Lecture 10

Memory in Python

Announcements For This Lecture

Assignment 1

- Work on your revisions
  - Read feedback carefully
  - Partial credit after Sunday
- Early survey results
  - 464 responded so far
  - Deadline is Sunday
  - **Avg Time**: 7.3 hours
  - **STD Dev**: 4.1 hours

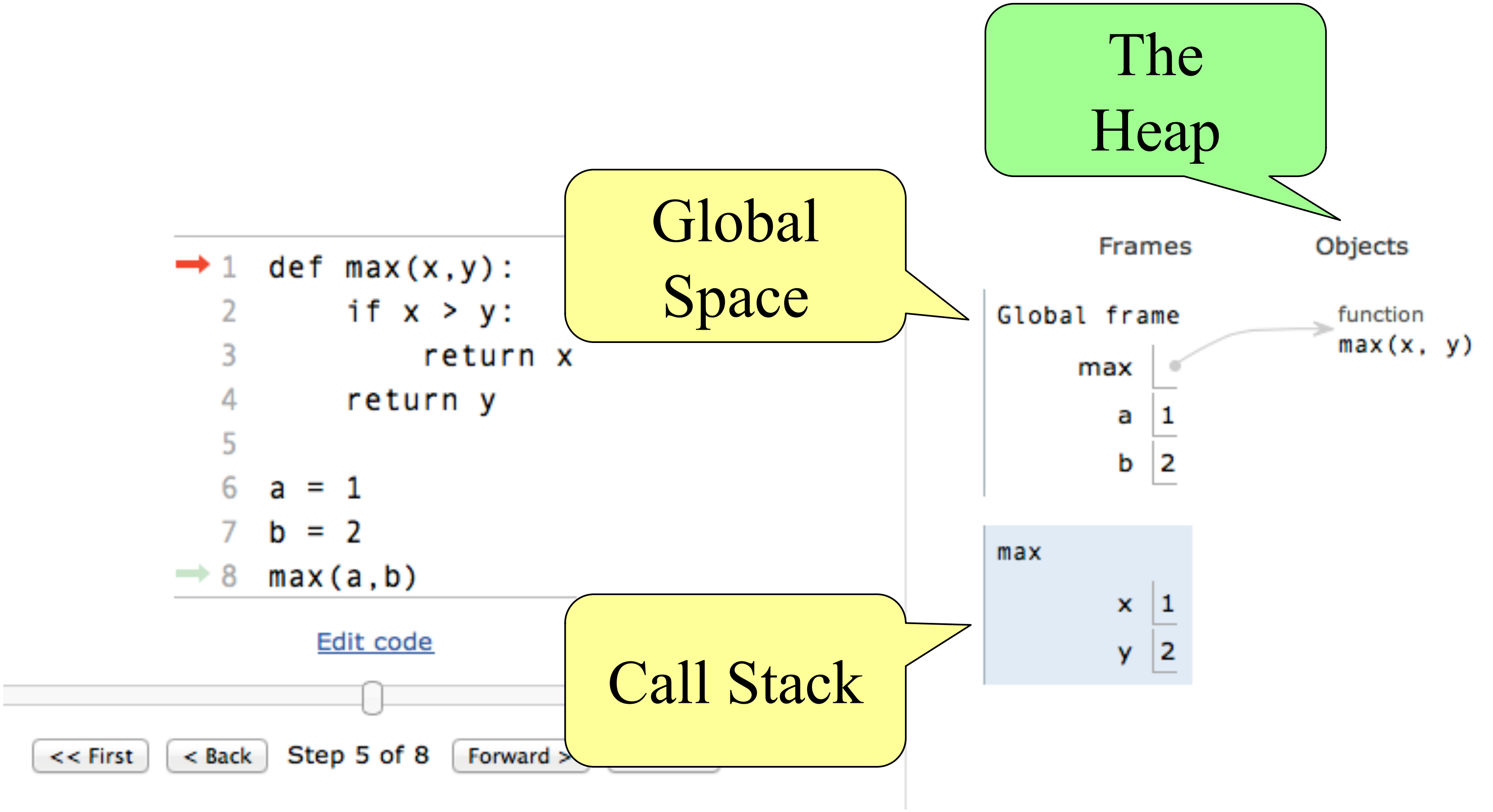
More Assignments

- Assignment 2 due **Sunday**
  - Scan and submit online
  - Upload before midnight
  - **Late:** -10% per day
  - No lates after Thursday
- Assignment 3 up **Monday**
  - Due Friday October 6
  - Should take as long as A1
  - Graded before exam

Speaking of the Exam

- **Prelim 1 is Oct 12th at 7:30-9:00**
  - Material is up to October 3rd
  - Questions come from labs or assignments
- **How do you study for it?**
  - Will post a study guide this weekend
  - Can also look at old exams on web page
- **Conflict with Prelim time?**
  - Submit to Prelim 1 Conflict assignment on CMS
  - Do not submit if you have no conflict

The Three "Areas" of Memory

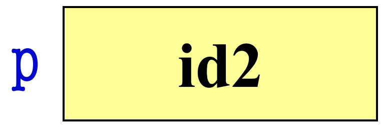


```
def max(x,y):
    if x > y:
        return x
    return y

a = 1
b = 2
max(a,b)
```

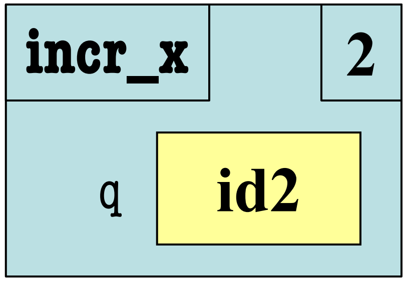
Global Space

- This is the **area you "start with"**
  - First memory area you learned to visualize
  - A place to store "global variables"
  - Lasts until you quit Python
- What are **global variables**?
  - **Any assignment not in a function definition**
  - Also **modules & function definitions!**
  - Will see more on this in a bit



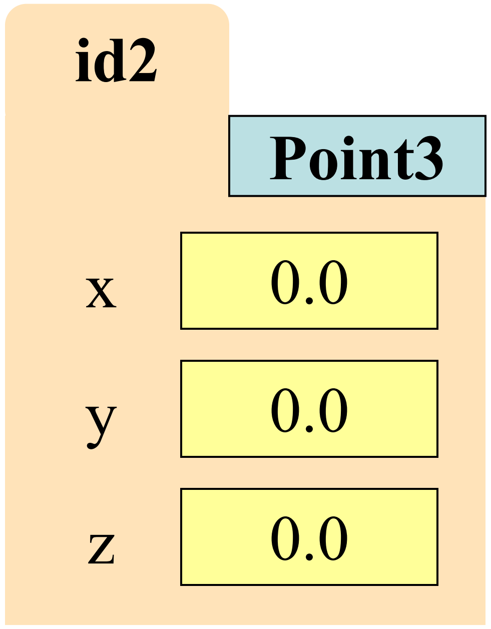
The Call Stack

- The area **where call frames live**
  - Call frames are created on a function call
  - May be several frames (functions call functions)
  - Each frame deleted as the call completes
- Area of volatile, temporary memory
  - Less permanent than global space
  - Think of as "scratch" space
- Primary focus of Assignment 2



Heap Space or “The Heap”

- **Where the “folders” live**
  - Stores *only* folders
- Can only **access indirectly**
  - Must have a variable with identifier
  - Can be in global space, call stack
- MUST have **variable with id**
  - If no variable has id, it is *forgotten*
  - Disappears in Tutor immediately
  - But not necessarily in practice
  - Role of the *garbage collector*



