

Lecture 16

Classes

Announcements for This Lecture

Prelim and Regrades

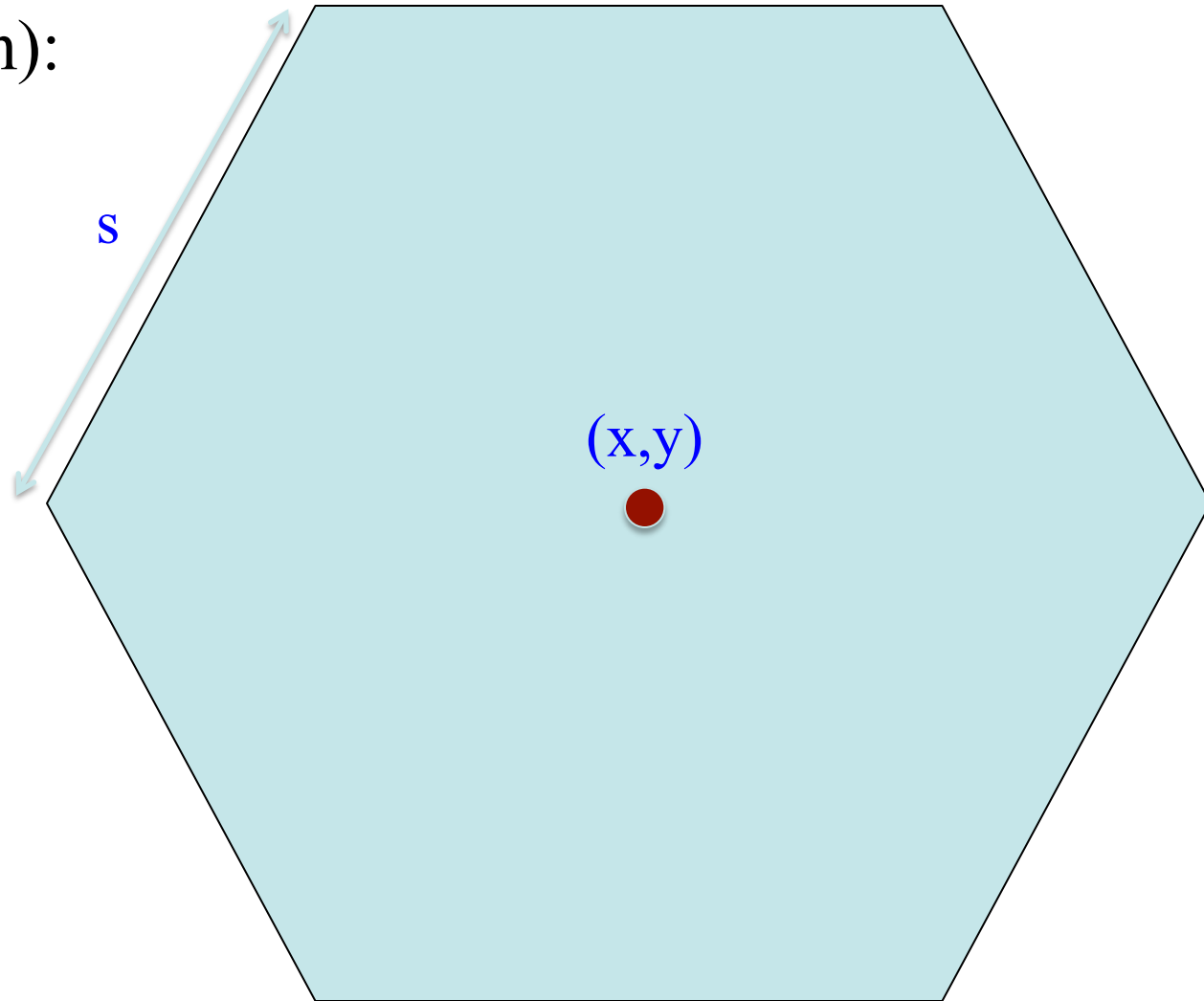
- Still have some prelims
 - Apparently were misfiled
 - Pick them up in office hours
- Regrades in CMS next week
 - Only for MAJOR mistakes
 - We reserve the right to take off points in a regrade
 - Score addition mistakes ok

Assignments/Reading

- A4 due next Thursday
 - Bug fixes are uploaded
 - Hopefully started by now
- **DO NOT UPGRADE TO OS X MAVERICKS!**
- **Reading:** Chapters 15, 16
 - Chapter 17 for next week
 - Guest lecture on Tuesday

