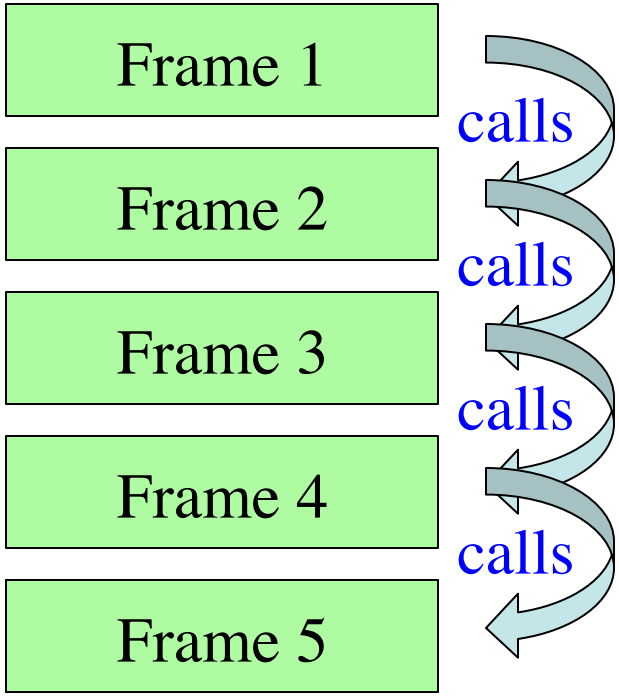




The Call Stack

- Functions are "stacked"
  - Cannot remove one above w/o removing one below
  - Sometimes draw bottom up (better fits the metaphor)
- Stack represents memory as a "high water mark"
  - Must have enough to keep the **entire stack** in memory
  - Error if cannot hold stack



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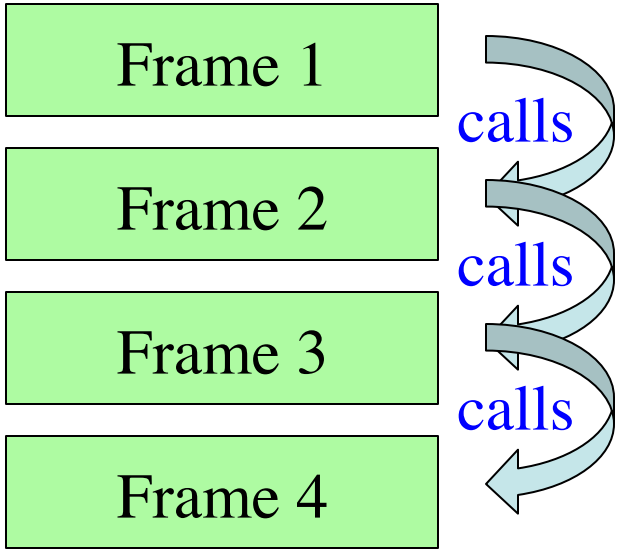

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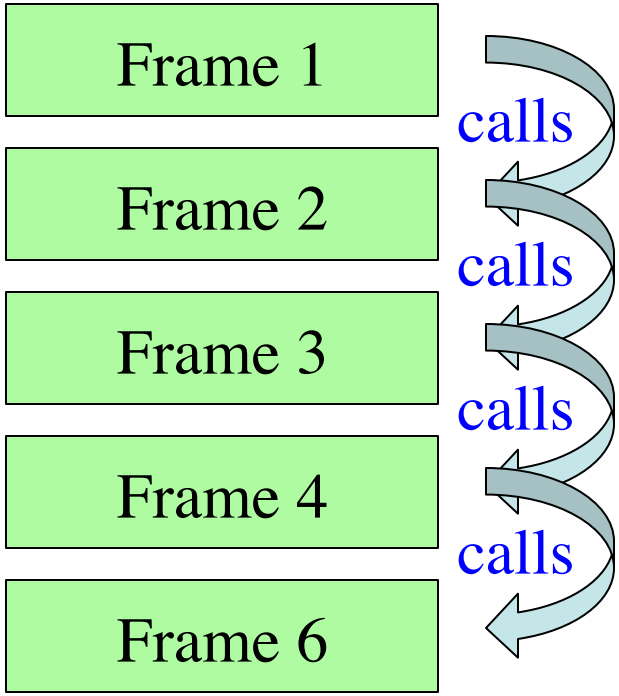

The Call Stack

- Functions are "stacked"
  - Can
    w/o
  - Son
    (bet

Book adds a special "frame" called `module`. This is **WRONG**! Module is global space