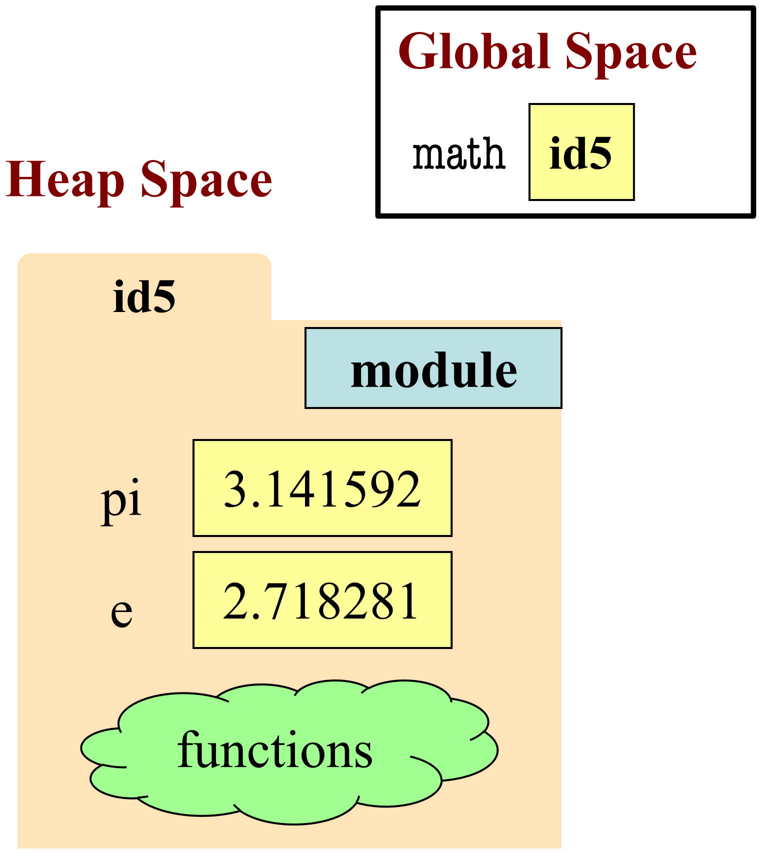
Everything is an Object!

- Last time we saw that everything is an object
  - Must have a folder in the heap
  - Must have variable in global space, call stack
  - But ignore basic types (`int`, `float`, `bool`, `str`)
- Includes **modules** and **function definitions**!
  - Object is created by `import`
  - Object is created by `def`
  - Already seen this in Python Tutor

Modules and Global Space

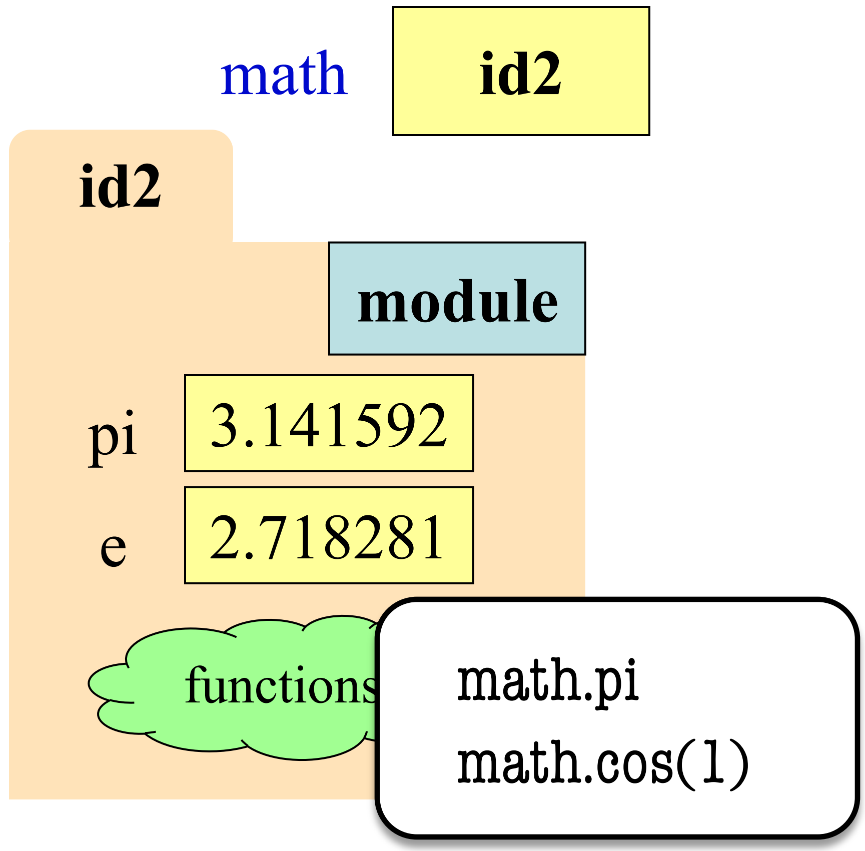
- Importing a module:
  - Creates a global variable (same name as module)
  - Puts contents in a **folder**
    - Module variables
    - Module functions
  - Puts folder id in variable
- **from** keyword dumps contents to global space

```
import math
```



