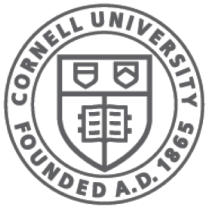
http://www.cs.cornell.edu/courses/cs1110/2019sp

Lecture 7: Objects (Chapter 15)

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]

Type: set of values & operations on them

Type **float:**

- Values: real numbers
- Ops: +, -, *, /, **

Type **int:**

- Values: integers
- Ops: +, -, *, //, %, **

Type **bool:**

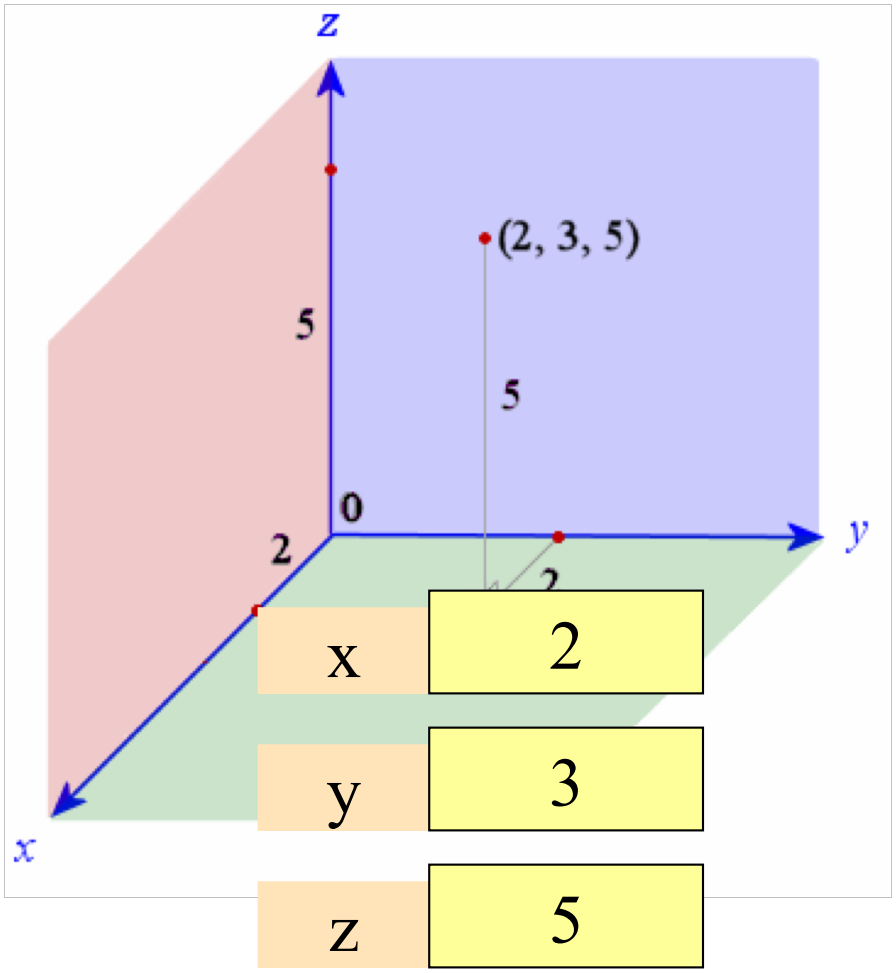
- Values: integers
- Ops: not, and, or

Type **str:**

- Values: string literals
  - Double quotes: **“abc”**
  - Single quotes: **‘abc’**
- Ops: + (concatenation)

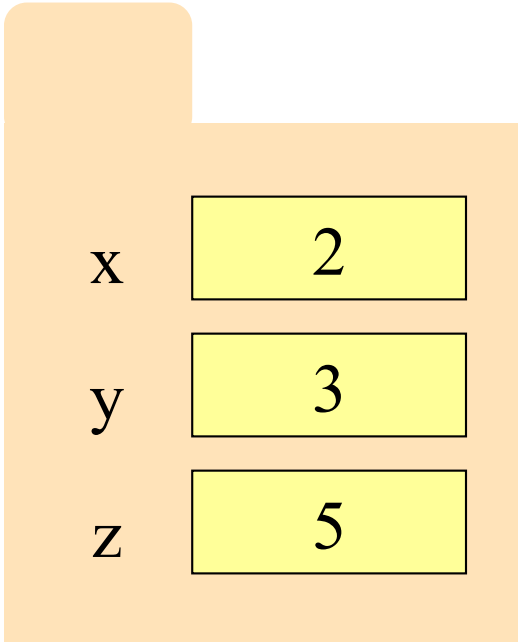
Built-in Types are not "Enough"

- Want a point in 3D space
  - We need three variables
  - x, y, z coordinates
- What if have a lot of points?
  - Vars x0, y0, z0 for first point
  - Vars x1, y1, z1 for next point
  - …
  - This can get really messy
- How about a single variable that represents a point?



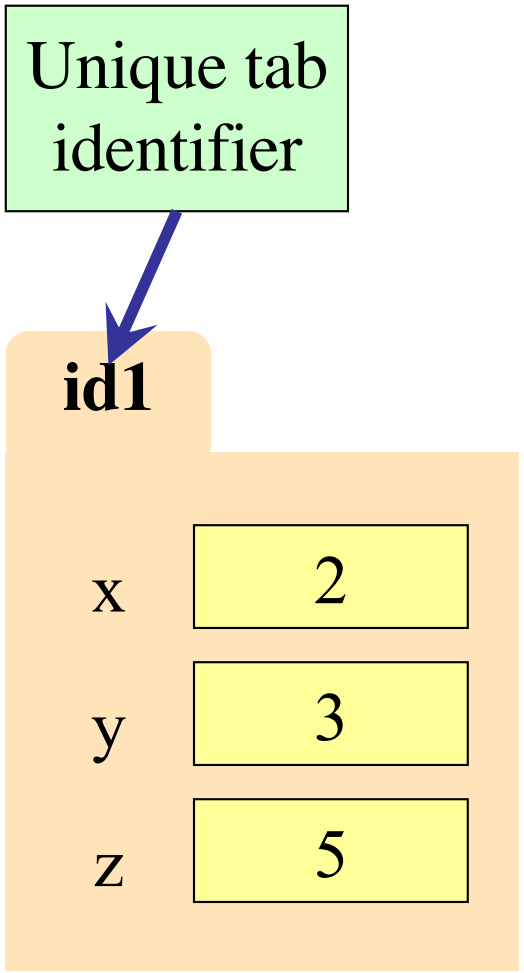
Built-in Types are not "Enough"

- Want a point in 3D space
  - We need three variables
  - x, y, z coordinates
- What if have a lot of points?
  - Vars x0, y0, z0 for first point
  - Vars x1, y1, z1 for next point
  - …
  - This can get really messy
- How about a single variable that represents a point?
- Can we stick them together in a "folder"?
- Motivation for **objects**



