Lecture 9

# Objects

# Announcements for Today

## Assignment 1

- We are starting grading
  - Will take most of the day
  - Grades 9am tomorrow
- Resubmit until correct
  - Read feedback in CMS
  - Reupload/request regrade
- If you were very **wrong**…
  - You got an e-mail
  - More 1-on-1s this week

## Assignment 2

- Posted **Today**
  - Written assignment
  - Do while revising A1
  - Relatively short (2-3 hrs)
- Due next **Tuesday**
  - Submit as a PDF
  - Scan or phone picture
  - **US Letter format!**

# The Basic Python Types

- Type **int**:
  - **Values**: integers
  - **Ops**: +, –, *, //, %, **
- Type **float**:
  - **Values**: real numbers
  - **Ops**: +, –, *, /, **
- Type **bool**:
  - **Values**: **True** and **False**
  - **Ops**: not, and, or

- Type **str**:
  - **Values**: string literals
    - Double quotes: `"abc"`
    - Single quotes: `'abc'`
  - **Ops**: + (concatenation)

Are the the only types that exist?

# Example: Points in 3D Space

```
def distance(x0,y0,z0,x1,y1,z1):
    """Returns distance between points (x0,y0,y1) and (x1,y1,z1)

    Param x0: x-coord of 1st point
    Precond: x0 is a float

    Param y0: y-coord of 1st point
    Precond: y0 is a float

    Param z0: z-coord of 1st point
    Precond: z0 is a float
    ....
    """
```

- This is very unwieldy
  - Specification is too long
  - Calls needs many params
  - Typo bugs are very likely
- Want to reduce params
  - Package points together
  - How can we do this?

# Points as Their Own Type

```
def distance(p0,p1):
    """Returns distance between points p0 and p1

    Param p0: The second point
    Precond: p0 is a Point3

    Param p1: The second point
    Precond: p1 is a Point3"""
    …
```

This lecture will help you make sense of this spec.

# Classes: Custom Types

- **Class**: Custom type **not built into** Python
  - Just like with functions: built-in & defined
  - Types not built-in are **provided by modules**
- Might seem weird: `type(1)` => `<class 'int'>`
  - In Python 3 `type` and `class` are **synonyms**
  - We will use the historical term for clarity

`introcs` provides several **classes**

# Objects: Values for a Class

- **Object**: A specific **value** for a class type
  - Remember, a type is a set of values
  - Class could have infinitely many objects
- **Example**: Class is `Point3`
  - One object is **origin**; another **x-axis** `(1,0,0)`
  - These objects go in params distance function
- Sometimes refer to objects as **instances**
  - Because a value is an instance of a class
  - Creating an object is called *instantiation*

# How to Instantiate an Object?

- Other types have **literals**
  - **Example**: 1, `'abc'`, **true**
  - No such thing for objects
- Classes are provided by modules
  - Modules typically provide new functions
  - In this case, gives a function to make objects
- **Constructor function** has same name as class
  - Similar to types and type conversion
  - **Example**: **str** is a type, `str(1)` is a function call

# Demonstrating Object Instantiation

```
>>> import Point3 from introcs # Module with class
>>> p = Point3(0,0,0)          # Create point at origin
>>> p                          # Look at this new point
<class 'introcs.geom.point.Point3'>(0.0,0.0,0.0)
>>> type(p) == Point3          # Check the type
True
>>> q = Point3(1,2,3)          # Make new point
>>> q                          # Look at this new point
<class 'introcs.geom.point.Point3'>(1.0,2.0,3.0)
```

# What Does an Object Look Like?

- Objects can be a bit strange to understand
  - Don’t look as simple as strings or numbers
  - **Example**: `<class 'introcs.Point3'>(0.0,0.0,0.0)`
- To understand objects, need to *visualize* them
  - Use of metaphors to help us think like Python
  - Call frames (assume seen) are an example
- To visualize we rely on the **Python Tutor**
  - Website linked to from the course page
  - But use only that one! Other tutors are different.