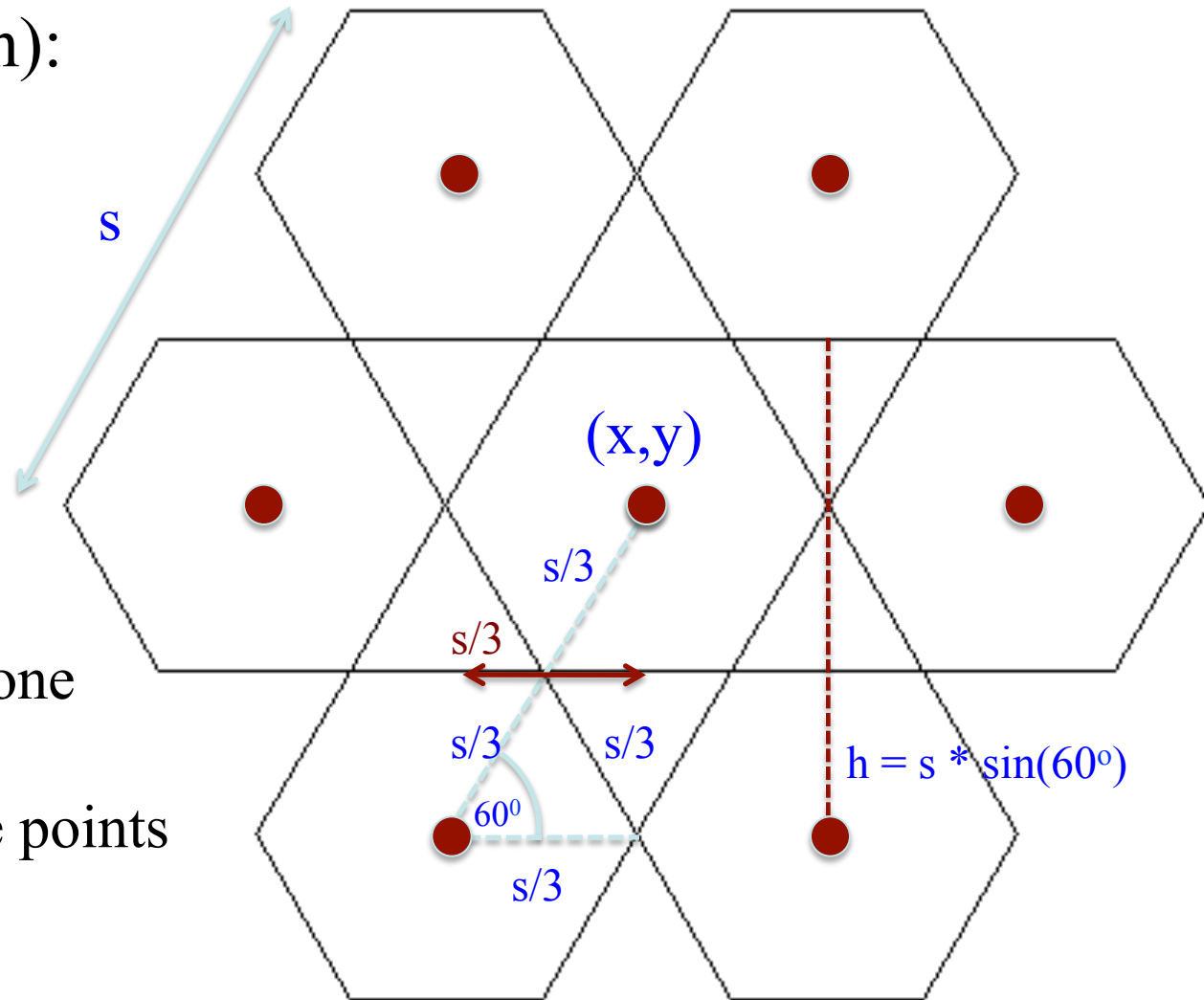
A4: Grisly Snowflakes

- Given (as shown):
 - Length s
 - Point (x,y)



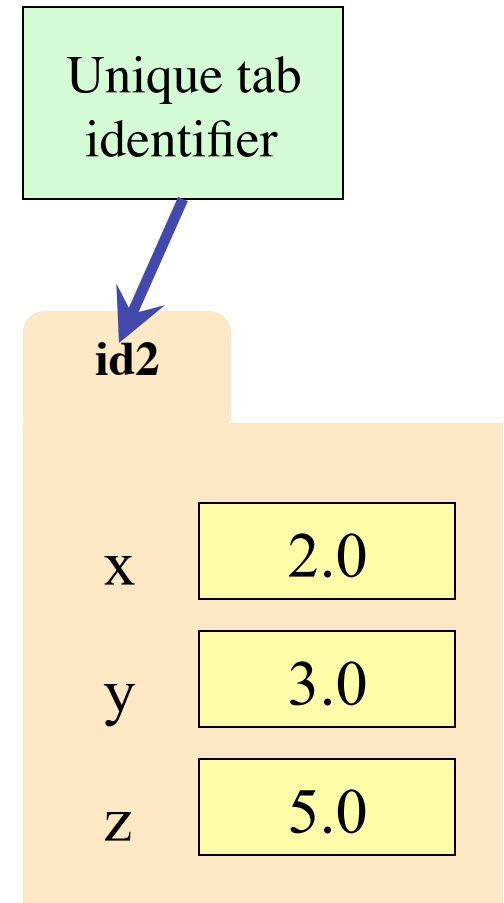
A4: Grisly Snowflakes

- Given (as shown):
 - Length s
 - Point (x,y)
- Find:
 - Coordinates of all red points
- Draw:
 - Snowflakes of one less depth and size $s/3$ at those points