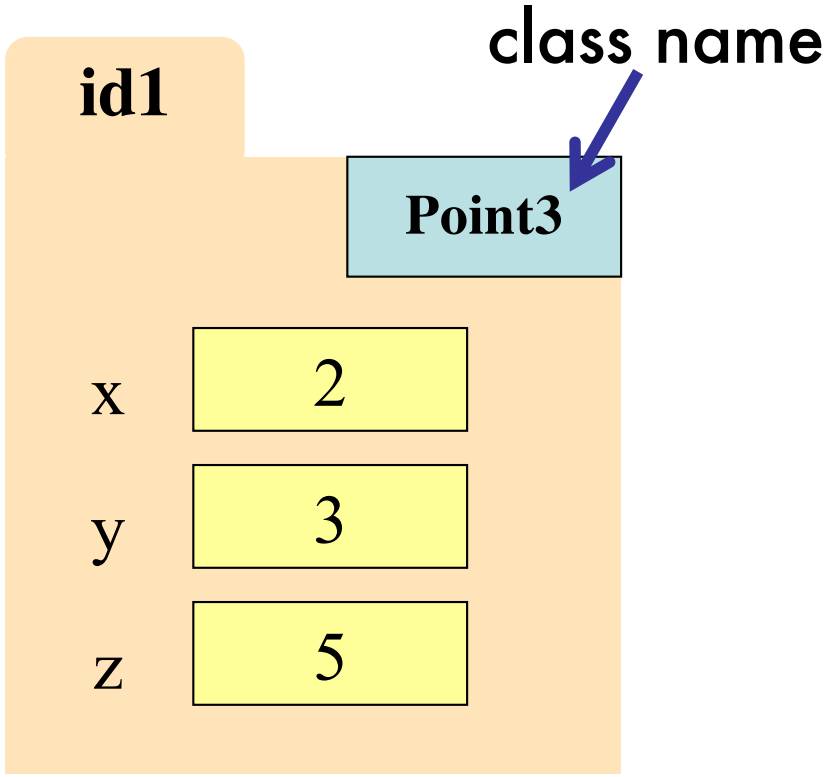
Objects: Organizing Data in Folders

- An object is like a **manila folder**
- It contains other variables
  - Variables are called **attributes**
  - These values can change
- It has an **ID** that identifies it
  - Unique number assigned by Python (just like a NetID for a Cornellian)
  - Cannot ever change
  - Has no meaning; only identifies



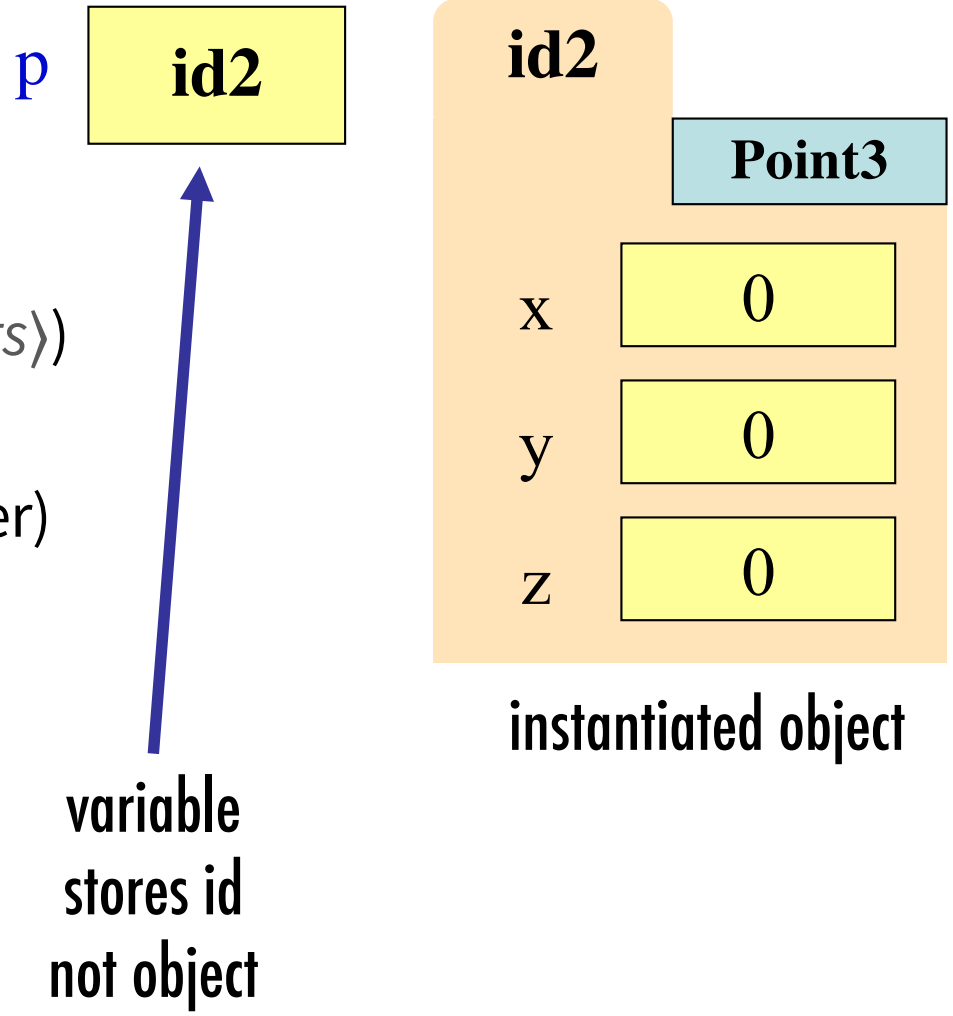
Classes: user-defined types for Objects

- Values must have a type
  - An object is a **value**
  - Object type is a **class**
- **Modules** provide classes
- **Example**: shapes.py
  - Defines: Point3, Rectangle classes



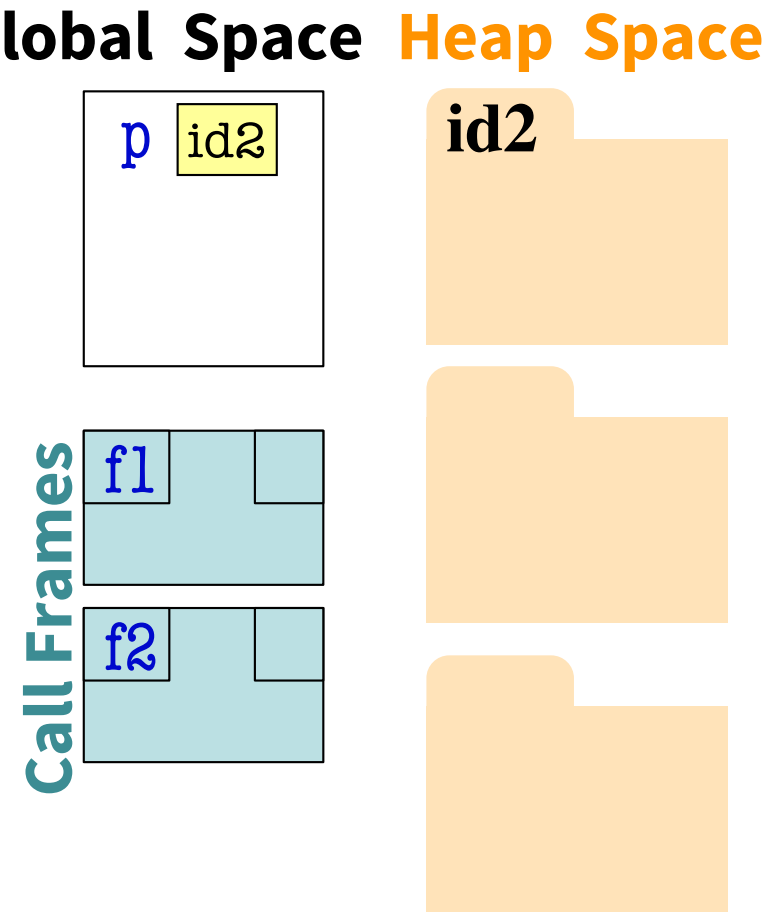
Constructor: Function to make Objects

- How do we create objects?
  - Other types have literals
  - No such thing for objects
- **Constructor Function**:
  - **Format:** ⟨*class name*⟩(⟨*arguments*⟩)
  - **Example**: Point3(0,0,0)
  - Makes a new object (manila folder) with a ***new id***
  - Called an *instantiated* object
  - Returns folder ***id*** as value
- **Example**: p = Point3(0, 0, 0)
  - Creates a Point object
  - Stores object's ***id*** in p