# Metaphor: Objects are Folders

```
>>> import introcs
```

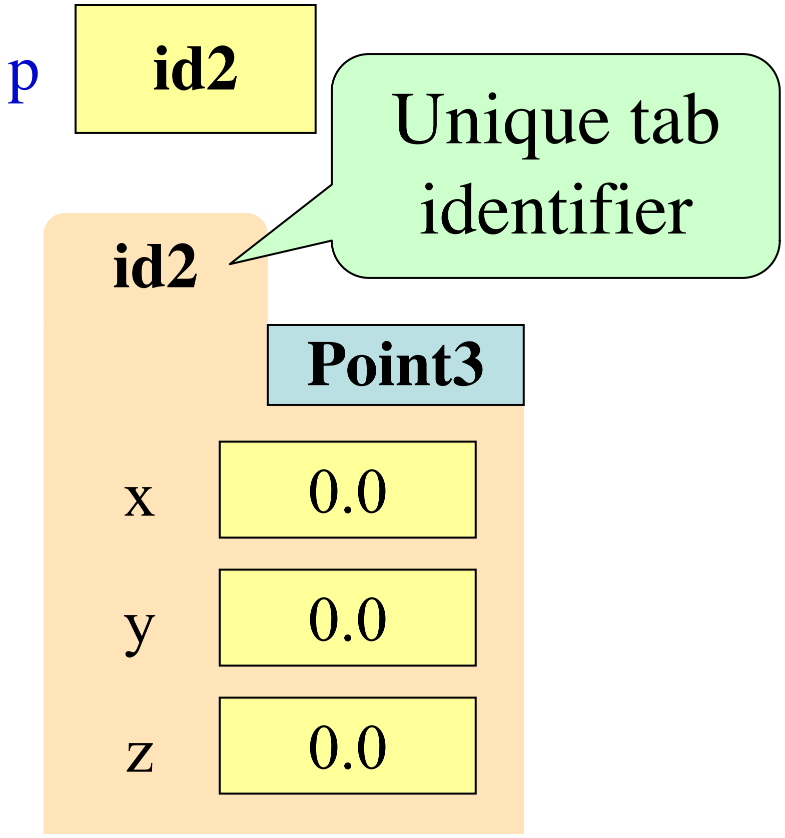
Need to import module that has Point class.

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

Constructor is function. Prefix w/ module name.

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

Shows the ID of p.



p id2

Unique tab identifier

id2

Point3

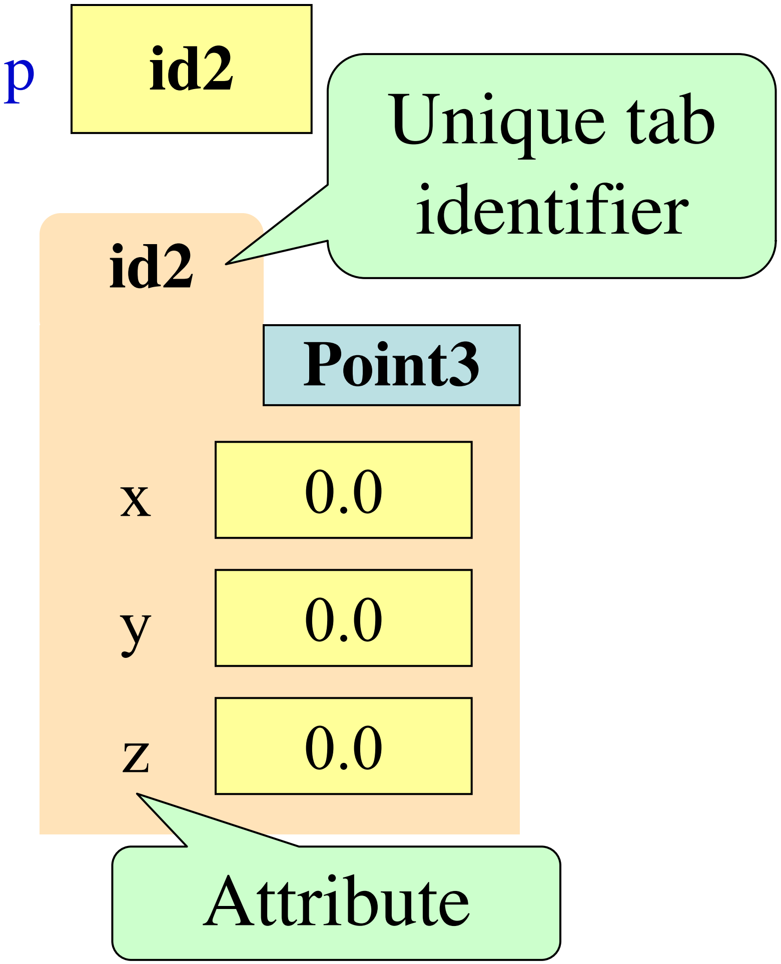
x 0.0

y 0.0

z 0.0

# Metaphor: Objects are Folders

- **Idea**: Data too "big" for p
  - Split into many variables
  - Put the variables in folder
  - They are called **attributes**
- Folder has an identifier
  - Unique (like a netid)
  - Cannot ever change
  - Has no real meaning; only identifies folder