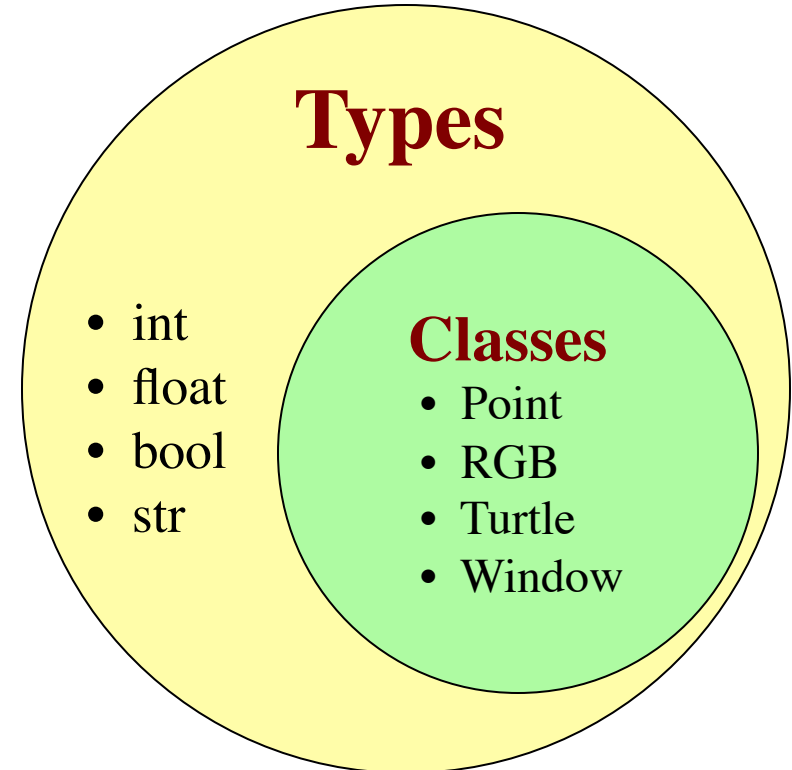
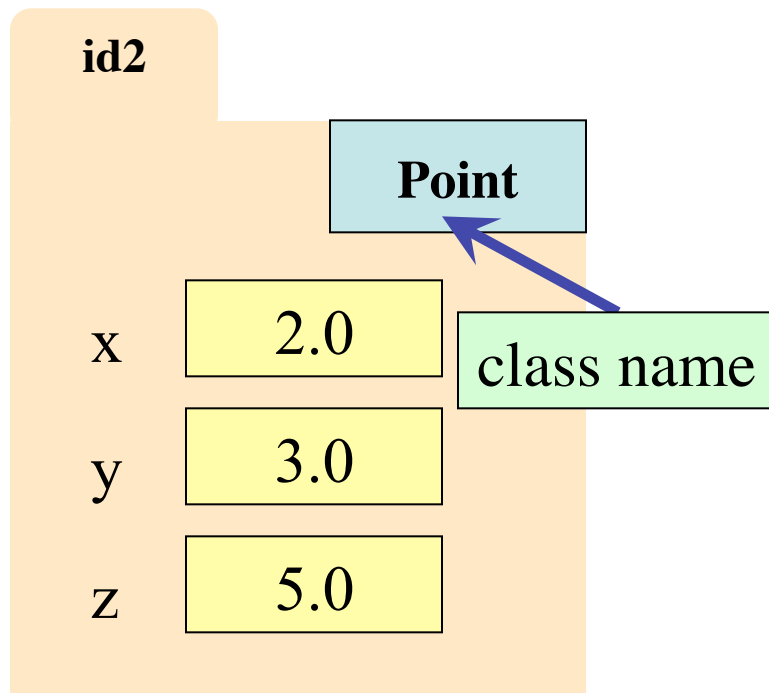
Recall: Objects as Data in Folders

- An object is like a **manila folder**
- It contains other variables
 - Variables are called **attributes**
 - Can change values of an attribute (with assignment statements)
- It has a “tab” that identifies it
 - Unique number assigned by Python
 - Fixed for lifetime of the object



Recall: Classes are Types for Objects

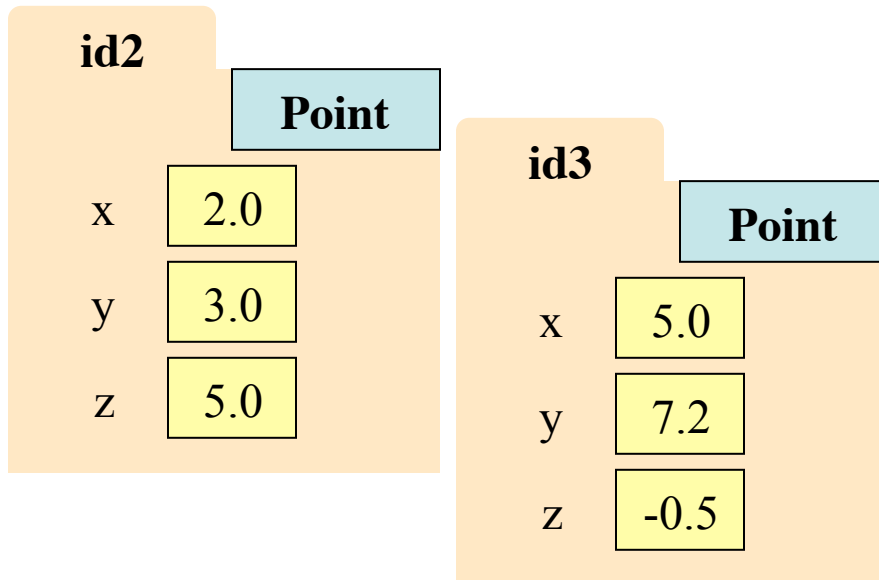
- Values must have a type
 - An object is a **value**
 - Object type is a **class**
- Classes are how we add new types to Python