Storage in Python

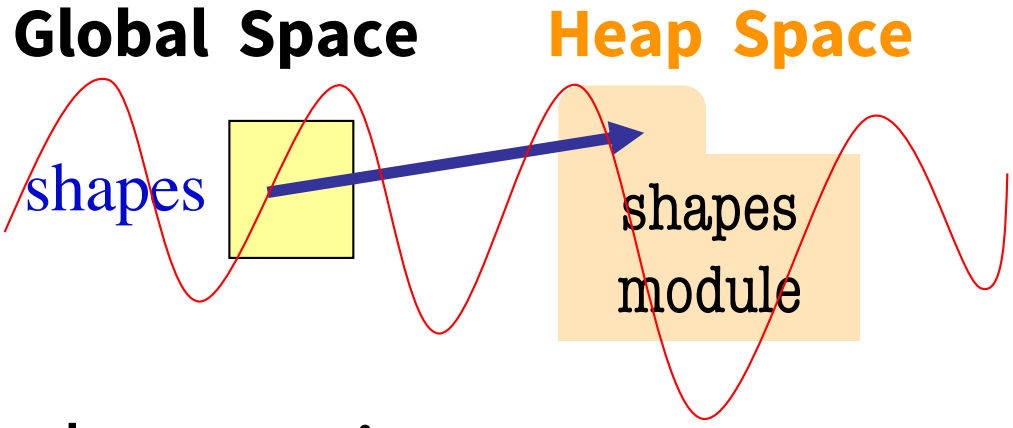
- **Global Space**
  - What you "start with"
  - Stores global variables
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly
- **Call Frames**
  - Parameters
  - Other variables local to function
  - Lasts until function returns



Constructors and Modules

```
>>> import shapes
```

Need to import module that has Point class.



- This **is** what's actually happening
- Python Tutor draws this.

CS 1110 omits module variables & folders (also omit all the built-in functions)

→ makes your diagrams cleaner

Constructors and Modules

```
>>> import shapes
```

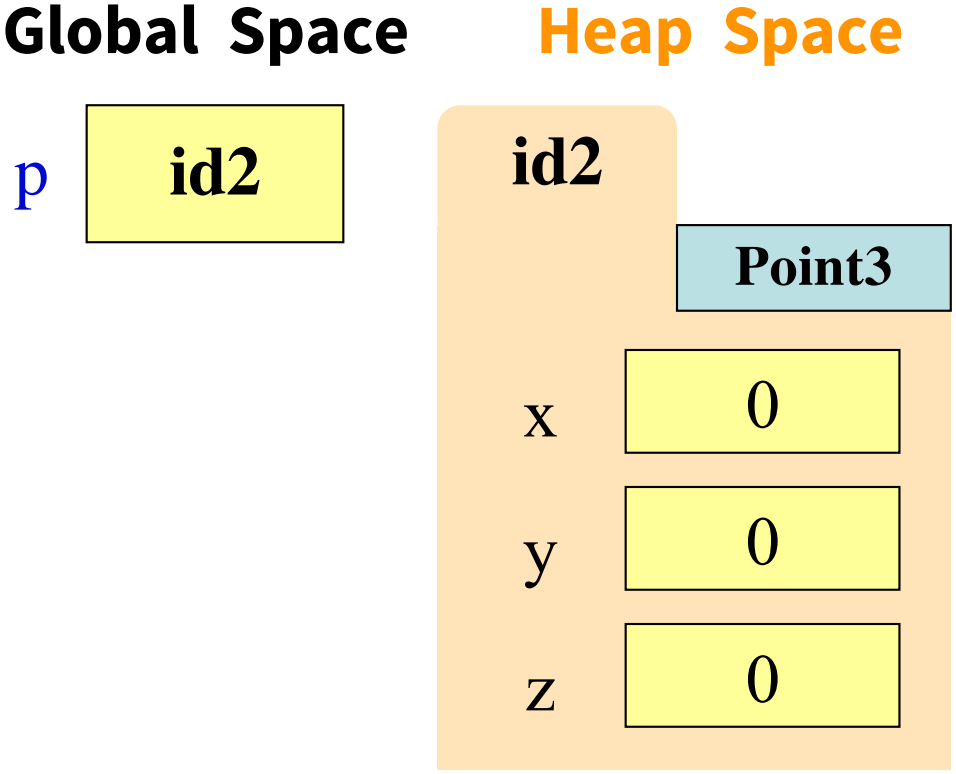
Need to import module that has Point class.

```
>>> p = shapes.Point3(0,0,0)
```

Constructor is function. Prefix w/ module name.