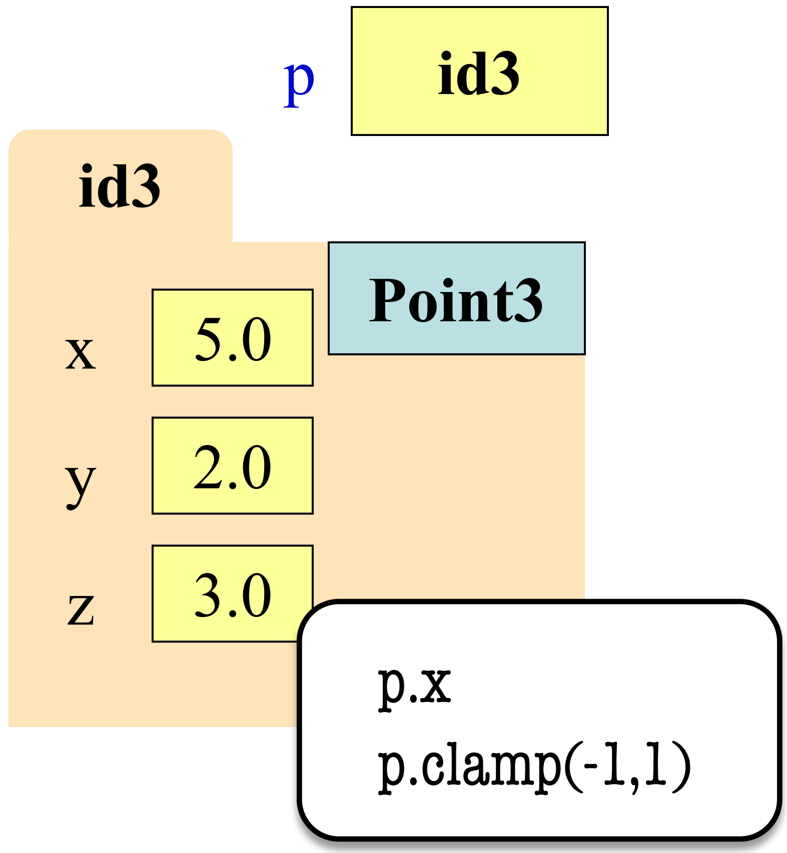
Modules vs Objects

Module



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

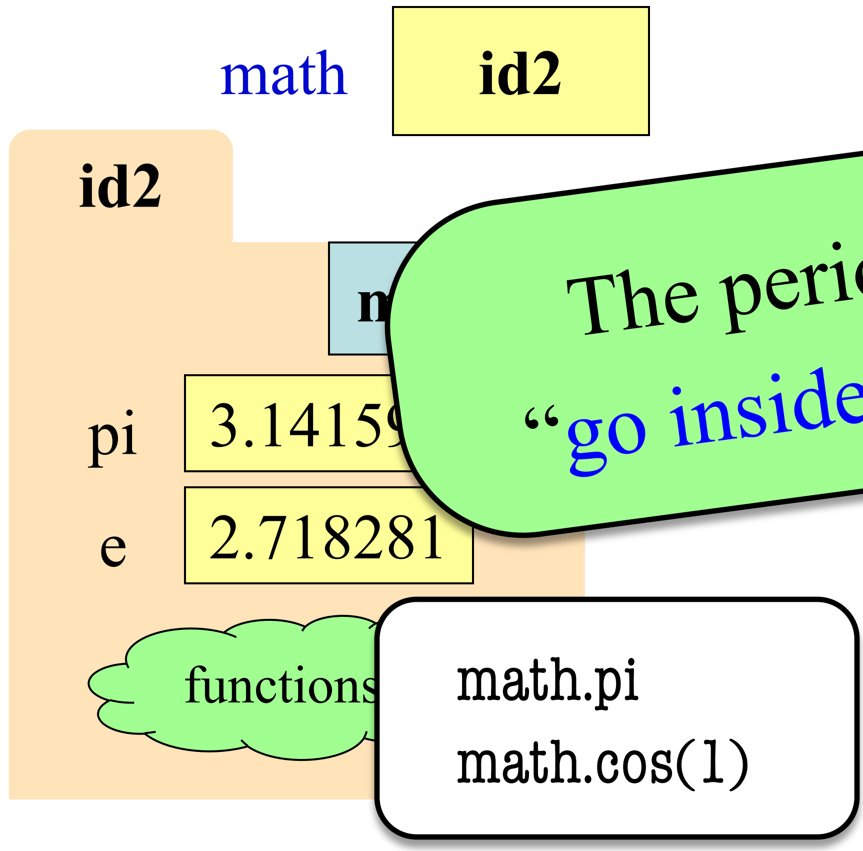
Object



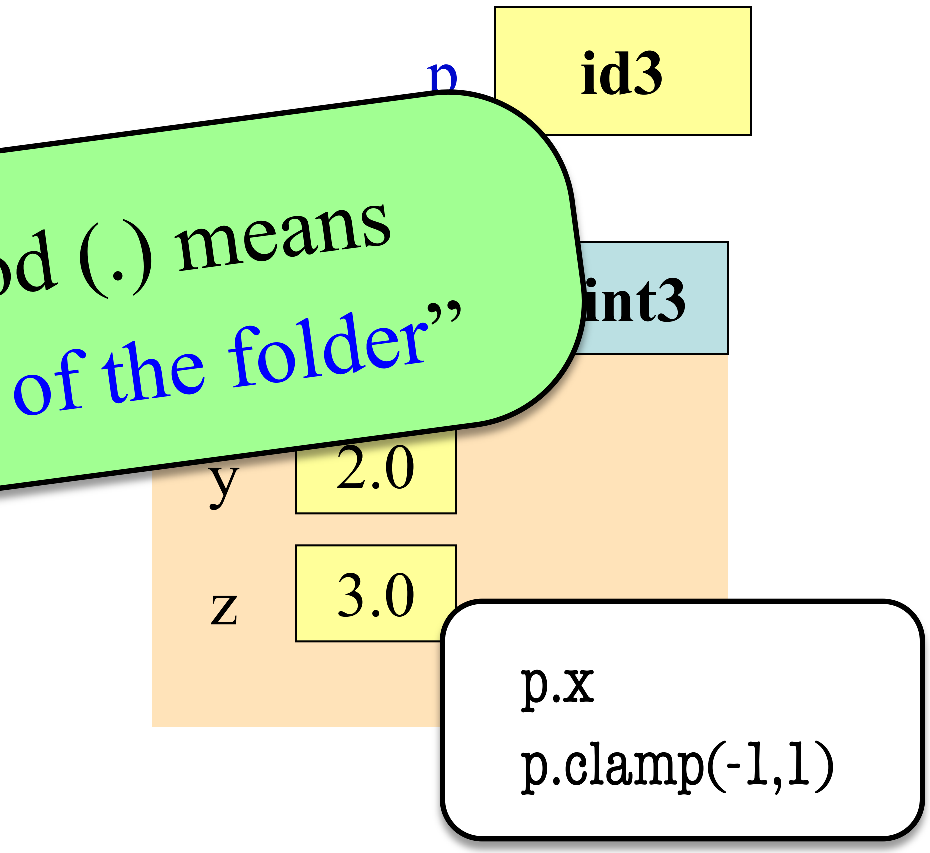
```
p.x
p.clamp(-1,1)
```

Modules vs Objects

Module	Object



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



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

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

So Why Have Both?

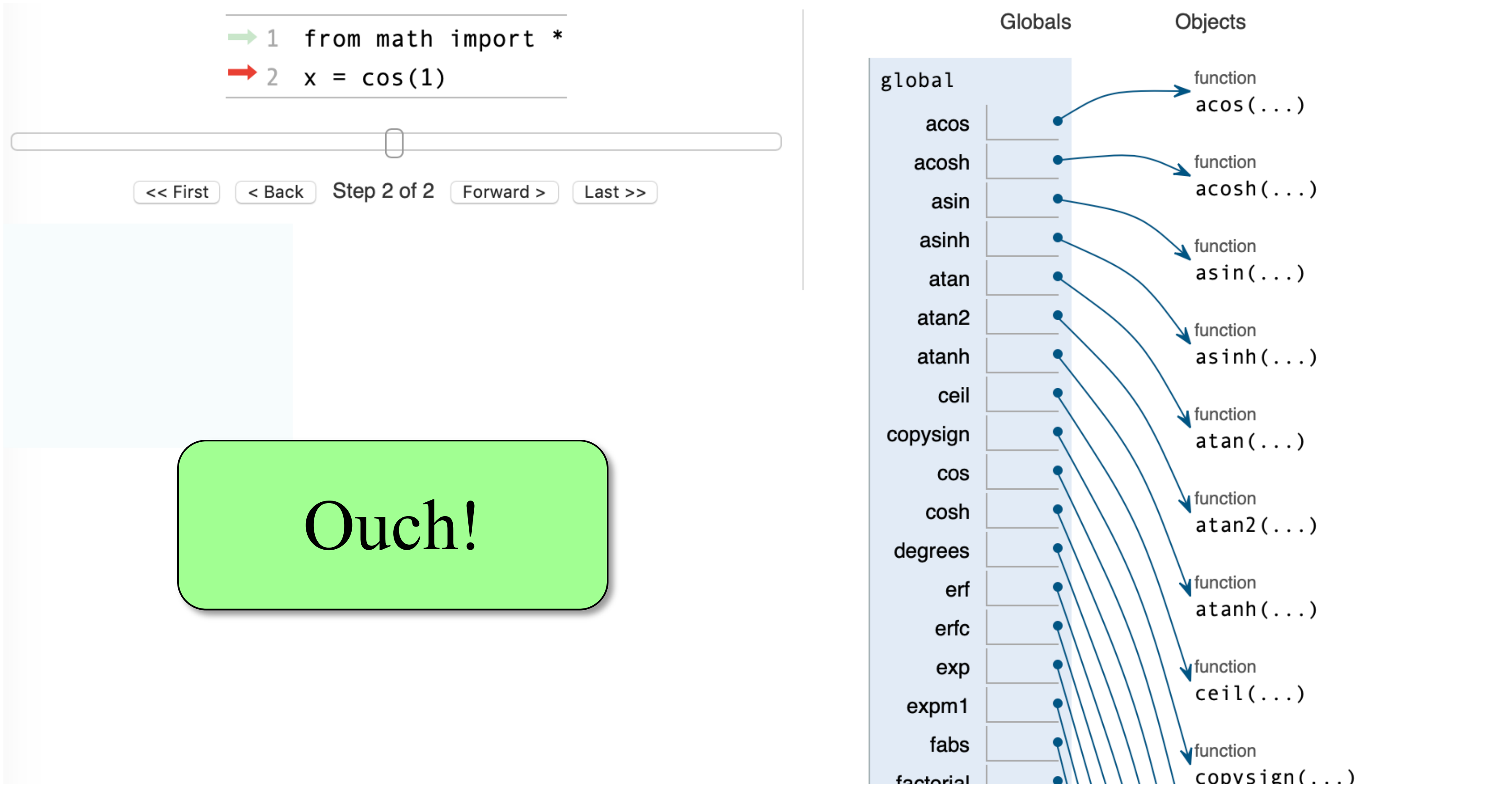
- Question is a matter of program design
  - Some software will use modules like objects
- Classes can have **many instances**
  - Infinitely many objects for the `Point3` class
  - Reason we need a constructor function
- Each module is **a unique instance**
  - Only one possibility for `pi`, `cosine`
  - That is why we import them
  - Sometimes refer to as *singleton* objects

So Why Have Both?