Classes Have Folders Too

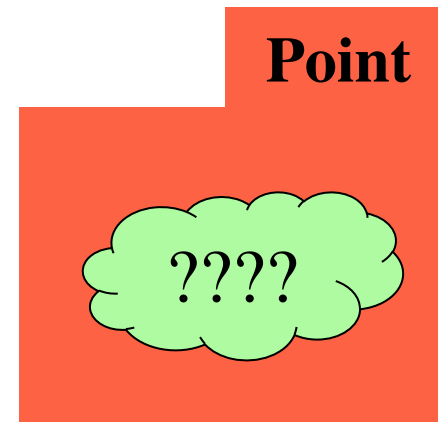
Object Folders

- Separate for each *instance*



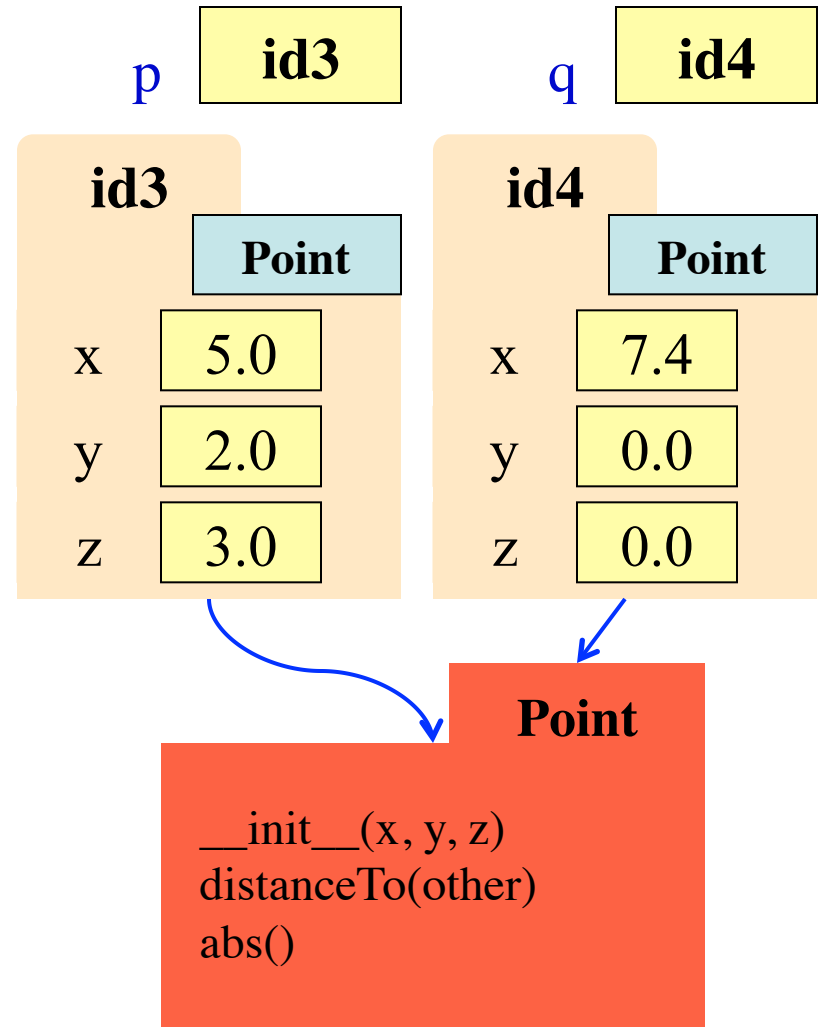
Class Folders

- Data common to all instances



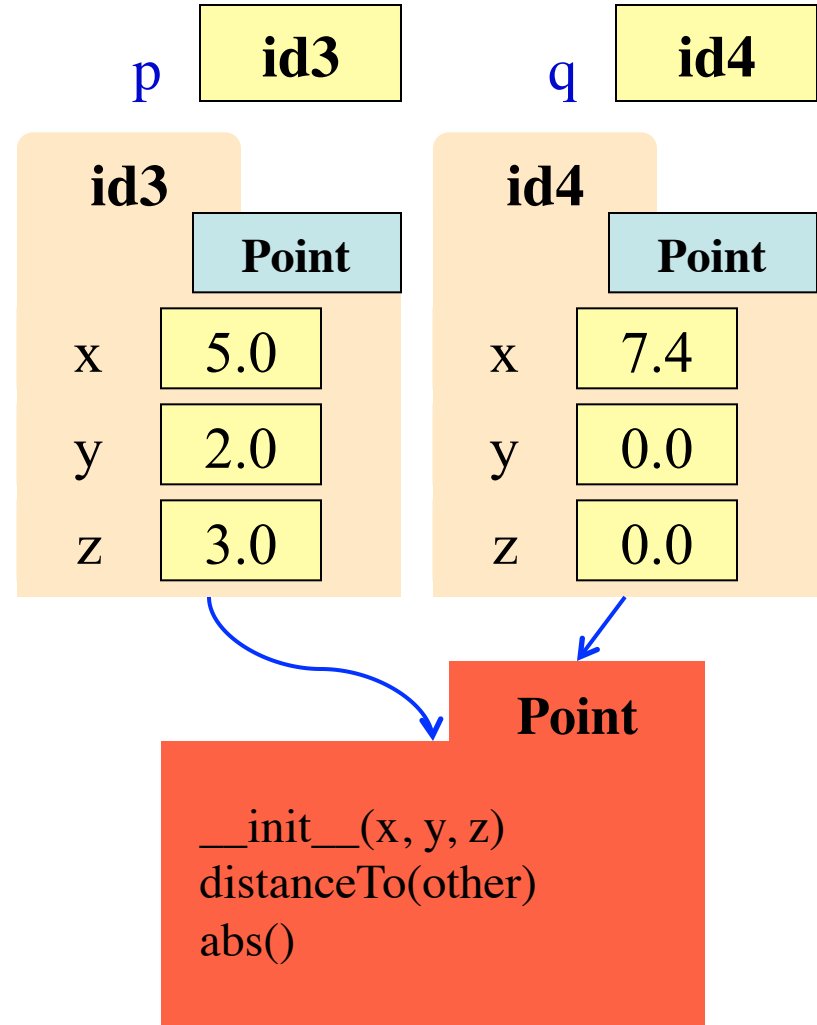
Recall: Objects can have Methods

- **Method:** function tied to object
 - Function call:
`<function-name>(<arguments>)`
 - Method call:
`<object-variable>.<function-call>`
 - Use of a method is a *method call*
- **Example:** `p.distanceTo(q)`
 - Both `p` and `q` act as arguments
 - Very much like `distanceTo(p, q)`
- Methods (often) in **class folders**



Name Resolution for Objects

- `<object>.<name>` means
 - Go the folder for *object*
 - Find attribute/method *name*
 - If missing, check **class folder**
 - If not in either, raise error
- For most Python objects
 - **Attributes** are in **object** folder
 - **Methods** are in **class** folder
- Rules can be broken...
(but not in this class)



The Class Definition

Goes inside a module, just like a function definition.

class *<class-name>*(object):

"""Class specification"""

<function definitions>

<assignment statements>

<any other statements also allowed>

```
class Example(object):  
    """The simplest possible class."""  
    pass
```

Example

The Class Definition

Goes inside a module, just like a function definition.

keyword **class**
Beginning of a class definition

class *<class-name>*(object):

Do not forget the colon!