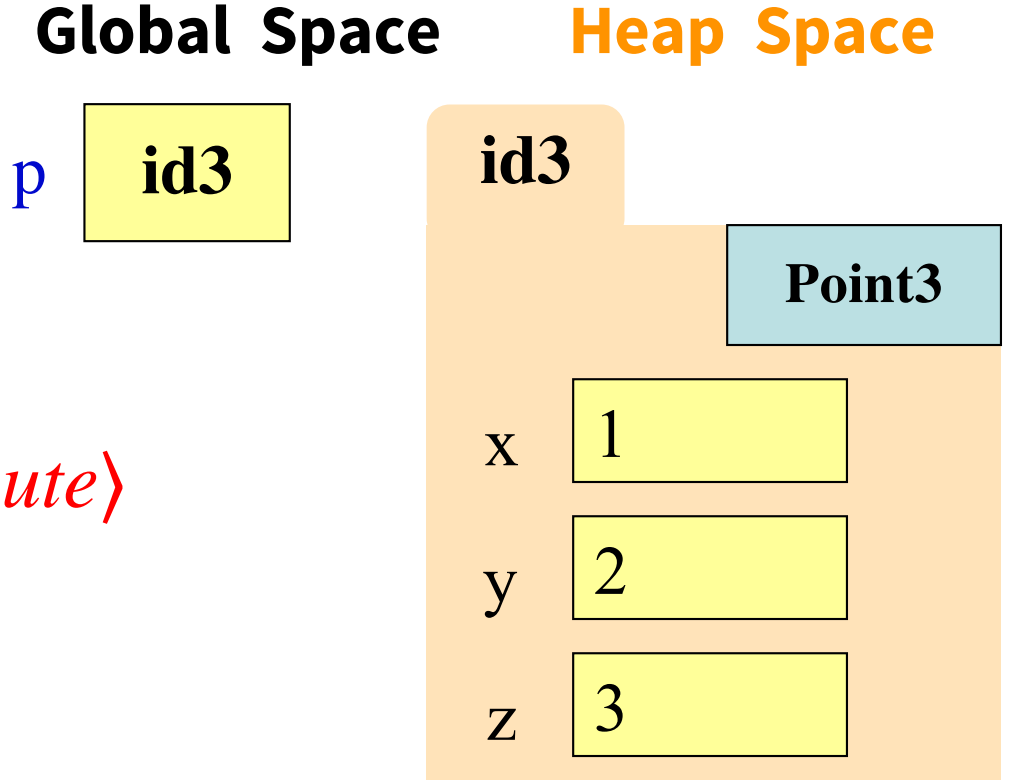
```
>>> id(p)
```

Shows the ***id*** of p



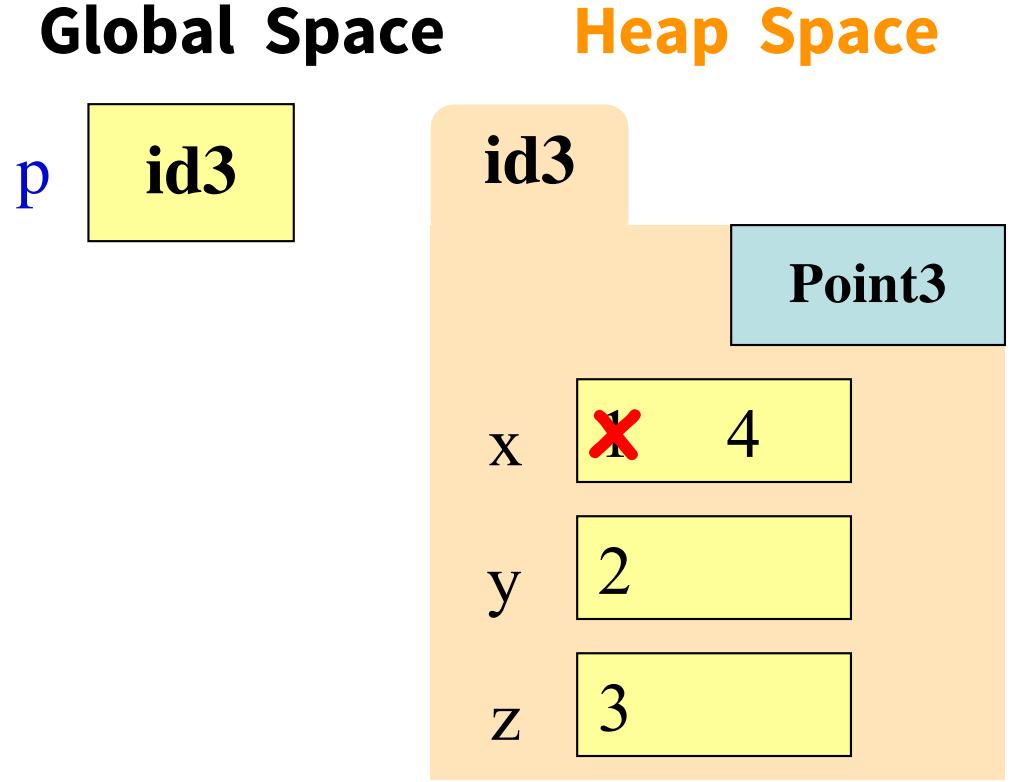
Accessing Attributes

- Attributes are variables that live inside of objects
  - Can **use** in expressions
  - Can **assign** values to them
- **Format**: ⟨*variable*⟩.⟨*attribute*⟩
  - **Example**: `p.x`
  - Look like module variables
- To evaluate `p.x`, Python:
  1. finds folder with ***id*** stored in `p`
  2. returns the value of `x` in that folder



Accessing Attributes Example

- **Example**:
  - p = shapes.Point3(1, 2, 3)
  - p.x = p.x + 3

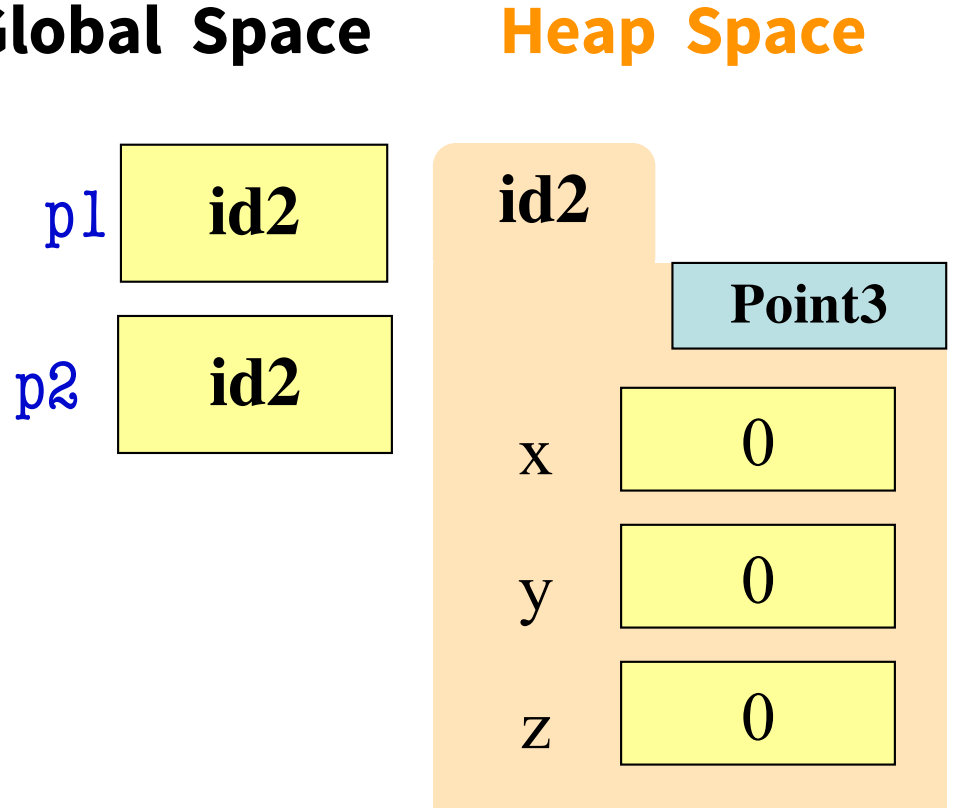


Object Variables

- Variable stores object ***id***
  - **Reference** to the object
  - Reason for folder analogy
- Assignment uses object ***id***
  - **Example**:

```
p1 = shapes.Point3(0, 0, 0)
p2 = p1
```

  - Takes contents from `p1`
  - Puts contents in `p2`
  - Does not make new folder!



This is the cause of many mistakes in this course

Attribute Assignment (Question)