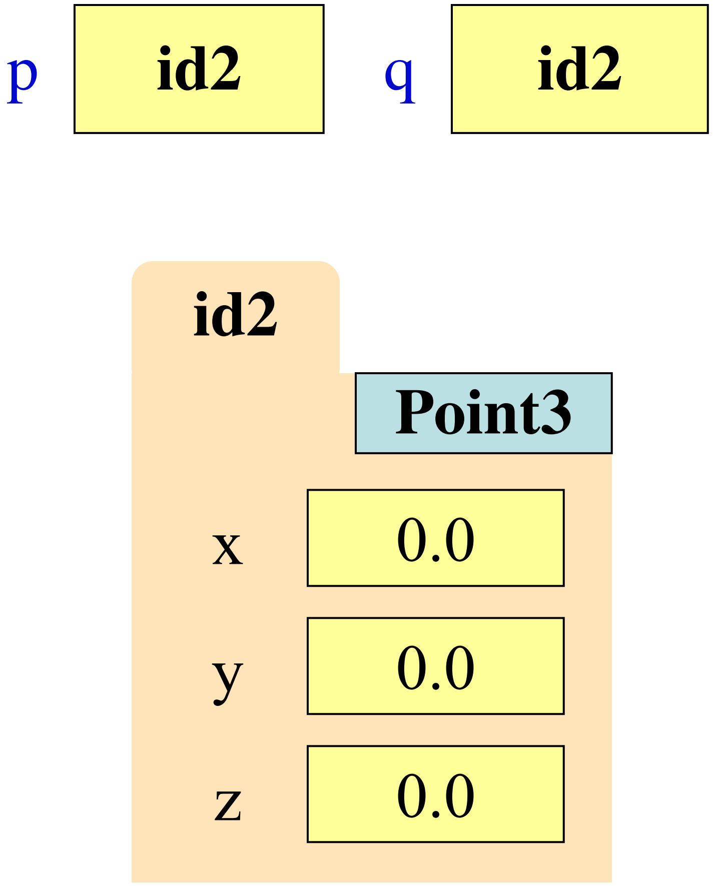


Unique tab identifier

Attribute

# Object Variables

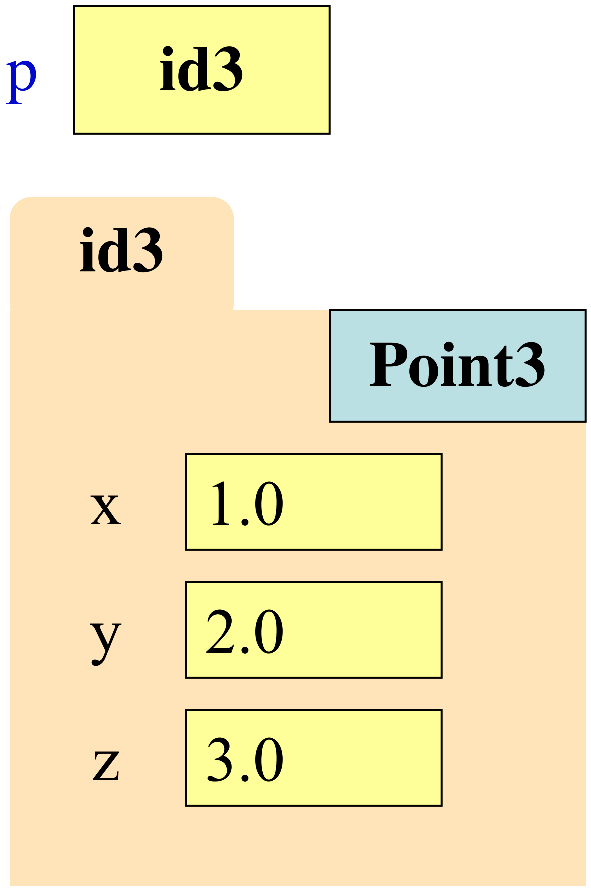
- Variable stores object name
  - **Reference** to the object
  - Reason for folder analogy
- Assignment uses object name
  - **Example**: q = p
  - Takes name from p
  - Puts the name in q
  - Does not make new folder!
- This is the cause of many mistakes for beginners



# Objects and Attributes

- Attributes live inside objects
  - Can access these attributes
  - Can use them in expressions
- **Access**: <variable>.<attr>
  - Look like module variables
  - **Recall**: math.pi
- **Example**

```
>>> p = introcs.Point3(1,2,3)
>>> a = p.x + p.y
```



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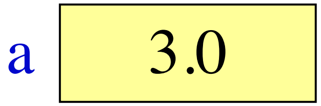
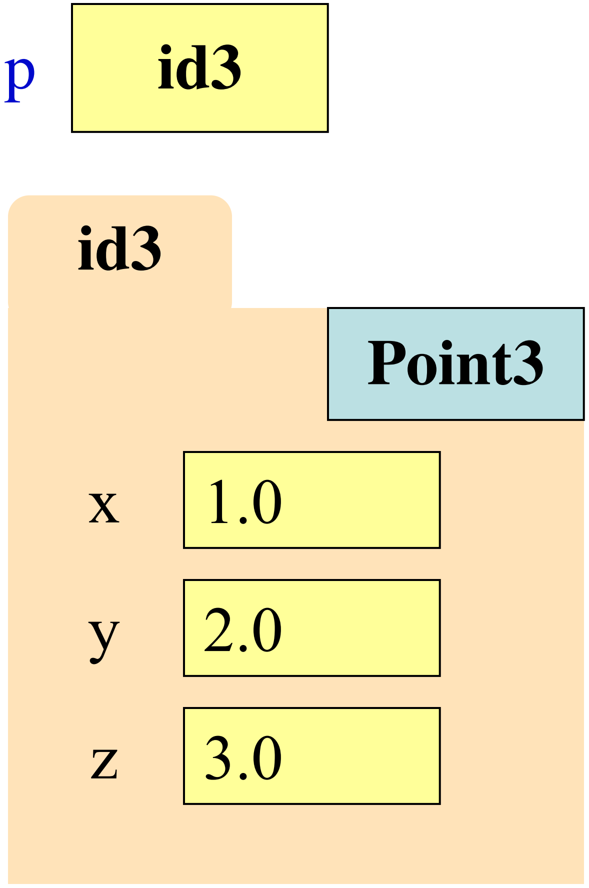