Specification
(similar to one for a function)

"""Class specification"""

more on this later

<function definitions>

to define **methods**

<assignment statements>

...but not often used

to define **attributes**

<any other statements also allowed>

```
class Example(object):  
    """The simplest possible class."""  
    pass
```

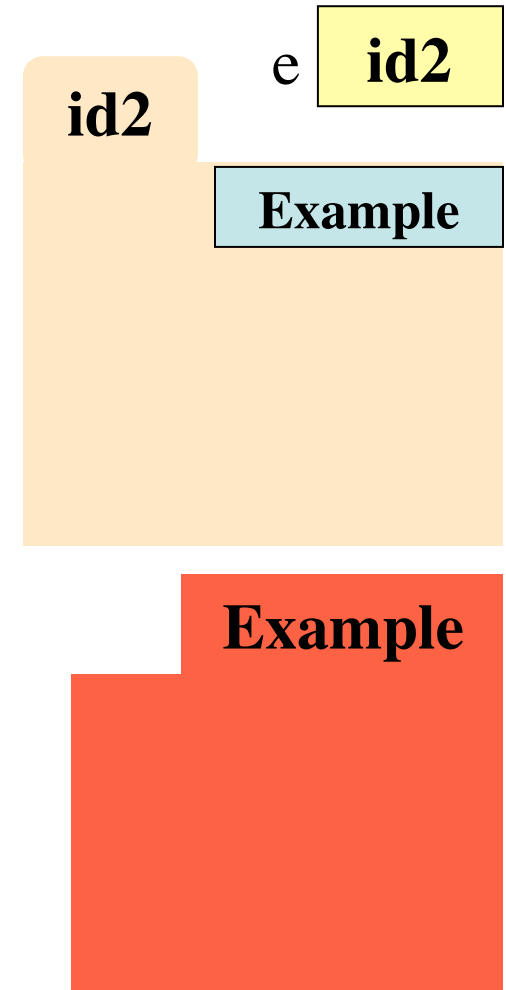
Example

Python creates after reading the class definition

Recall: Constructors

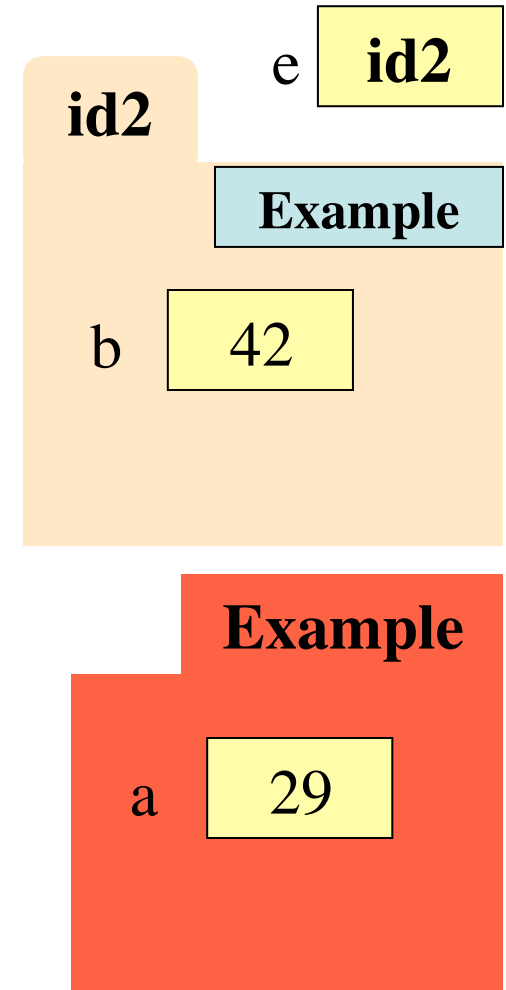
- Function to create new instances
 - Function name == class name
 - Created for you automatically
- Calling the constructor:
 - Makes a new object folder
 - Initializes attributes
 - Returns the id of the folder
- By default, takes no arguments
 - `e = Example()`

Will come back to this

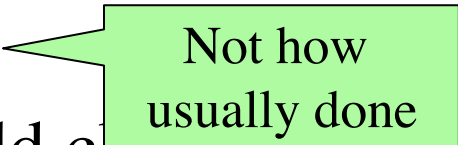


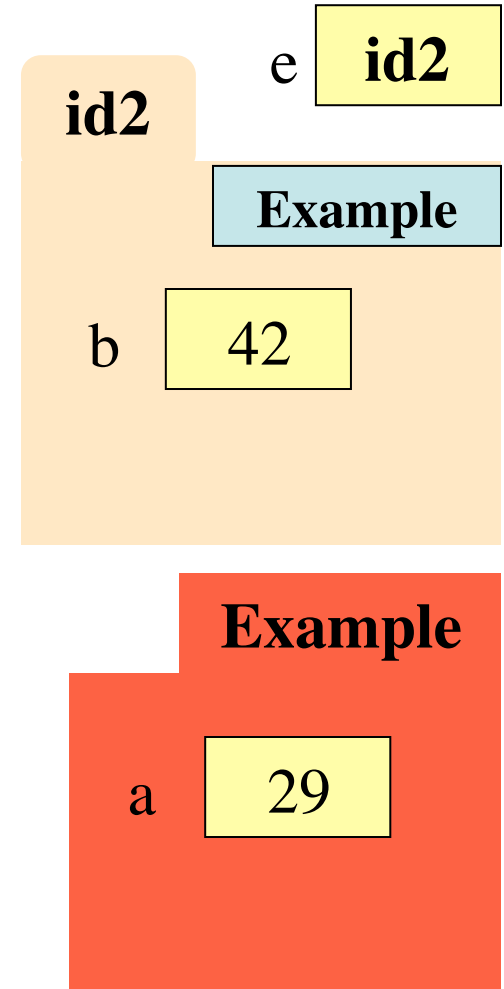
Instances and Attributes

- Assignments add object attributes
 - `<object>.<att> = <expression>`
 - **Example:** `e.b = 42`
- Assignments can add class attributes
 - `<class>.<att> = <expression>`
 - **Example:** `Example.a = 29`
- Objects can access class attributes
 - **Example:** `print e.a`
 - But assigning it creates object attribute
 - **Example:** `e.a = 10`
- **Rule:** check object first, then class