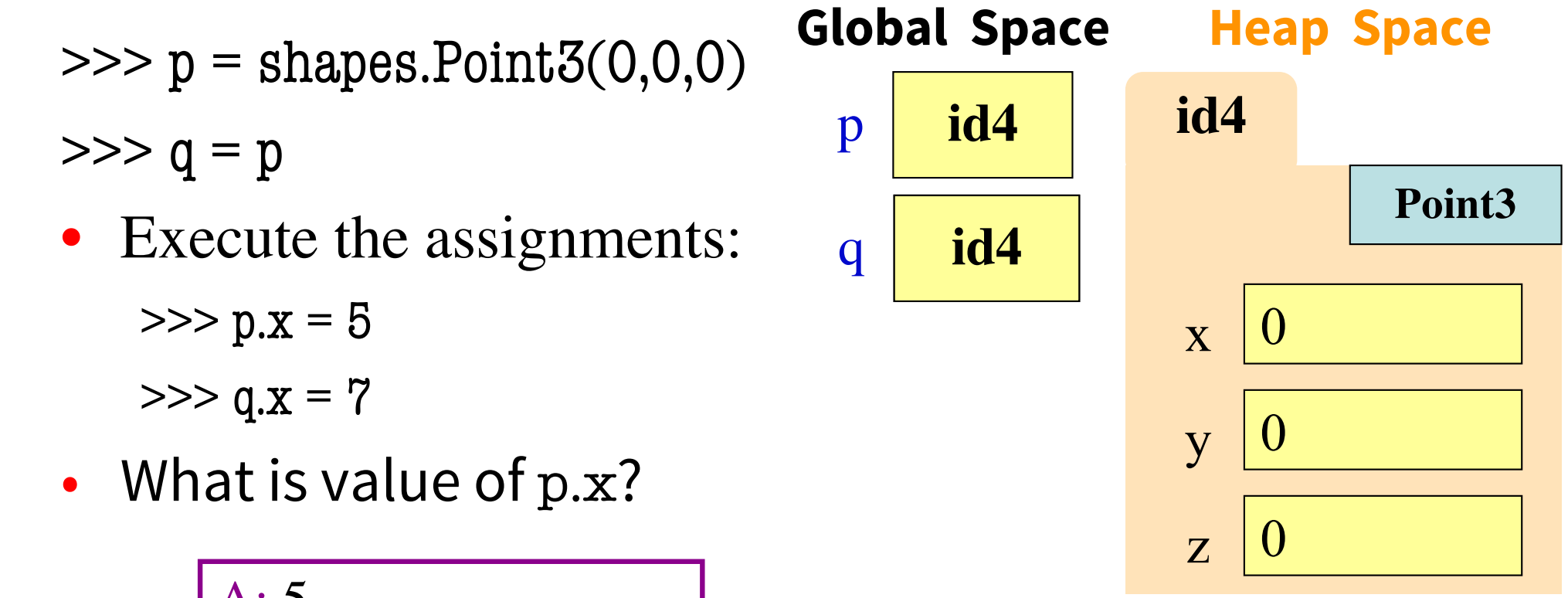
```
>>> p = shapes.Point3(0,0,0)
>>> q = p
```

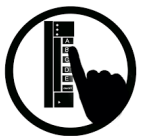
- Execute the assignments:

```
>>> p.x = 5
>>> q.x = 7
```

- What is value of `p.x`?

A: 5
B: 7
C: **id4**
D: I don't know





Attribute Assignment (Solution)

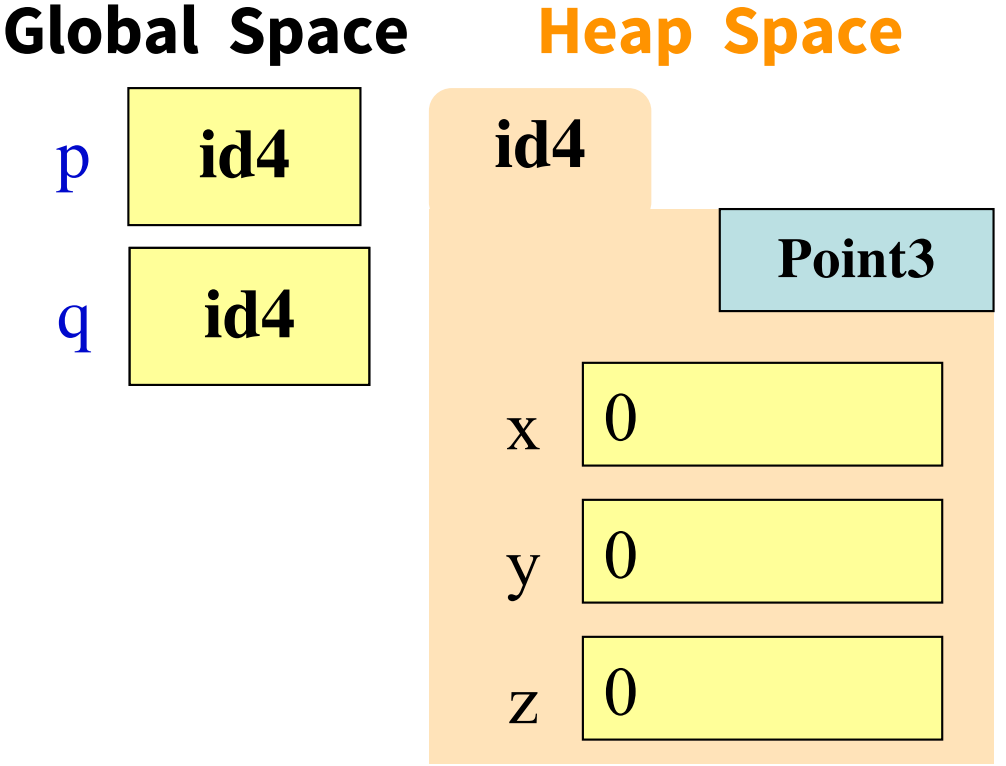
```
>>> p = shapes.Point3(0,0,0)
>>> q = p
```

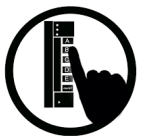
- Execute the assignments:

```
>>> p.x = 5
>>> q.x = 7
```

- What is value of `p.x`?

A: 5
B: 7 **CORRECT**
C: **id4**
D: I don't know



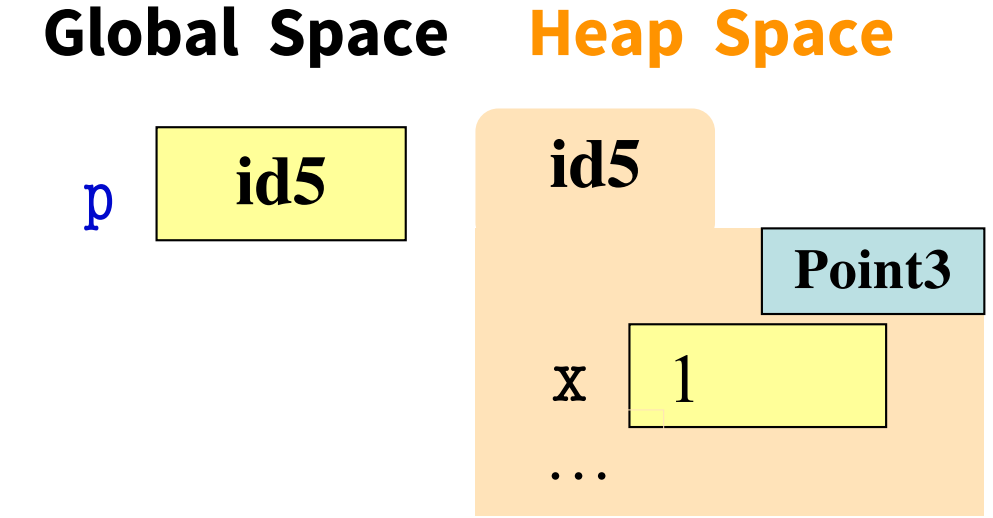


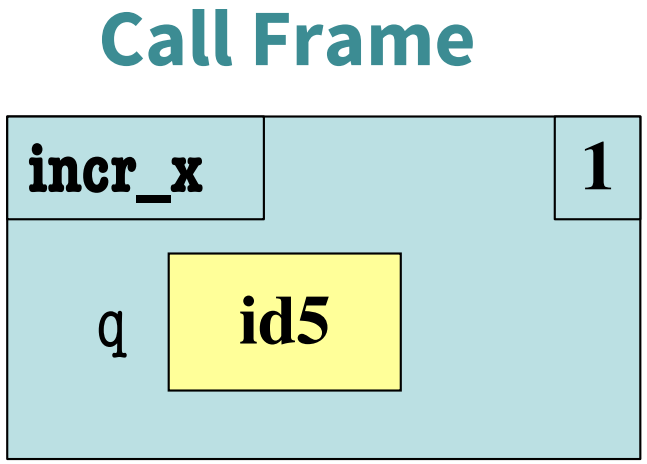
Call Frames and Objects (1)