- Question is a matter of program design
  - Some software will use modules like objects
- Classes can have **many instance**
  - Infinitely m
  - Re
- Each **stance**
  - Only one possibility for `pi`, `cosine`
  - That is why we import them
  - Sometimes refer to as *singleton* objects

Choice is an advanced topic beyond scope of this course

How About **import** *?



```
from math import *
x = cos(1)
```

Ouch!

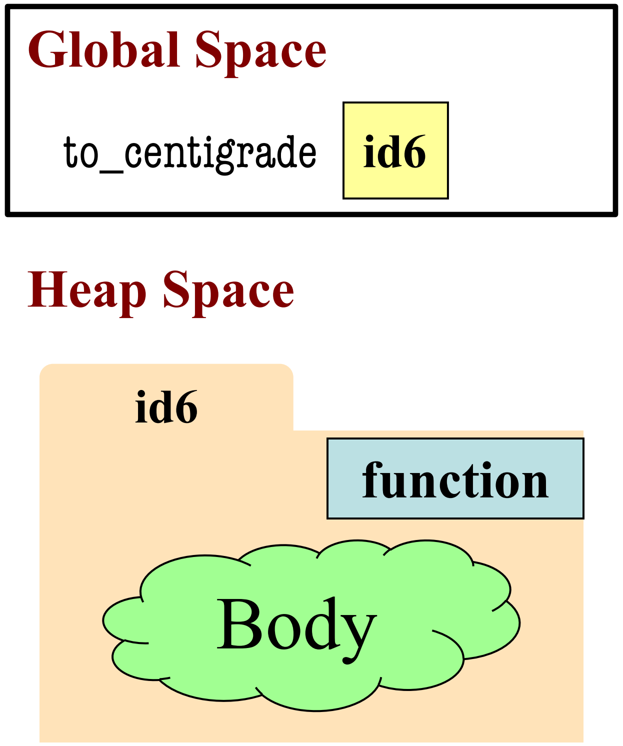
Functions and Global Space

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

```
>>> to_centigrade
<fun to_centigrade at 0x100498de8>
>>> to_centigrade (32)
0.0
```

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

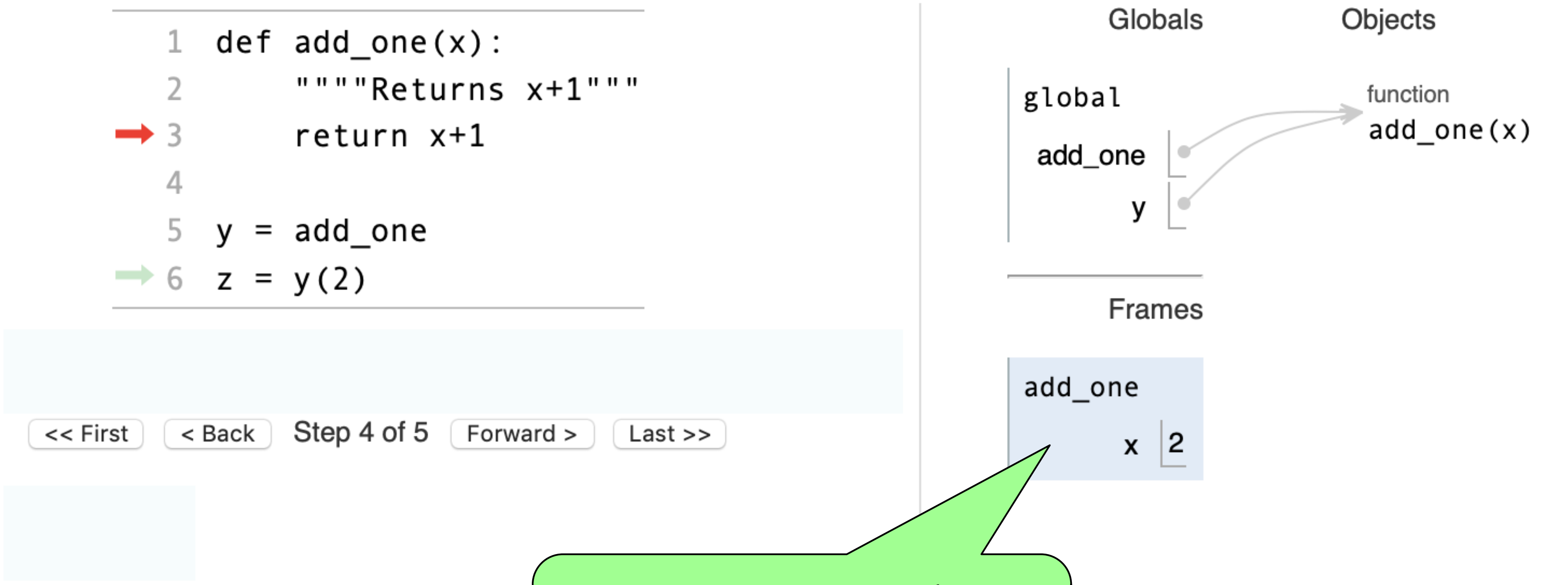
Body



Working with Function Variables

- So function definitions are **objects**
  - Function names are just variables
  - Variable refers to a folder storing the code
  - If you reassign the variable, it is lost
- You can assign them to other **variables**
  - Variable now refers to that function
  - You can use that **NEW** variable to call it
  - Just use variable in place of function name

Example: add_one

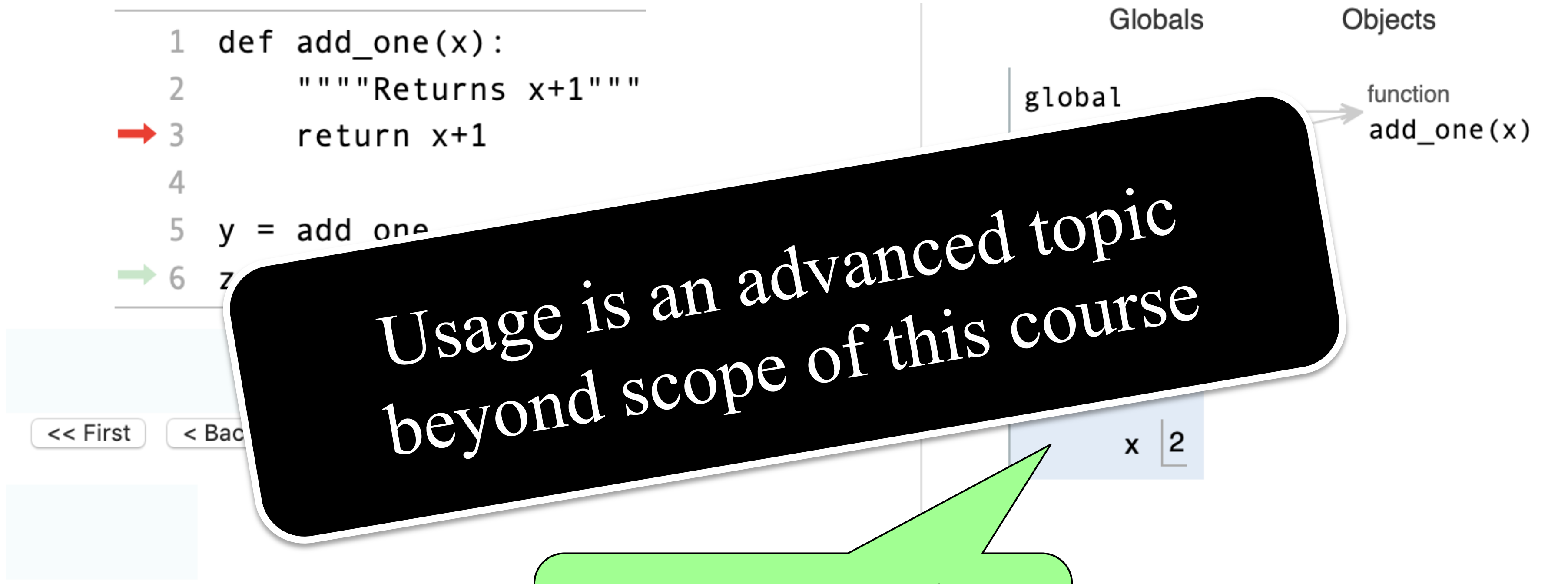


```
def add_one(x):
    """Returns x+1"""
    return x+1

y = add_one
z = y(2)
```

Frame remembers the original name

Example: add_one



```
def add_one(x):
    """Returns x+1"""
    return x+1

y = add_one
z
```

Usage is an advanced topic beyond scope of this course

Frame remembers the original name

Why Show All This?