a

3.0



p

**id3**

**id3**

**Point3**

x

1.0

y

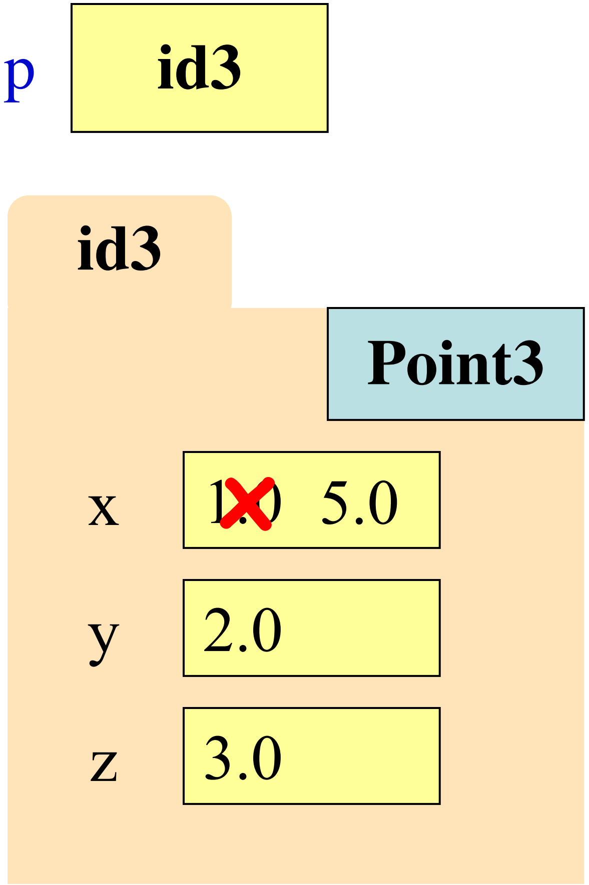
2.0

z

3.0

# Objects and Attributes

- Can also **assign** attributes
  - Reach into folder & change
  - Do without changing `p`
- `<var>.<attr> = <exp>`
  - **Example**: `p.x = p.y+p.z`
  - See this in visualizer
- This is very powerful
  - Another reason for objects
  - Why need visualization



# Exercise: Attribute Assignment

- Recall, q gets name in p

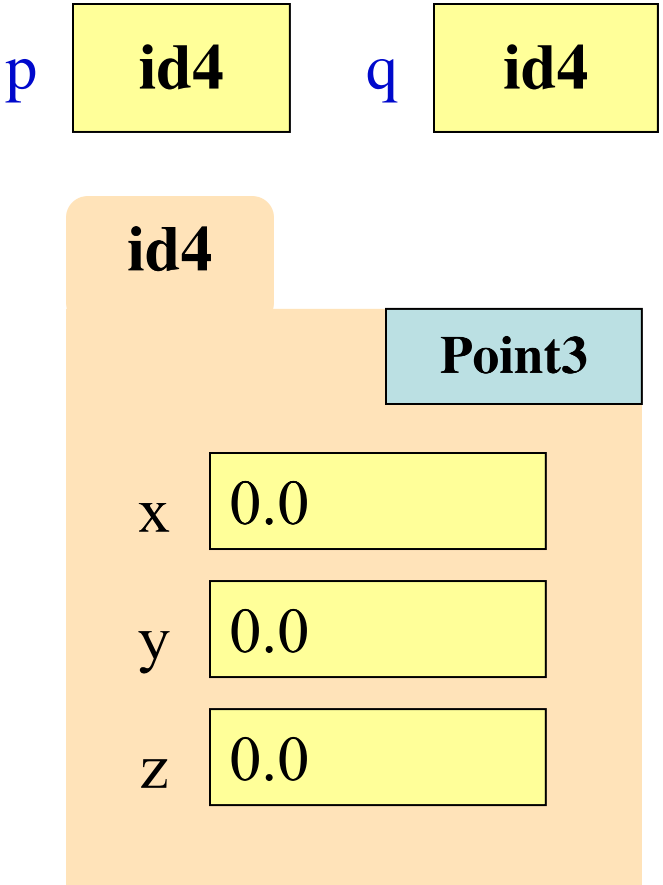
```
>>> p = introcs.Point3(0,0,0)
>>> q = p
```

- Execute the assignments:

```
>>> p.x = 5.6
>>> q.x = 7.4
```

- What is value of p.x?