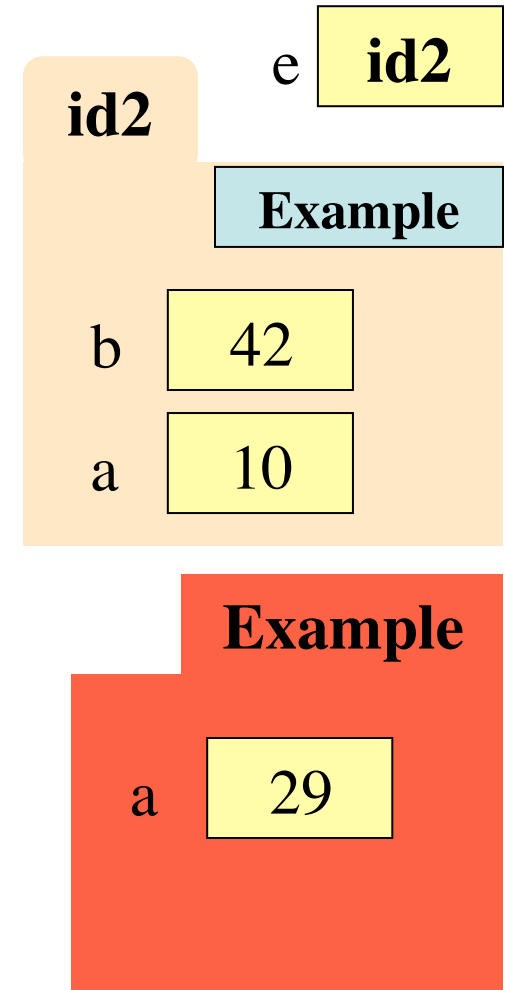
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Instances and Attributes

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 - `<object>.<att> = <expression>`
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- Assignments can add class attributes
 - `<class>.<att> = <expression>`
 - **Example:** `Example.a = 29`
- Objects can access class attributes
 - **Example:** `print e.a`
 - But assigning it creates object attribute
 - **Example:** `e.a = 10`
- **Rule:** check object first, then class



Invariants

- Properties of an attribute that must be true
- Works like a precondition:
 - If invariant satisfied, object works properly
 - If not satisfied, object is “corrupted”
- **Examples:**
 - **Point** class: all attributes must be floats
 - **RGB** class: all attributes must be ints in 0..255
- Purpose of the **class specification**

The Class Specification

```
class Worker(object):
```

```
    """An instance is a worker in an organization.
```

```
Instance has basic worker info, but no salary information.
```

```
ATTRIBUTES:
```

```
    lname: Worker's last name. [str]
```

```
    ssn:    Social security no. [int in 0..999999999]
```

```
    boss:  Worker's boss.      [Worker, or None if no boss]
```

The Class Specification

```
class Worker(object):
```

Short
summary

```
    """An instance is a worker in an organization.
```

More
detail

Attribute
list

```
    Instance has basic worker info, but no salary information.
```

Description

```
    ATTRIBUTES:
```

Invariant

Attribute
Name

```
    lname: Worker's last name. [str]
```

```
    ssn: Social security no. [int in 0..999999999]
```

```
    boss: Worker's boss. [Worker, or None if no boss]
```

Method Definitions

- Looks like a function def
 - But indented *inside* class
 - The first parameter is always called **self**
- In a method call:
 - Parentheses have one less argument than parameters
 - The object in front is passed to parameter self
- **Example:** `a.distanceTo(b)`

self

q

```
class Point(object):
```

```
    """Instances are points in 3d space
       x: x coord [float]
       y: y coord [float]
       z: z coord [float]    """
```

```
    def distanceTo(self,q):
```

```
        """Returns: dist from self to q
           Precondition: q a Point"""
```

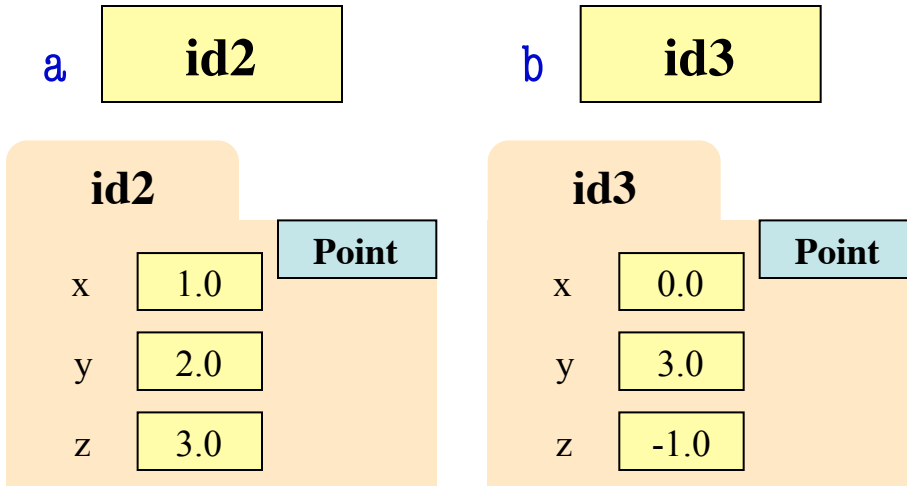
```
        assert type(q) == Point
```

```
        sqrdst = ((self.x-q.x)**2 +
                  (self.y-q.y)**2 +
                  (self.z-q.z)**2)
```

```
        return math.sqrt(sqrdst)
```