- Objects can be altered in a function call
  - Object variables hold *id*s!
  - Folder can be accessed from global variable or parameter
- **Example**:

```
def incr_x(q):
    q.x = q.x + 1
```

```
>>> p = shapes.Point3(1, 2, 3)
>>> incr_x(p)
```



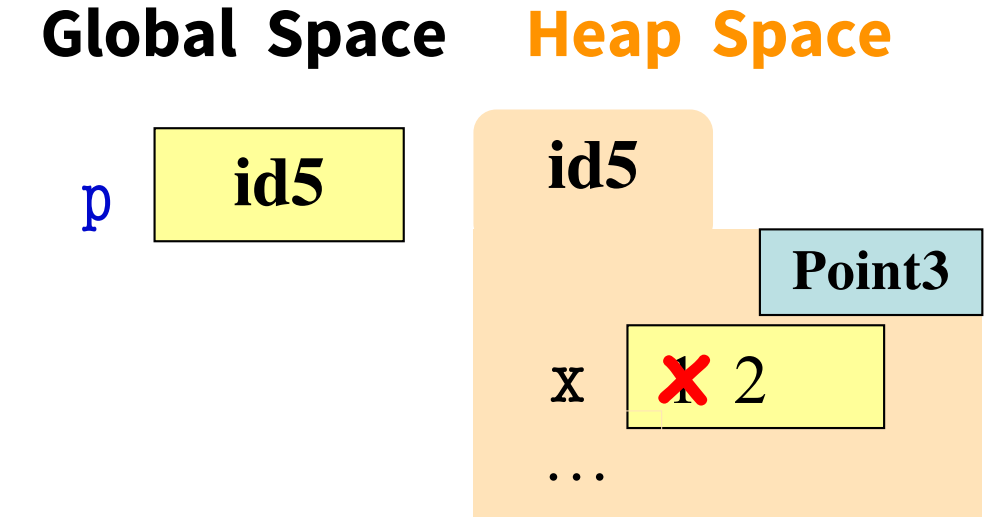


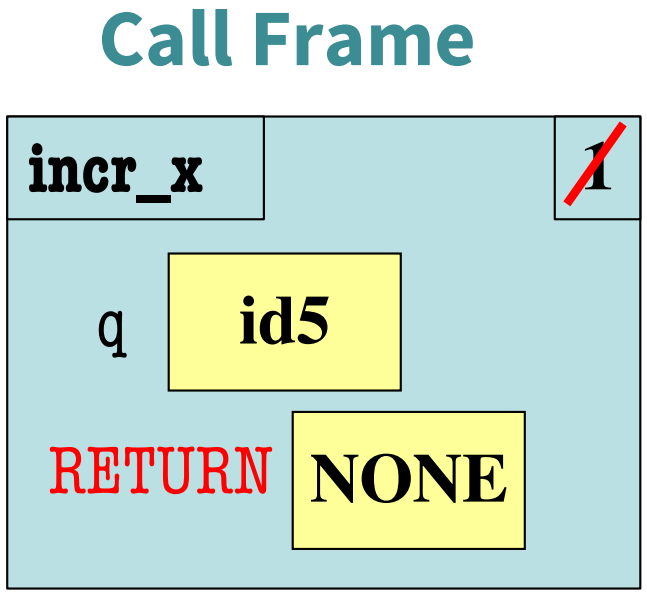
Call Frames and Objects (2)

- Objects can be altered in a function call
  - Object variables hold *id*s!
  - Folder can be accessed from global variable or parameter
- **Example**:

```
def incr_x(q):
1       q.x = q.x + 1
```

```
>>> p = shapes.Point3(1, 2, 3)
>>> incr_x(p)
```



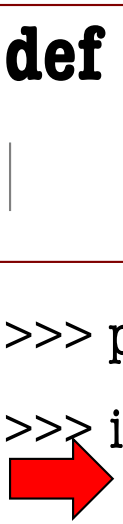


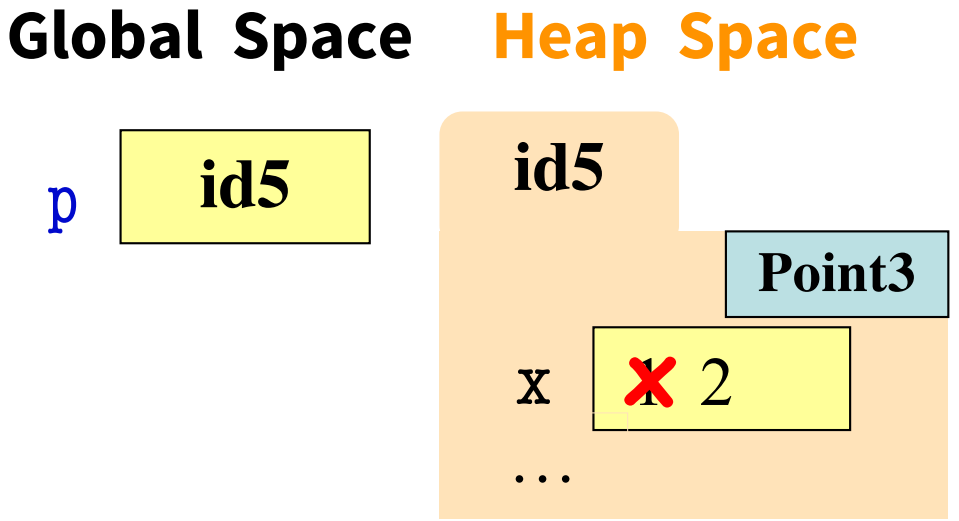
Call Frames and Objects (3)

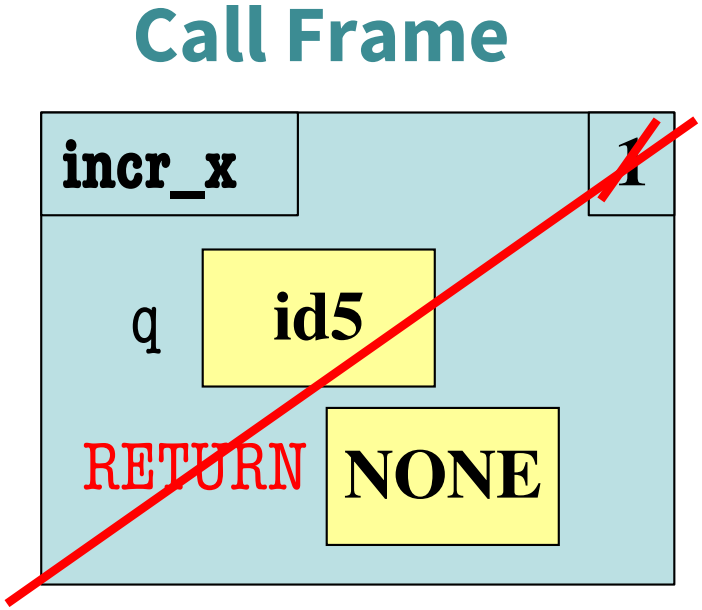
- Objects can be altered in a function call
  - Object variables hold *id*s!
  - Folder can be accessed from global variable or parameter
- **Example**:

```
def incr_x(q):
    q.x = q.x + 1
```

```
>>> p = shapes.Point3(1, 2, 3)
>>> incr_x(p)
```