A: 5.6
B: 7.4
C: **id4**
D: I don't know



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B: 7.4 **CORRECT**

C: **id4**

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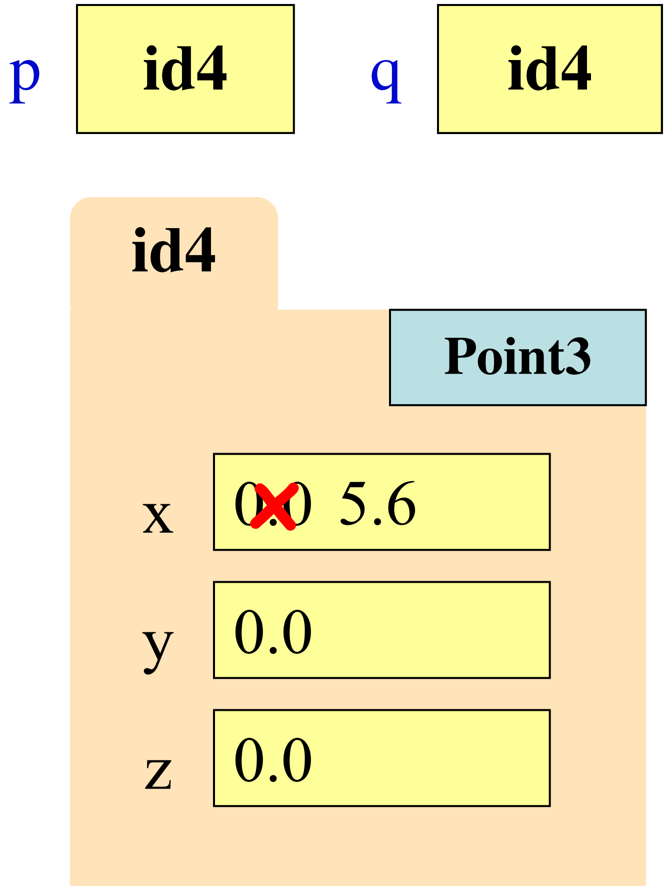

# Exercise: Attribute Assignment

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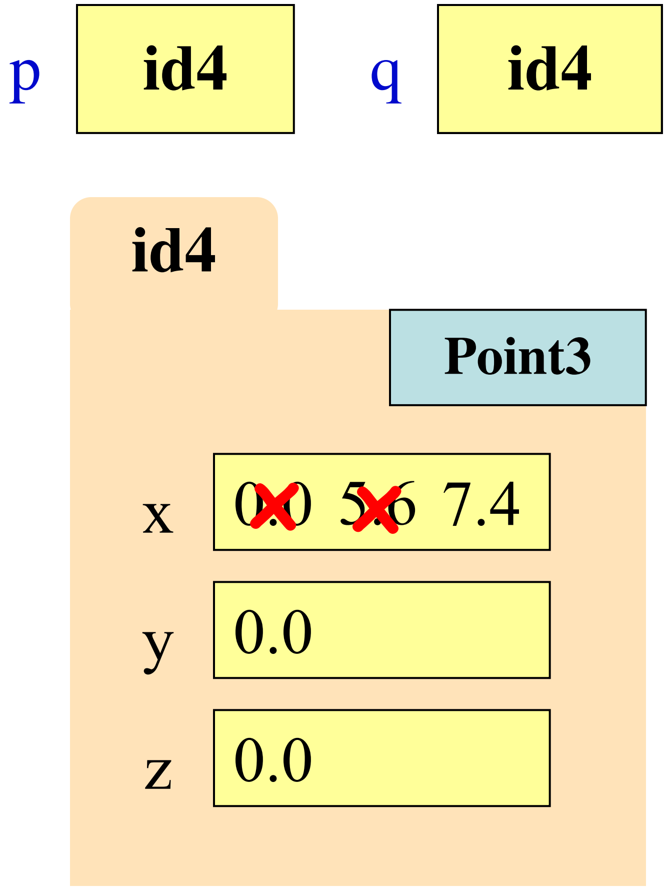


p **id4**

q **id4**

**id4**

**Point3**

x ~~0.0~~ ~~5.6~~ 7.4

y 0.0

z 0.0

# Objects Allow for Mutable Functions

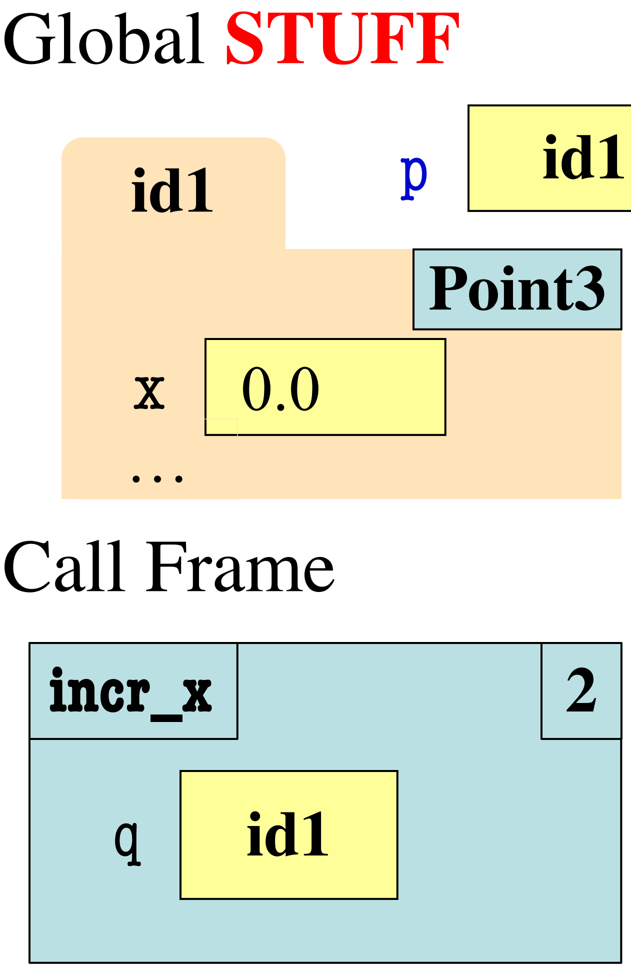
- **Mutable function**: *alters* the parameters
  - Often a procedure; no return value
- Until now, this was impossible
  - Function calls **COPY** values into new variables
  - New variables erased with call frame
  - Original (global?) variable was unaffected
- But object variables are *folder names*
  - Call frame refers to same folder as original
  - Function may modify the contents of this folder