Methods Calls

- **Example:** `a.distanceTo(b)`



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```

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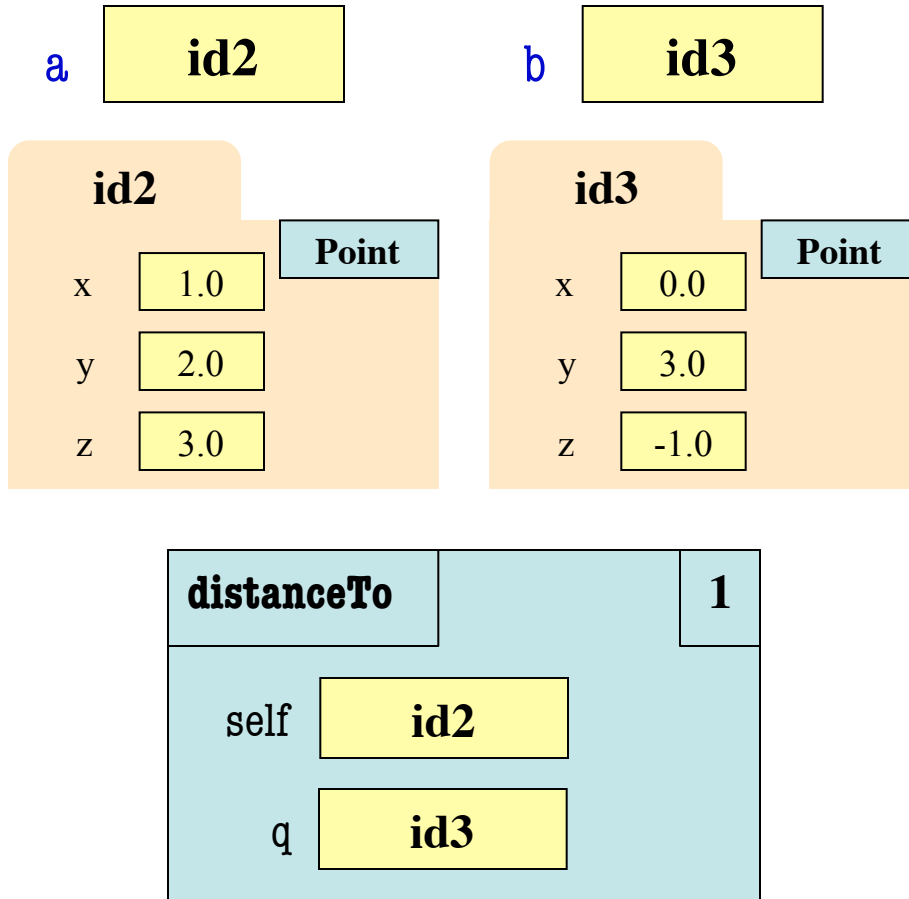
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Methods Calls

- **Example:** `a.distanceTo(b)`



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Initializing the Attributes of an Object (Folder)

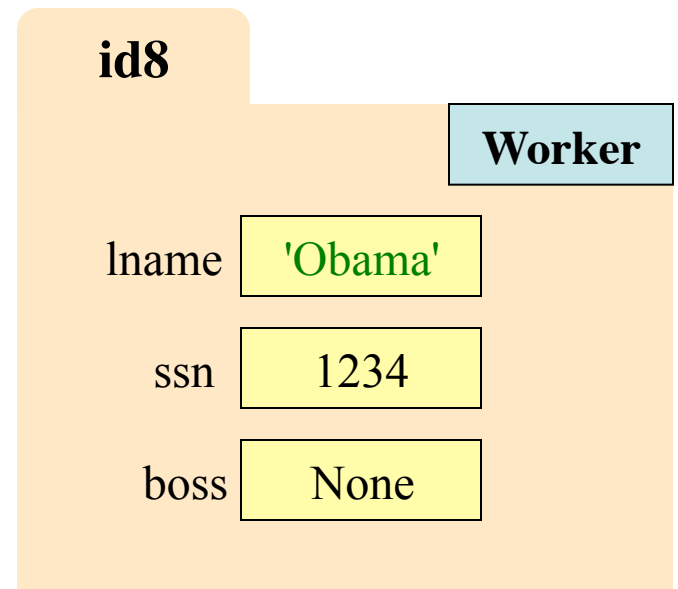
- Creating a new Worker is a multi-step process:
 - `w = Worker()` ← Instance is empty
 - `w.lname = 'White'`
 - ...
- Want to use something like
 - `w = Worker('White', 1234, None)`
 - Create a new Worker **and** assign attributes
 - lname to 'White', ssn to 1234, and boss to None
- Need a **custom constructor**

Special Method: `__init__`

```
w = Worker('Obama', 1234, None)
```

```
def __init__(self, n, s, b):  
    """Initializer: creates a Worker  
  
    Has last name n, SSN s, and boss b  
  
    Precondition: n a string, s an int in  
    range 0..999999999, and b either  
    a Worker or None.  
    self.lname = n  
    self.ssn = s  
    self.boss = b
```

Called by the constructor



Special Method: `__init__`

two underscores

```
w = Worker('Obama', 1234, None)
```

don't forget self

```
def __init__(self, n, s, b):
```

"""Initializer: creates a Worker

Has last name n, SSN s, and boss b

Precondition: n a string, s an int in range 0..999999999, and b either a Worker or None.

```
self.lname = n
```

```
self.ssn = s
```

```
self.boss = b
```

Called by the constructor

id8

Worker

lname 'Obama'