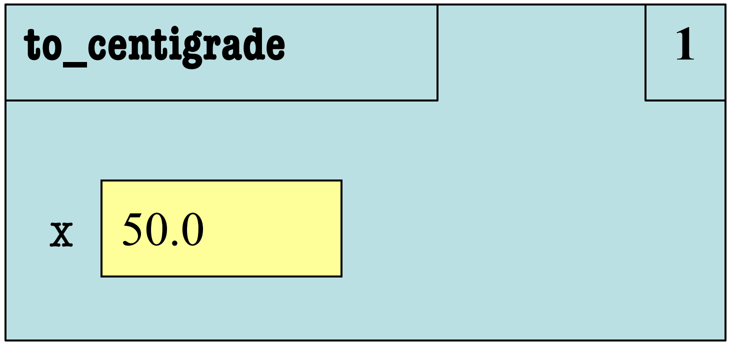
- Many of these are **advanced topics**
  - Only advanced programmers need
  - Will never need in the context of 1110
- But you might use them by *accident*
- **Goal: Teach you to read error messages**
  - Need to understand what messages say
  - Only way to debug your own code
  - This means understanding the **call stack**

Recall: 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

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

Call: to_centigrade(50.0)



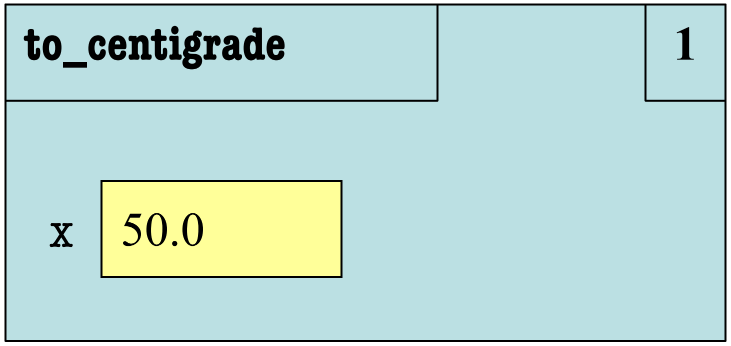
Aside: What Happens Each Frame Step?

- 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

Recall: 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)



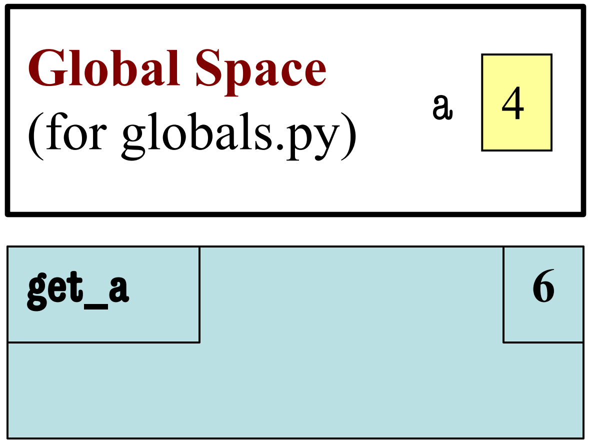
What is happening here?

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

Function Access to Global Space

- Consider code to right
    - Global variable a
    - Function definition get_a
- Consider the call get_a()
    - Call frame to the right
    - What happens?

A: It crashes
B: Returns None
C: Returns 4
D: I don't know



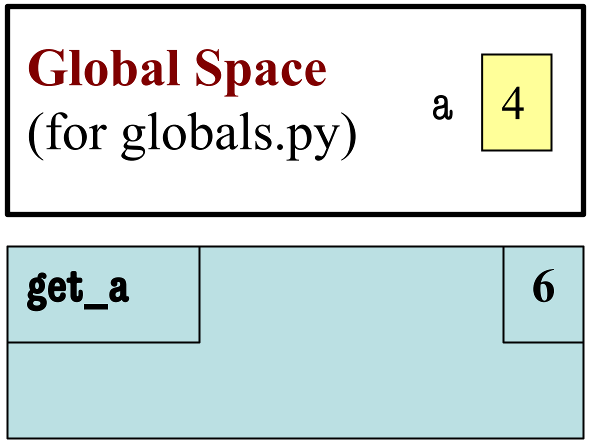
```
# globals.py
"""Show how globals work"""
a = 4 # global space

def get_a():
    return a
```

Function Access to Global Space

- Consider code to right
  - Global variable a
  - Function definition get_a
- Consider the call get_a()
  - Call frame to the right
  - What happens?

A: It crashes
B: Returns None
C: Returns 4 **CORRECT**
D: I don't know

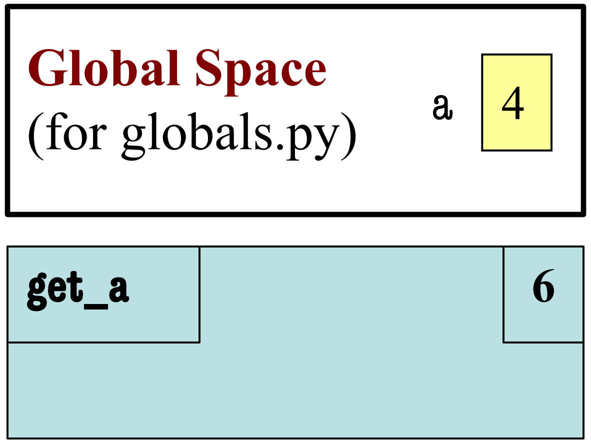


```
# globals.py
"""Show how globals work"""
a = 4 # global space

def get_a():
    return a
```

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
  - Makes a *new local variable*!
  - Why we limit to constants

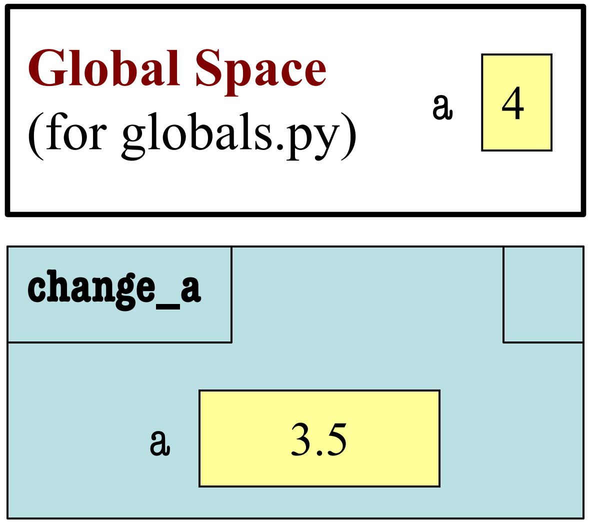


```
# globals.py
"""Show how globals work"""
a = 4 # global space

def get_a():
    return a
```

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
  - Makes a *new local variable*!
  - Why we limit to constants