# Example: Mutable Function Call

- **Example**:

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

```
>>> p = Point3(0,0,0)
>>> p.x
0.0
>>> incr_x(p)
>>> p.x
1.0
```

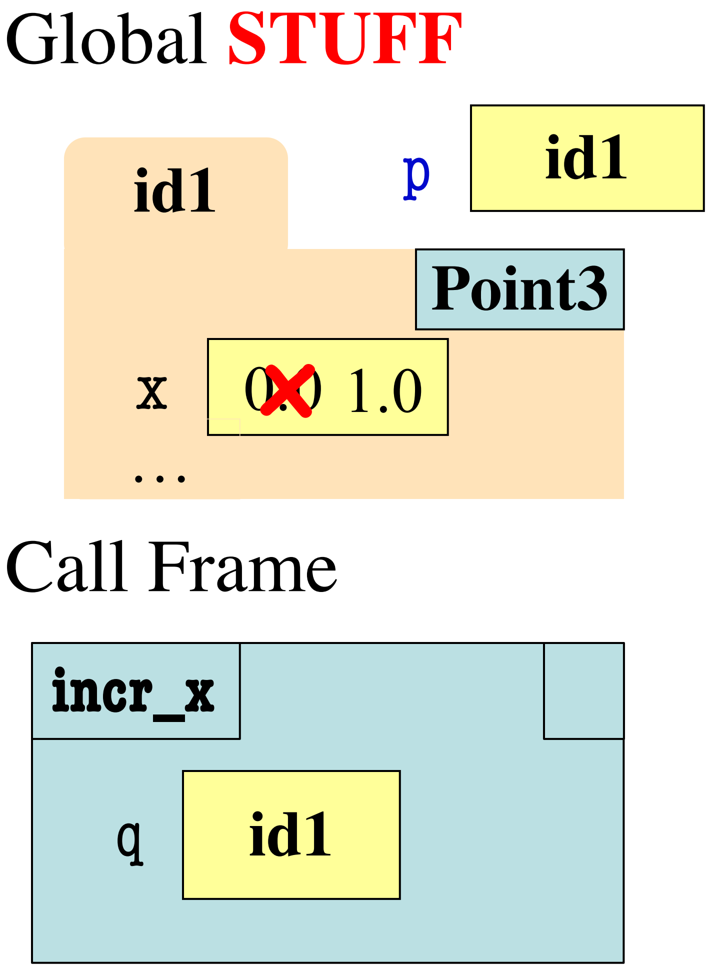


# Example: Mutable Function Call

- **Example**:

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

```
>>> p = Point3(0,0,0)
>>> p.x
0.0
>>> incr_x(p)
>>> p.x
1.0
```