How Many Folders (Question)

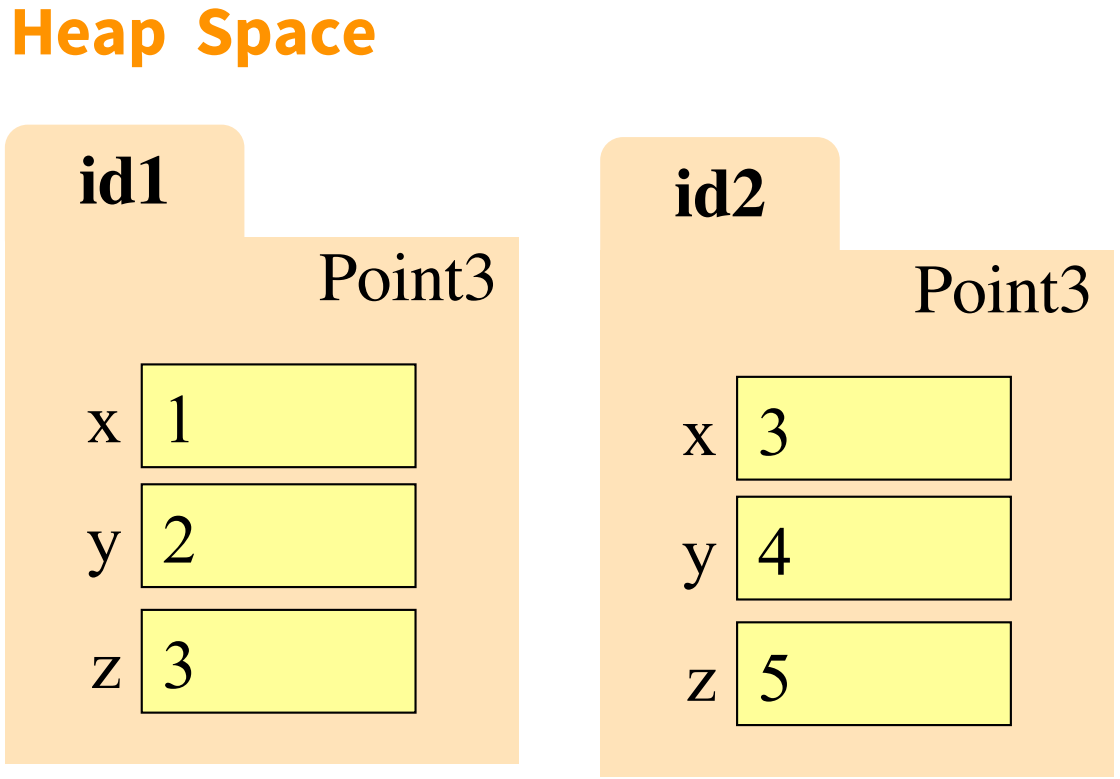
```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)
```

Draw everything that gets created.
How many folders get drawn?

How Many Folders (Solution)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)
```

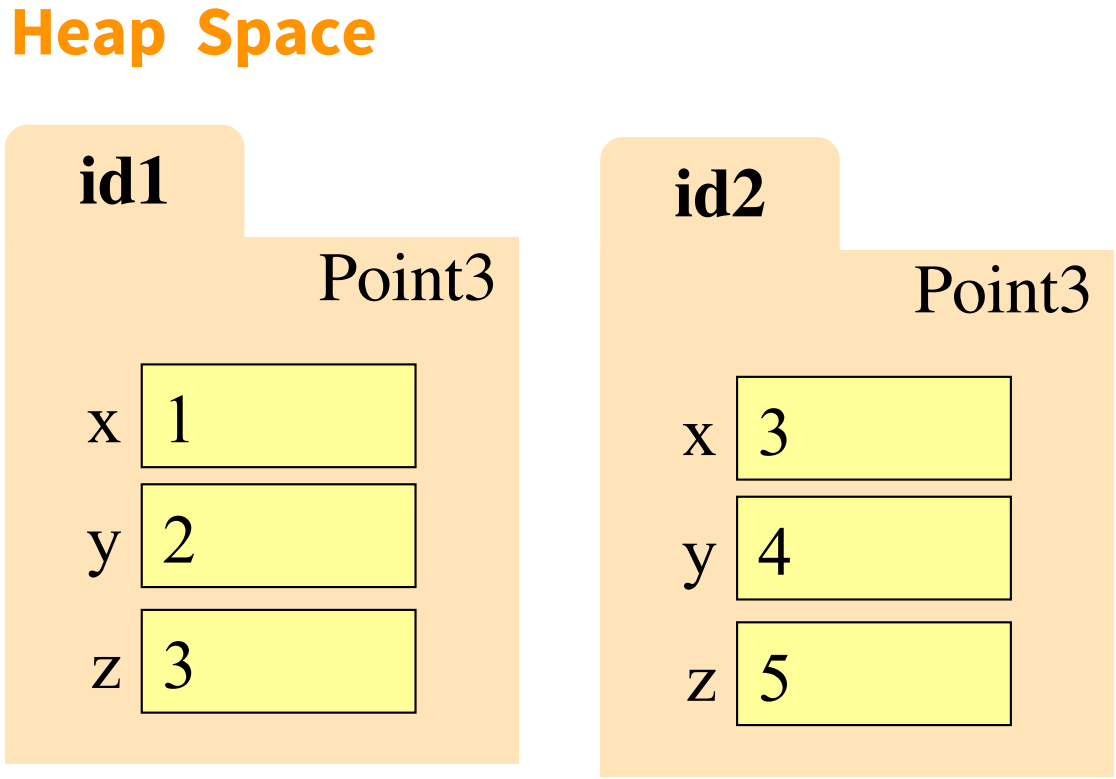
Draw everything that gets created.
How many folders get drawn?



What Else? (Question)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)
```