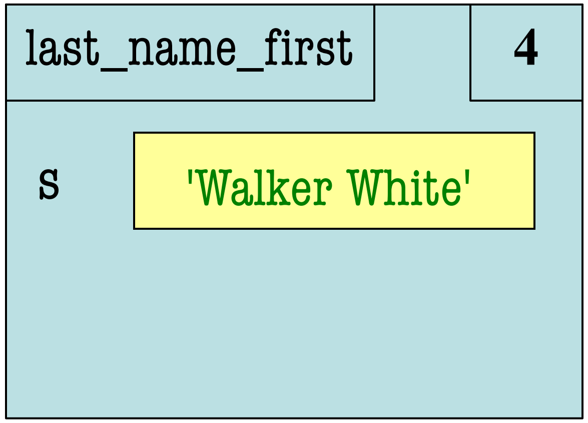
```
# globals.py
"""Show how globals work"""
a = 4 # global space

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

Frames and Helper Functions

```
1.  def last_name_first(s):
2.      """Precond: s in the form
3.      'first-name last-name' """
4.      first = first_name(s)
5.      last = last_name(s)
6.      return last + ',' + first
7.
8.  def first_name(s):
9.      """Precond: see above"""
10.     end = s.find(' ')
11.     return s[0:end]
```

Call: last_name_first('Walker White'):

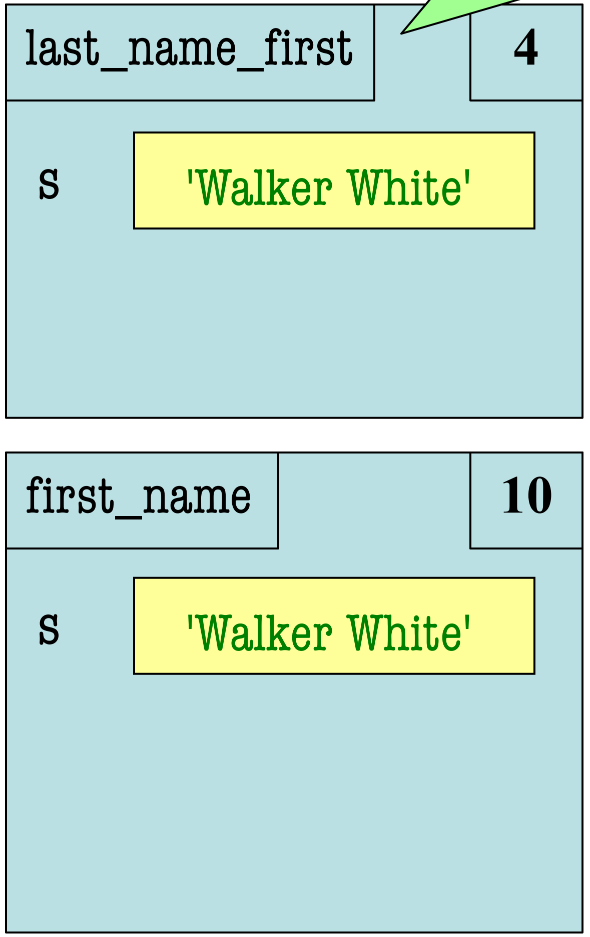


Frames and Helper Functions

```
1.  def  last_name_first(s):
2.        """Precond: s in the form
3.        'first-name last-name' """
4.        first = first_name(s)
5.        last = last_name(s)
6.        return last + ',' + first
7.
8.  def  first_name(s):
9.         """Precond: see above"""
10.        end = s.find(' ')
11.        return s[0:end]
```

Call: last

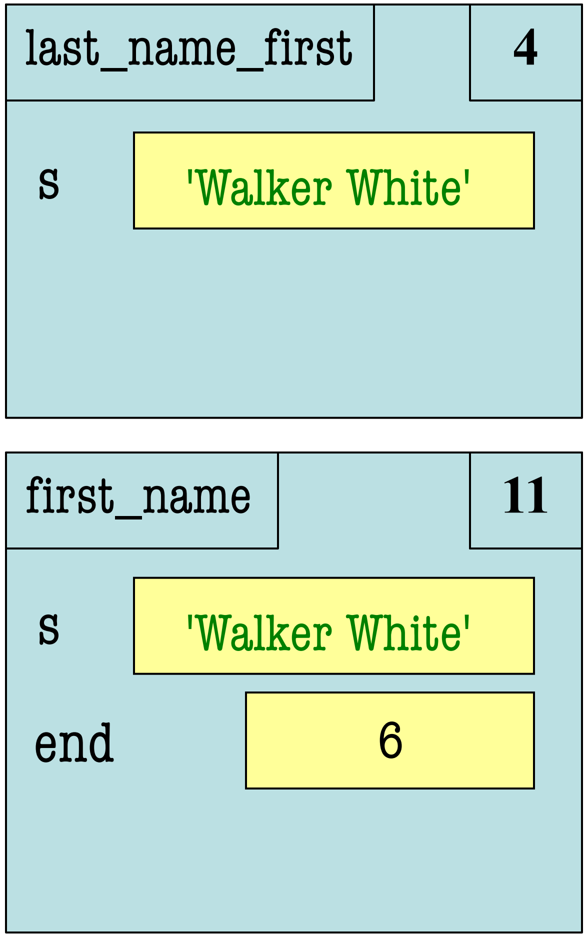
Not done. Do not erase!



Frames and Helper Functions

```
1.  def  last_name_first(s):
2.      """Precond: s in the form
3.      'first-name last-name' """
4.      first = first_name(s)
5.      last = last_name(s)
6.      return last + ',' + first
7.
8.  def  first_name(s):
9.      """Precond: see above"""
10.     end = s.find(' ')
11.     return s[0:end]
```

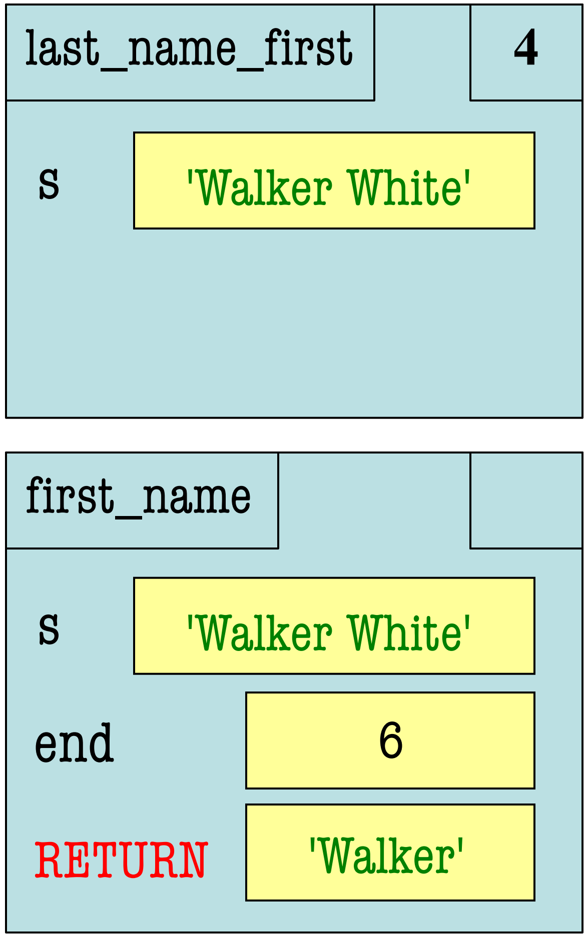
Call: last_name_first('Walker White'):



Frames and Helper Functions

```
1.  def  last_name_first(s):
2.          """Precond: s in the form
3.          'first-name last-name' """
4.          first = first_name(s)
5.          last = last_name(s)
6.          return last + ',' + first
7.
8.  def  first_name(s):
9.          """Precond: see above"""
10.         end = s.find(' ')
11.         return s[0:end]
```

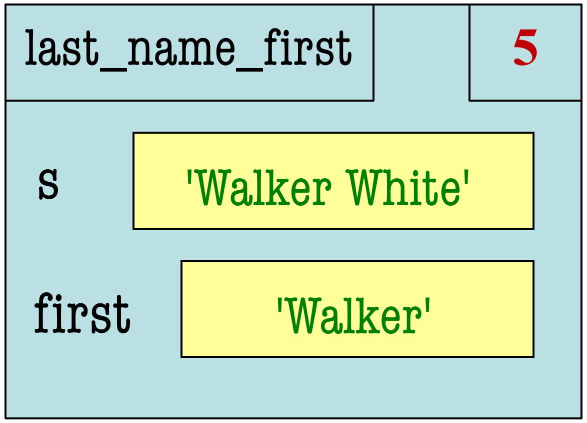
Call: last_name_first('Walker White'):



Frames and Helper Functions