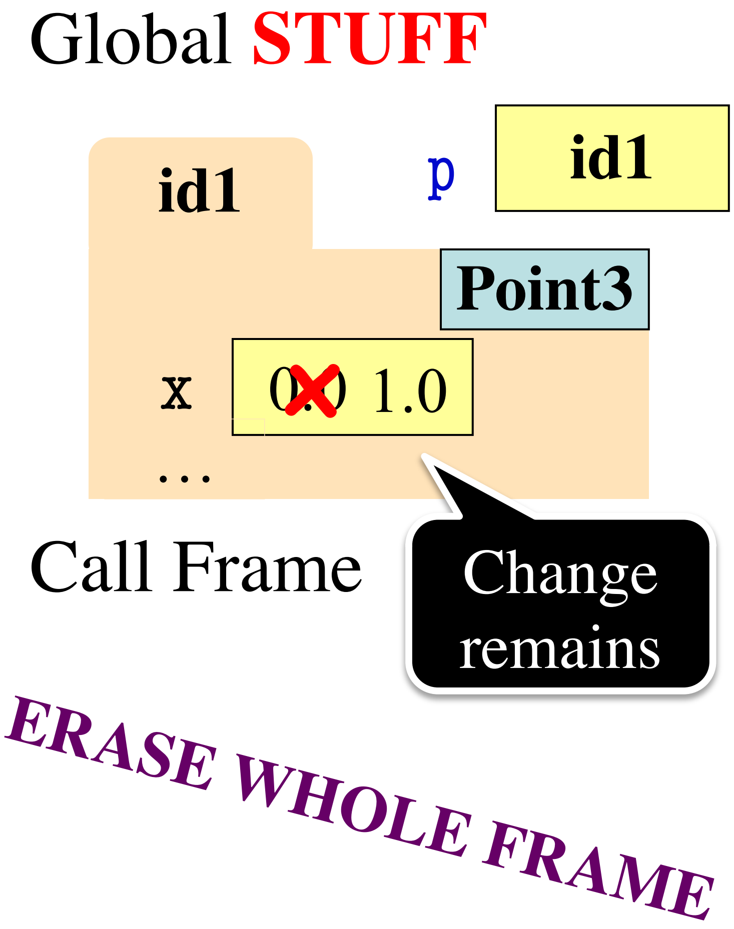


# Example: Mutable Function Call

- **Example:**

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

```
>>> p = Point3(0,0,0)
>>> p.x
0.0
>>> incr_x(p)
>>> p.x
1.0
```



# Methods: Functions Tied to Objects

- Have seen object folders contain variables
  - **Syntax**: ⟨obj⟩.⟨attribute⟩ (e.g. `p.x`)
  - These are called *attributes*
- They can also contain functions
  - **Syntax**: ⟨obj⟩.⟨method⟩(⟨*arguments*⟩)
  - **Example**: `p.clamp(-1,1)`
  - These are called *methods*
- Visualizer will not show these inside folders
  - Will see why in **November** (when cover Classes)

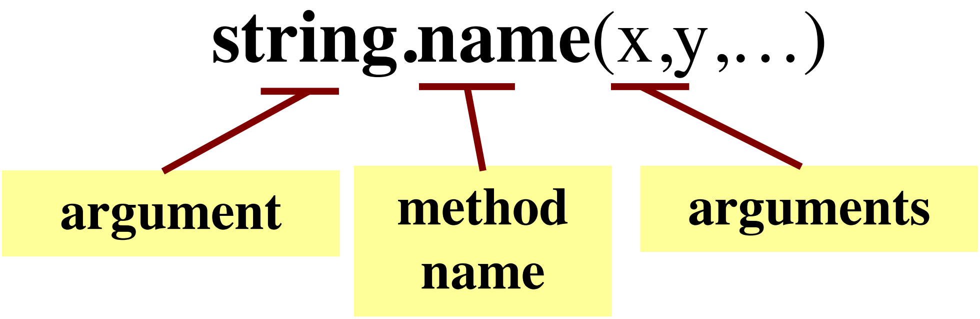
# Understanding Method Calls

- Object before the name is an *implicit* argument
- **Example**: distance

```
>>> p = Point3(0,0,0)     # First point
>>> q = Point3(1,0,0)     # Second point
>>> r = Point3(0,0,1)     # Third point
>>> p.distance(r)         # Distance between p, r
1.0
>>> q.distance(r)         # Distance between q, r
1.4142135623730951
```

# Recall: String Method Calls

- **Method calls** have the form



**string.name**(x,y,…)

**argument**

**method name**

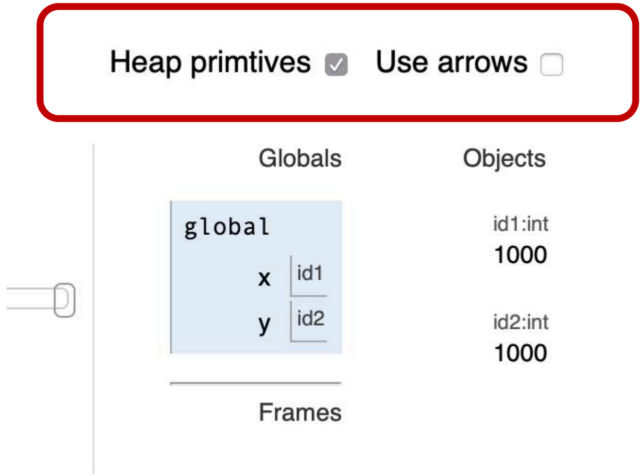
**arguments**

- The string in front is an **additional** argument
  - Just one that is not inside of the parentheses
  - **Why?** Will answer this later in course.

Are strings objects?