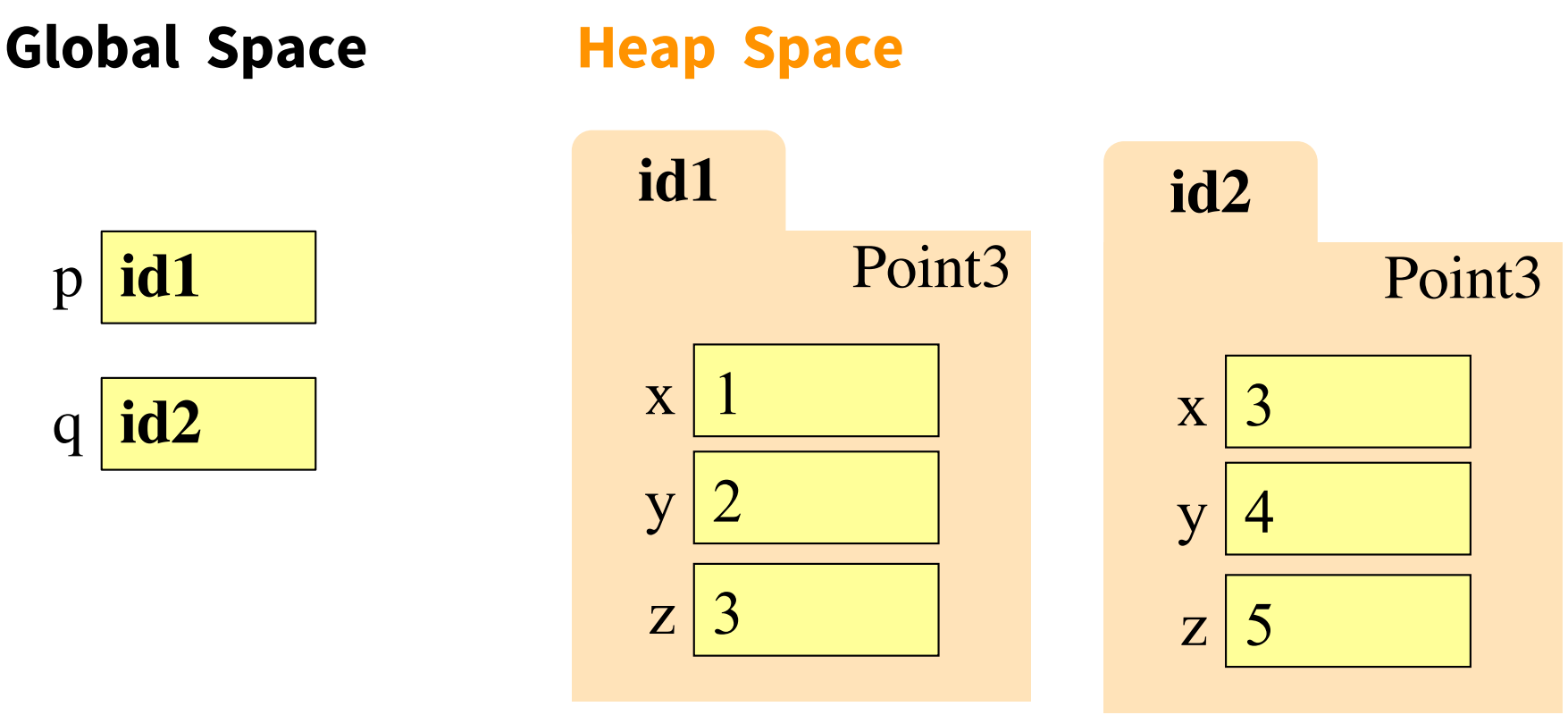
Draw everything that gets created.
How many folders get drawn?
What else gets drawn?



What Else? (Solution)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)
```

Draw everything that gets created.
How many folders get drawn?
What else gets drawn?



Swap (Question)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)

def swap_x(p, q):
1   t = p.x
2   p.x = q.x
3   q.x = t

swap_x(p, q)
```

What is in p.x at the end of this code?

A: 1
B: 2
C: 3
D: I don't know

Global Space

p **id1**

q **id2**

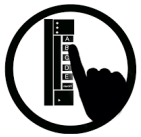
Heap Space

id1 Point3

x 1
y 2
z 3

id2 Point3

x 3
y 4
z 5



Swap (Solution)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)

def swap_x(p, q):
1   t = p.x
2   p.x = q.x
3   q.x = t

swap_x(p, q)
```

What is in p.x at the end of this code?

A: 1
B: 2
C: 3 **CORRECT**
D: I don't know

Global Space

p **id1**

q **id2**

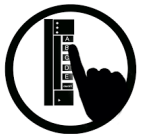
Heap Space

id1 Point3

x 1
y 2
z 3

id2 Point3

x 3
y 4
z 5



Global p (Question)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)

def swap(p, q):
1   t = p
2   p = q
3   q = t

swap(p, q)
```

What is in global p after calling swap?

A: **id1**
B: **id2**
C: I don't know

Global Space

p **id1**

q **id2**

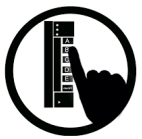
Heap Space

id1 Point3

x 1
y 2
z 3

id2 Point3

x 3
y 4
z 5



Global p (Solution)

```
import shapes
p = shapes.Point3(1,2,3)
q = shapes.Point3(3,4,5)

def swap(p, q):
1   t = p
2   p = q
3   q = t

swap(p, q)
```

What is in global p after calling swap?

A: **id1** **CORRECT**
B: **id2**
C: I don't know

Global Space

p	**id1**
q	**id2**

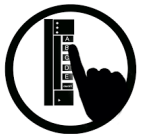
Heap Space

id1 Point3

x	1
y	2
z	3

id2 Point3

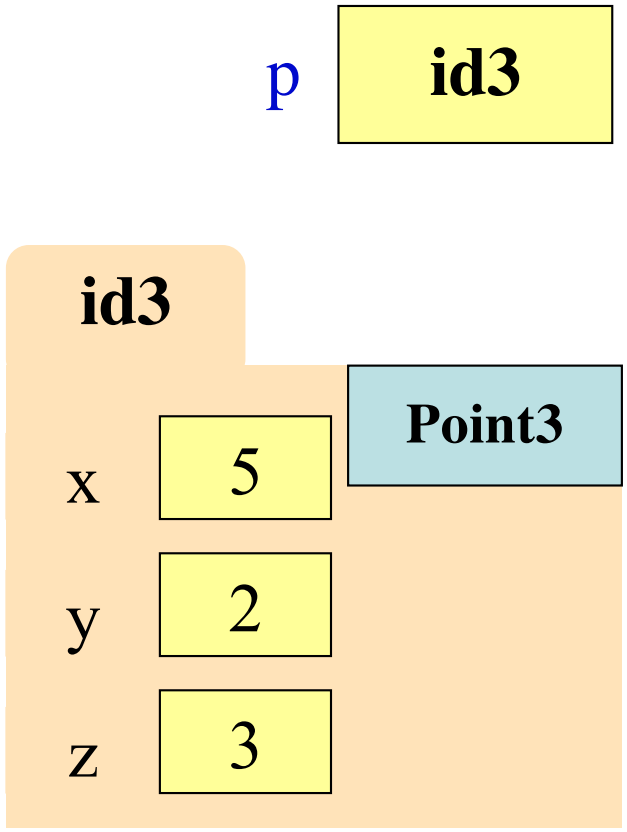
x	3
y	4
z	5



Methods: Functions Tied to Classes

- **Method**: function tied to object
  - Method call looks like a function call preceded by a variable name:

    ⟨*variable*⟩.⟨*method*⟩(⟨*arguments*⟩)



Example:

```
import shapes
p = shapes.Point3(1,2,3)
p.greet()
```

"Hi! I am a 3-dimensional point located at (4,2,3)"

Where else have you seen this??

Example: String Methods

- s_1.upper()
  - Returns returns an upper case version of s_1
- s.strip()
  - Returns a copy of s with white-space removed at ends
- s_1.index(s_2)
  - Returns position of the first instance of s_2 in s_1
  - error if s_2 is not in s_1
- s_1.count(s_2)
  - Returns number of times s_2 appears inside of s_1

Built-in Types vs. Classes

Built-in types

- Built-into Python
- Refer to instances as *values*
- Instantiate with *literals*
- Can ignore the folders

Classes

- Provided by modules
- Refer to instances as *objects*
- Instantiate w/ *constructors*
- Must represent with folders

Where To From Here?

- First, Understand **objects**
  - All Python programs use objects
  - Most small programs use objects of classes that are part of the Python Library
- Eventually, create your own **classes:**
  - the heart of OO Programming
  - the primary tool for organizing Python programs
- But we need to learn more basics first!