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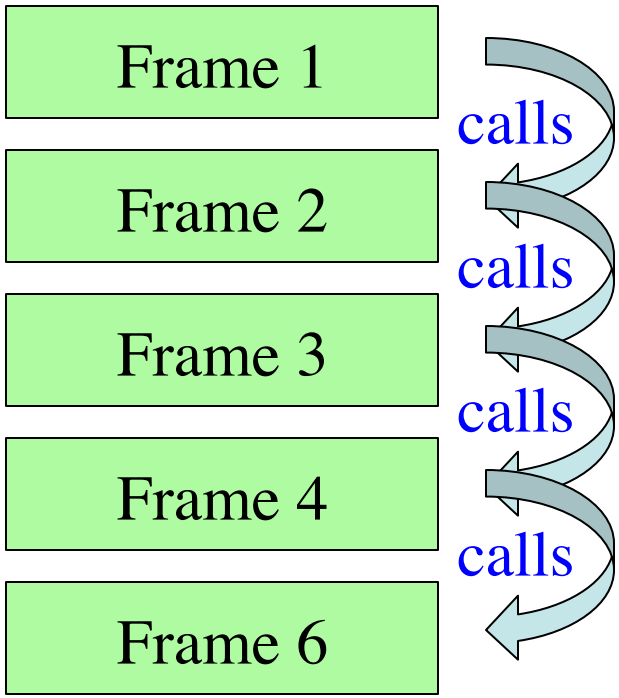
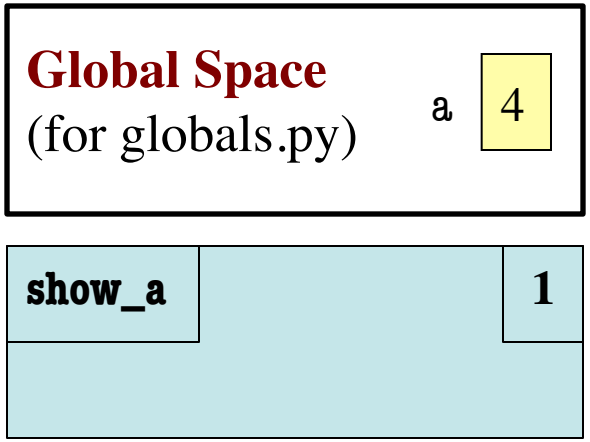


Function Access to Global Space

- All function definitions are in some module
- Call can access global space for **that module**
  - math.cos: global for math
  - temperature.to_centigrade uses global for temperature
- But **cannot** change values
  - Assignment to a global makes a new local variable!
  - Why we limit to constants




```
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"""Show how globals work"""
a = 4 # global space

def show_a():
    print a # shows global
```

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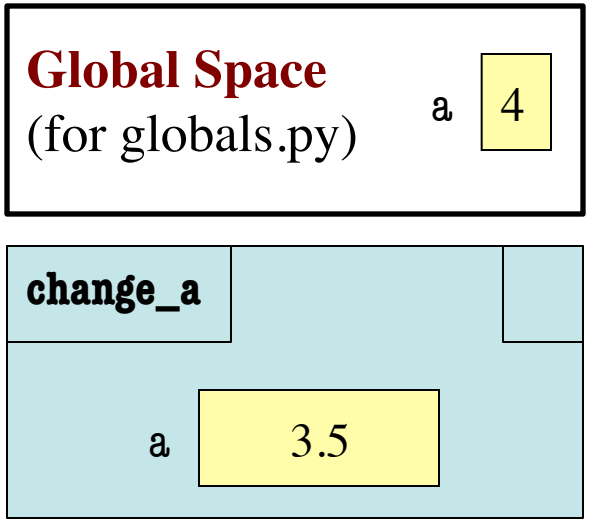



```
# globals.py
"""Show how globals work"""
a = 4 # global space

def change_a():
    a = 3.5 # local variable
```

Errors and the Call Stack

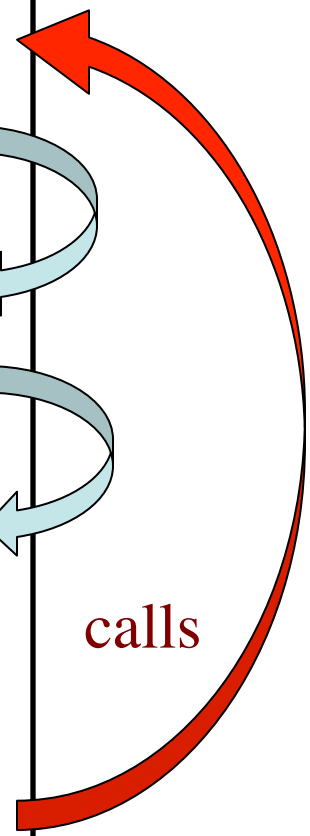
```
# error.py

def function_1(x,y):
    return function_2(x,y)

def function_2(x,y):
    return function_3(x,y)

def function_3(x,y):
    return x/y # crash here

if __name__ == '__main__':
    print function_1(1,0)
```



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```

Crashes produce the call stack:

```
Traceback (most recent call last):
  File "error.py", line 20, in <module>
    print function_1(1,0)
  File "error.py", line 8, in function_1
    return function_2(x,y)
  File "error.py", line 12, in function_2
    return function_3(x,y)
  File "error.py", line 16, in function_3
    return x/y
```

Make sure you can see line numbers in Komodo. Preferences ➔ Editor

Errors and the Call Stack

```
#

d
    return function_2(x,y)

def function_2(x,y):
    return function_3(x,y)

def function_3(x,y):
    return x/y # crash here

if
```

Application code.
Not a frame!

Where error occurred
(or where was found)

Crashes produce the call stack:

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