```
1.  def  last_name_first(s):
2.      """Precond: s in the form
3.      'first-name last-name' """
4.      first = first_name(s)
5.      last = last_name(s)
6.      return last + ',' + first
7.
8.  def  first_name(s):
9.      """Precond: see above"""
10.     end = s.find(' ')
11.     return s[0:end]
```

Call: last_name_first('Walker White'):

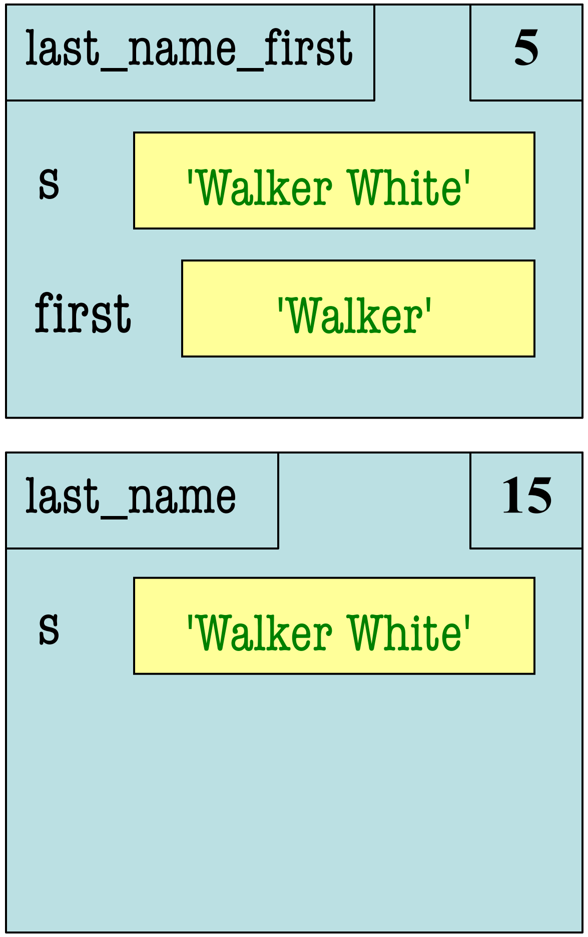


ERASE WHOLE FRAME

Frames and Helper Functions

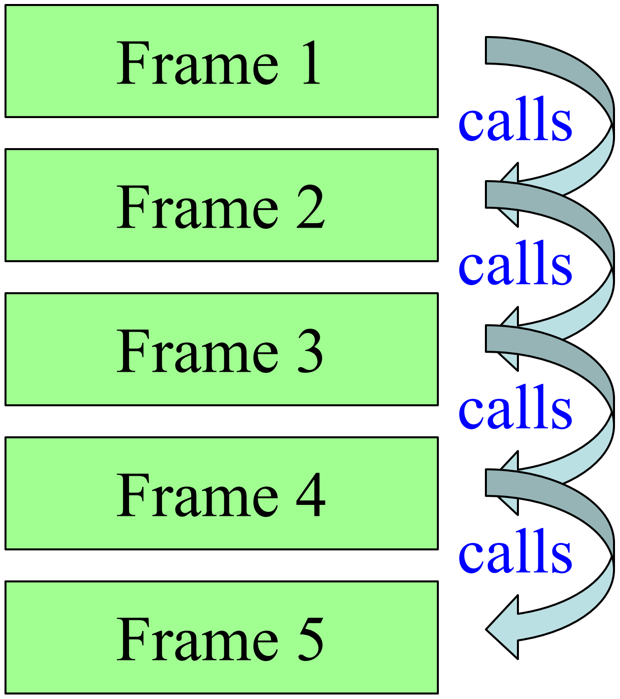
```
1.  def  last_name_first(s):
2.        """Precond: s in the form
3.        'first-name last-name' """
4.        first = first_name(s)
5.        last = last_name(s)
6.        return last + ',' + first
          . . .
13. def  last_name(s):
14.       """Precond: see above"""
15.       end = s.rfind(' ')
16.       return s[end+1:]
```

Call: last_name_first('Walker White'):



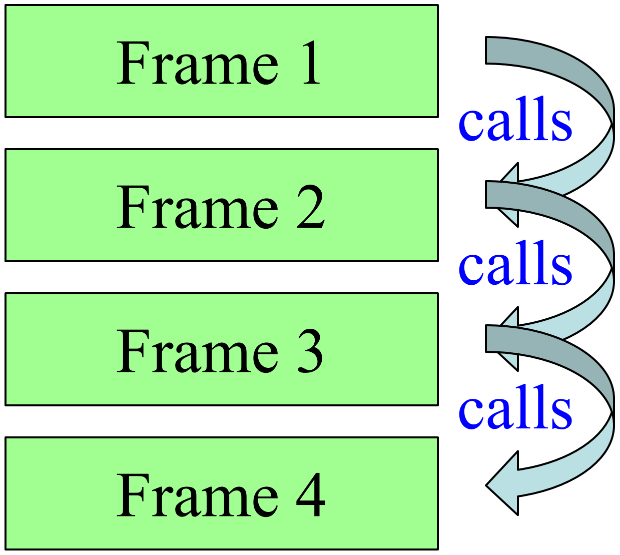
The Call Stack

- 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



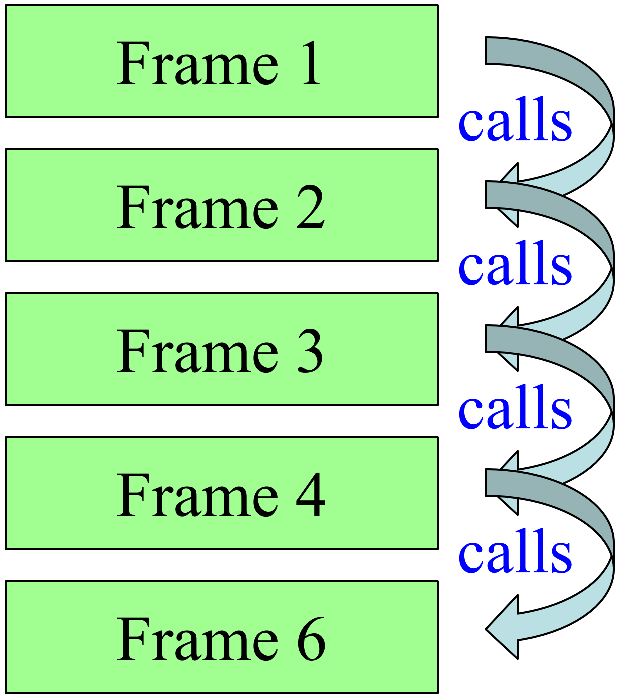
The Call Stack

- 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