# Surprise: All Values are Objects!

- Including basic values
  - int, float, bool, str



Heap primtives ☑ Use arrows ☐

Globals Objects

global

x id1

y id2

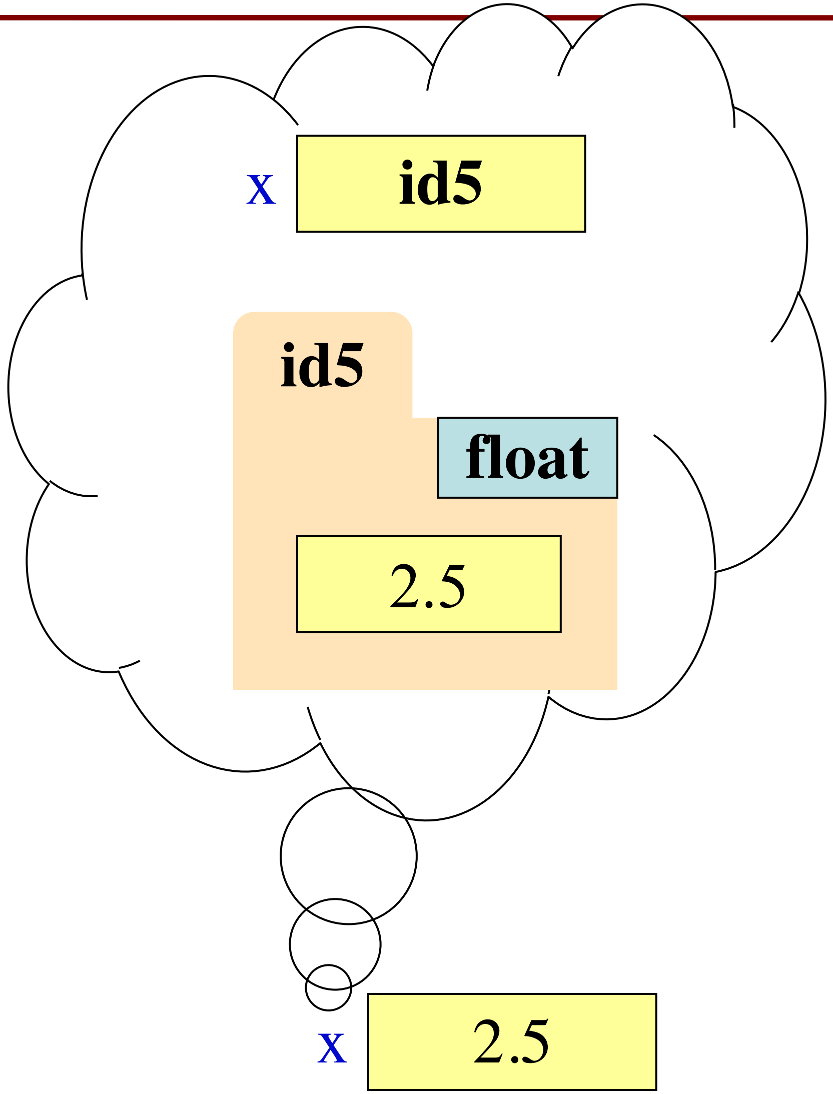
id1:int
1000

id2:int
1000

Frames

- **Example**:

```
>>> x = 1000
>>> id(x)
```



# This Explains A Lot of Things

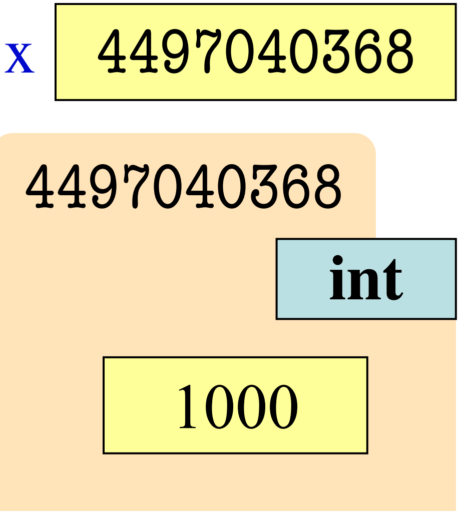
- Basic types act like classes
  - **Conversion function** is really a **constructor**
  - Remember **constructor**, **type** have same name
- Example:

```
>>> type(1)
<class 'int'>
>>> int('1')
1
```

- Design goals of Python 3
  - Wanted everything an object
  - Makes processing cleaner
- But makes learning harder
  - Objects are complex topic
  - Want to delay if possible

# But Not Helpful to Think This Way

- Number folders are **immutable**
  - "Variables" have no names
  - No way to reach in folder
  - No way to change contents



Makes a brand new int folder

```
>>> x = 1000
>>> y = 1000
>>> id(x)
4497040368
>>> id(y)
4497040400
>>> y = y+1
>>> id(y)
4497040432
```

# But Not Helpful to Think This Way

- Number folders are **immutable**
  - "Variables" have no names
  - No way to reach in folder
  - No way to change contents
- Remember **purpose of folder**
  - Show how objects can be altered
  - Show how variables "share" data
  - This **cannot happen** in basic types
- So just **ignore the folders**
  - (The are just metaphors anyway)

```
>>> x = 1000
>>> y = 1000
>>> id(x)
4497040368
>>> id(y)
4497040400
>>> y = y+1
>>> id(y)
4497040432
```

# Basic Types vs. Classes

| Basic Types | Classes |
|---|---|
| • Built-into Python | • Provided by modules |
| • Refer to instances as *values* | • Refer to instances as *objects* |
| • Instantiate with *literals* | • Instantiate w/ *constructors* |
| • Are all immutable | • Can alter attributes |
| • Can ignore the folders | • Must represent with folders |

In doubt? Use the Python Tutor

# Where To From Here?

- Right now, just try to understand **objects**
  - **All** Python programs use objects
  - The object classes are provided by Python
- OO Programming is about **creating classes**
  - But we will not get to this until after Prelim 1
- Similar to the **separation of functions**
  - First learned to **call functions** (**create objects**)
  - Then how to **define functions** (**define classes**)