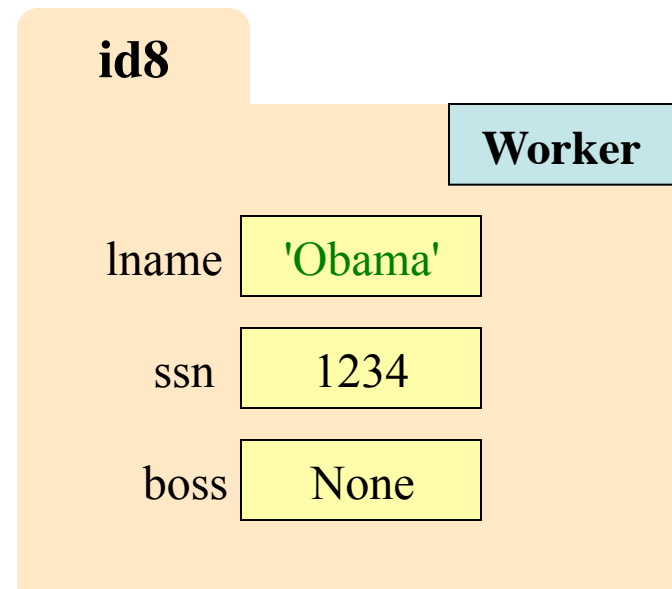
ssn 1234

boss None

Evaluating a Constructor Expression

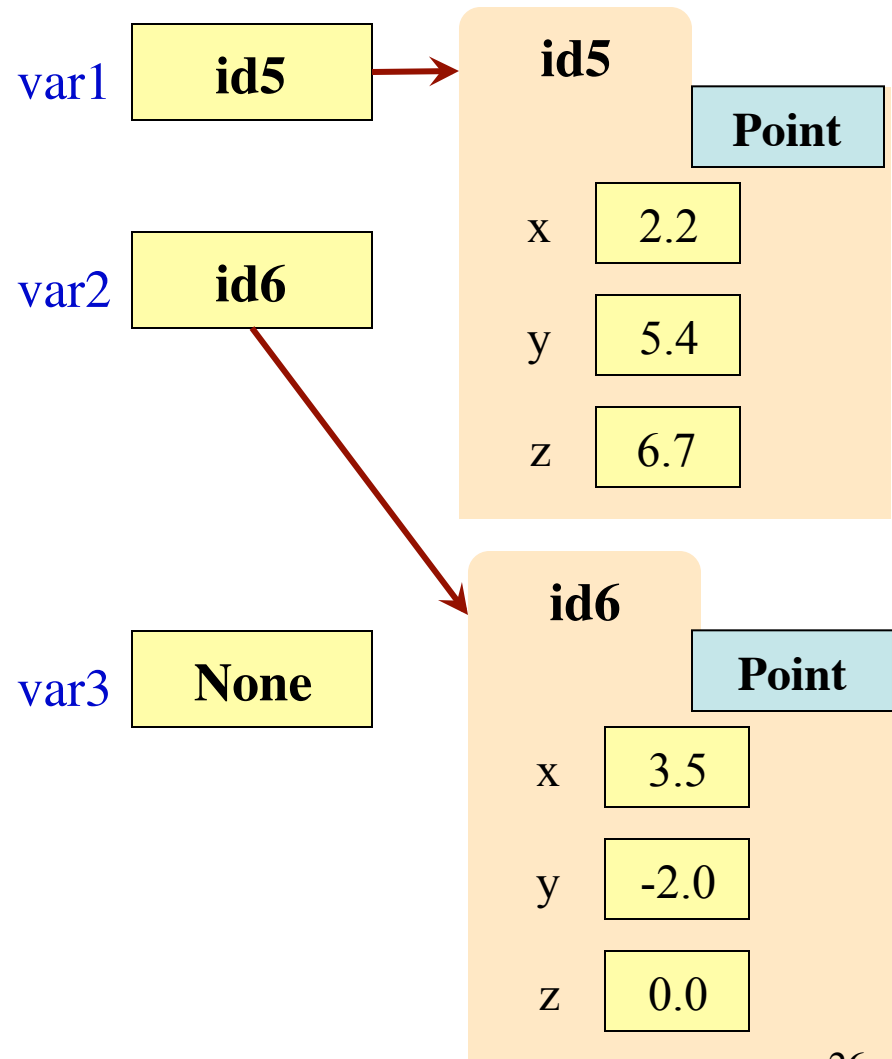
`Worker('Obama', 1234, None)`

1. Creates a new object (folder) of the class `Worker`
 - Instance is initially empty
2. Puts the folder into heap space
3. Executes the method `__init__`
 - Passes folder name to `self`
 - Passes other arguments in order
 - Executes the (assignment) commands in initializer body
4. Returns the object (folder) name



Aside: The Value None

- The boss field is a problem.
 - boss refers to a Worker object
 - Some workers have no boss
 - Or maybe not assigned yet (the buck stops there)
- **Solution:** use value None
 - **None:** Lack of (folder) name
 - Will reassign the field later!
- Be careful with None values
 - `var3.x` gives error!
 - There is no name in `var3`
 - Which Point to use?



Making Arguments Optional

- We can assign default values to `__init__` arguments
 - Write as assignments to parameters in definition
 - Parameters with default values are optional

- **Examples:**

- `p = Point()` # (0,0,0)
- `p = Point(1,2,3)` # (1,2,3)
- `p = Point(1,2)` # (1,2,0)
- `p = Point(y=3)` # (0,3,0)
- `p = Point(1,z=2)` # (1,0,2)

```
class Point(object):
```

```
    """Instances are points in 3d space"""
```

```
    x = 0.0 # x coord, float
```

```
    y = 0.0 # y coord, float
```

```
    z = 0.0 # z coord, float
```

```
    def __init__(self,x=0,y=0,z=0):
```

```
        """Initializer: makes a new Point
```

```
        Precondition: x,y,z are numbers"""
```

```
        self.x = x
```

```
        self.y = y
```

```
        self.z = z
```

```
    ...
```

Making Arguments Optional

- We can assign default values to `__init__` arguments
 - Write as assignments to parameters in definition
 - Parameters with default values are optional

- **Examples:**

- `p = Point()` # (0,0,0)
- `p = Point(1,2)` Assigns in order
- `p = Point(y=3)` Use parameter name when out of order
- `p = Point(1,z=2)` Can mix two approaches

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Making Arguments Optional

- We can assign default values to `__init__` arguments
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- **Examples:**

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- Annotations:
- Assigns in order
 - Use parameter name when out of order
 - Can mix two approaches

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```
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```

```
    def __init__(self,x=0,y=0,z=0):
```

```
        """Initializer: makes a new P
```

```
        Precondition:
```

Not limited to methods.
Can do with any function.