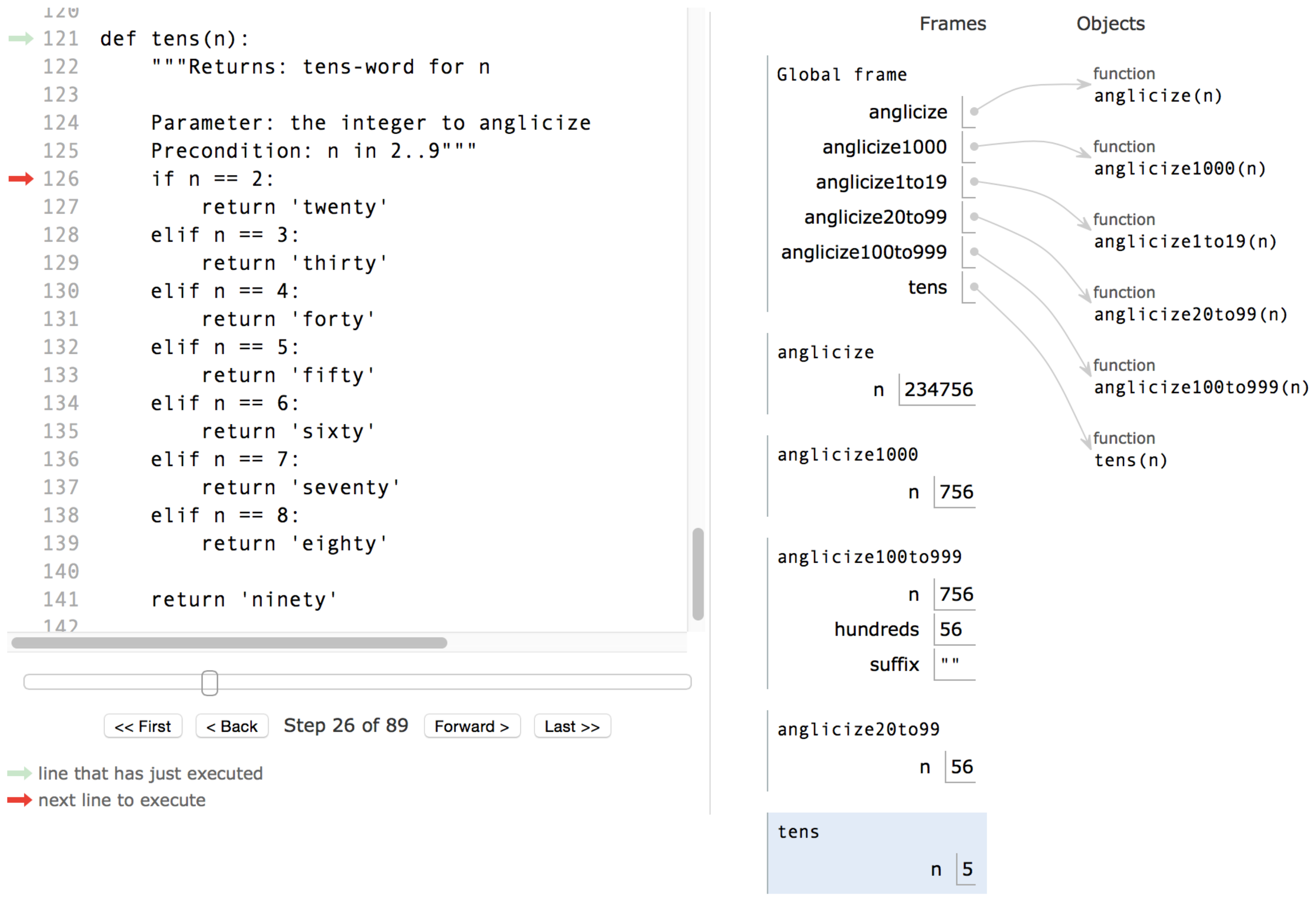


The Call Stack

- 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



Anglicize Example

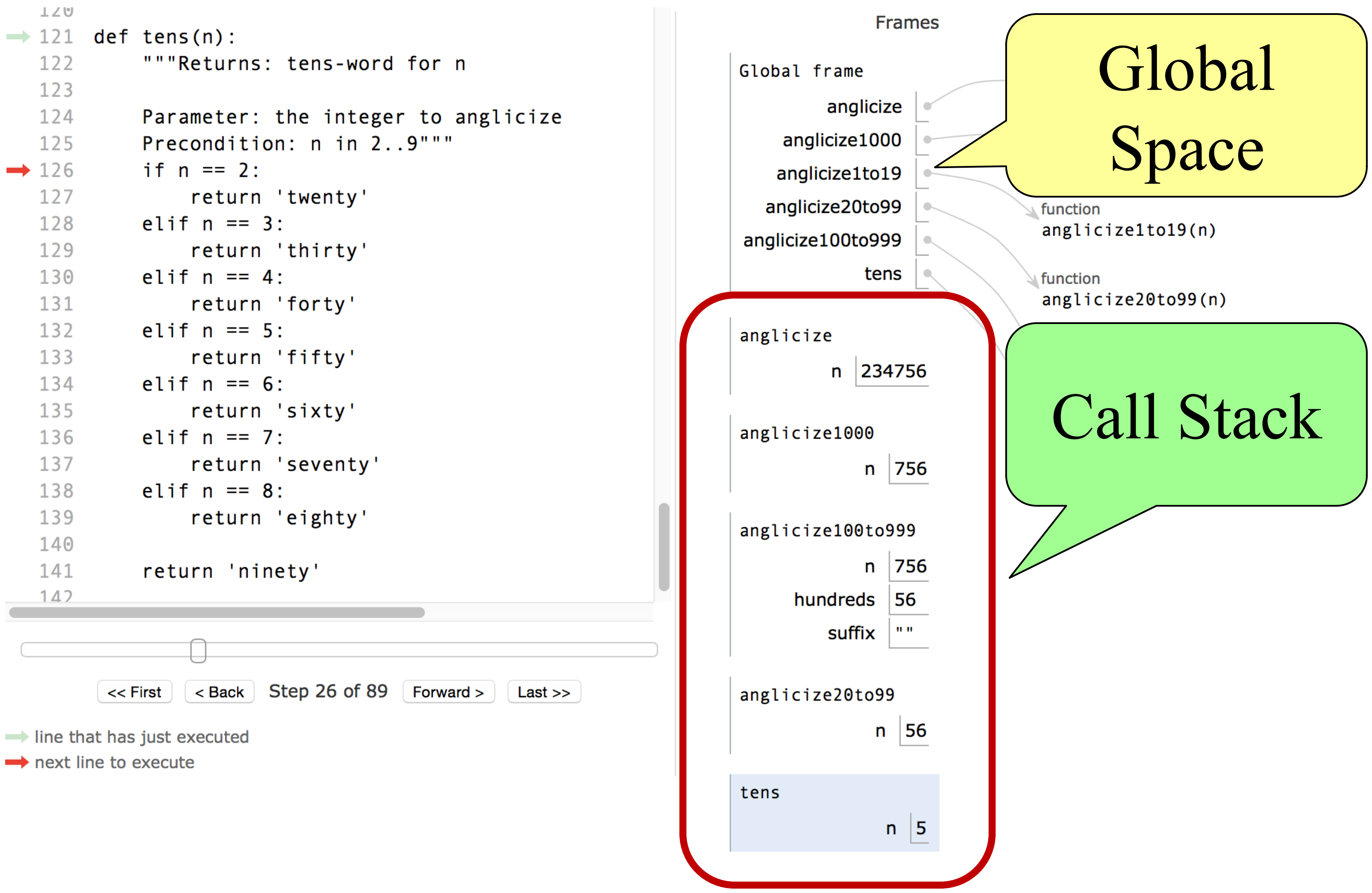


```
def tens(n):
    """Returns: tens-word for n

    Parameter: the integer to anglicize
    Precondition: n in 2..9"""
    if n == 2:
        return 'twenty'
    elif n == 3:
        return 'thirty'
    elif n == 4:
        return 'forty'
    elif n == 5:
        return 'fifty'
    elif n == 6:
        return 'sixty'
    elif n == 7:
        return 'seventy'
    elif n == 8:
        return 'eighty'

    return 'ninety'
```

Anglicize Example



```
def tens(n):
    """Returns: tens-word for n

    Parameter: the integer to anglicize
    Precondition: n in 2..9"""
    if n == 2:
        return 'twenty'
    elif n == 3:
        return 'thirty'
    elif n == 4:
        return 'forty'
    elif n == 5:
        return 'fifty'
    elif n == 6:
        return 'sixty'
    elif n == 7:
        return 'seventy'
    elif n == 8:
        return 'eighty'

    return 'ninety'
```