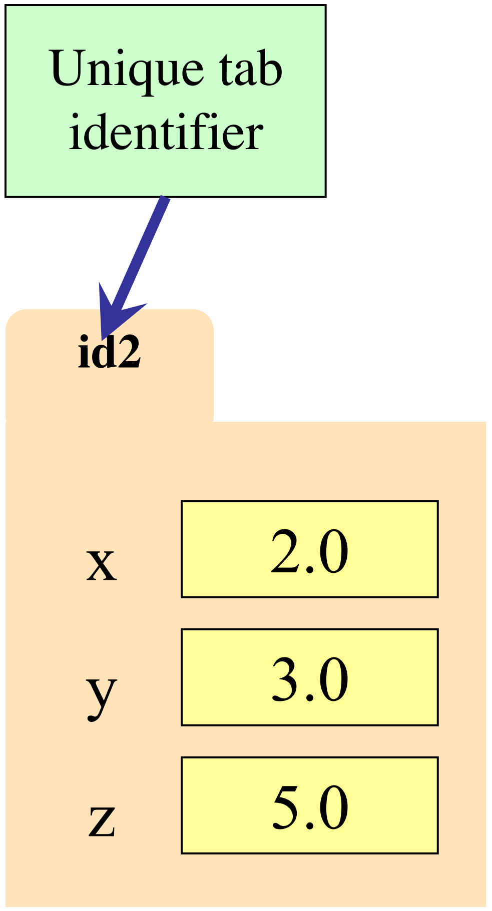
Module 20

Classes

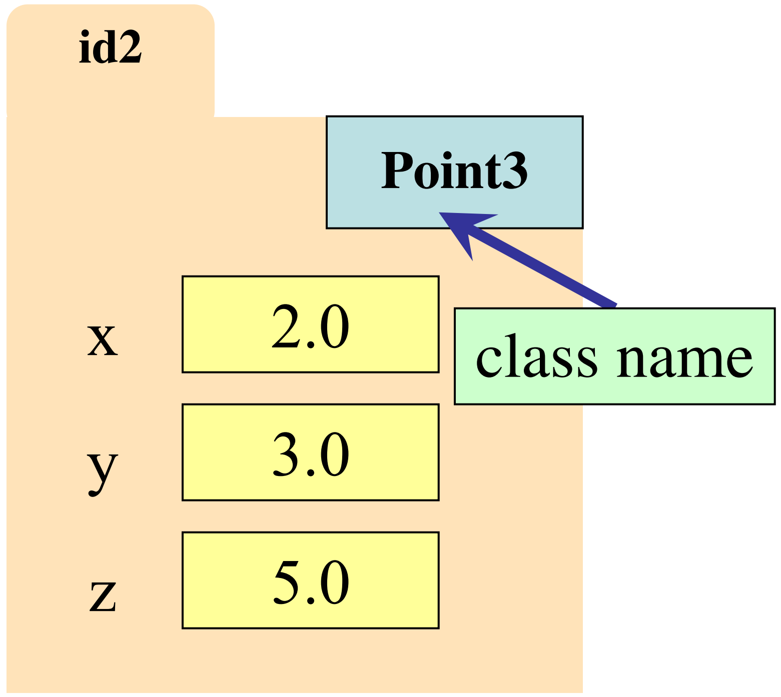
Recall: Objects as Data in Folders

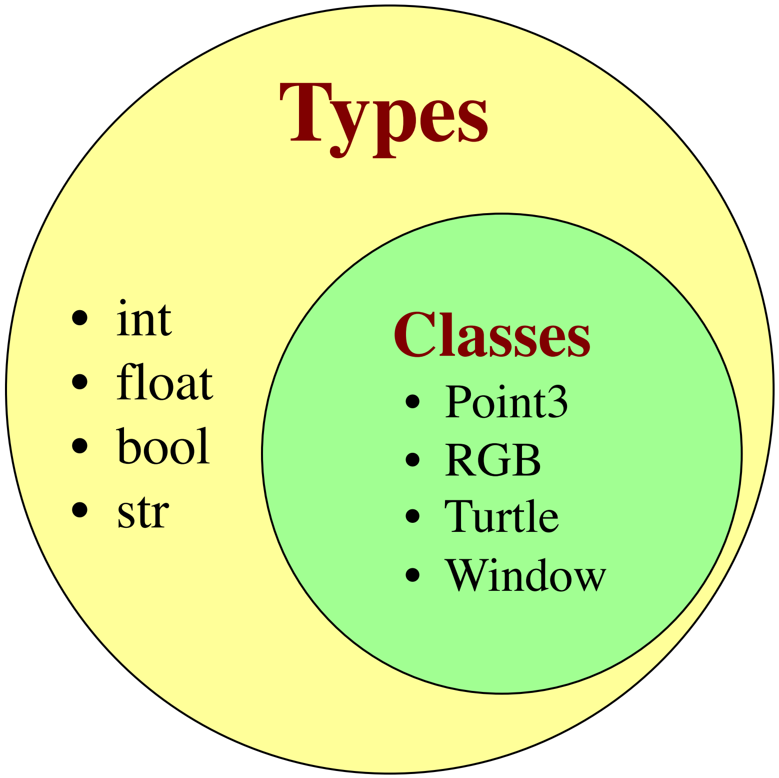
- An object is like a **manila folder**
- It contains other variables
  - Variables are called **attributes**
  - Can change values of an attribute (with assignment statements)
- It has a "tab" that identifies it
  - Unique number assigned by Python
  - Fixed for lifetime of the object



Recall: Classes are Types for Objects

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





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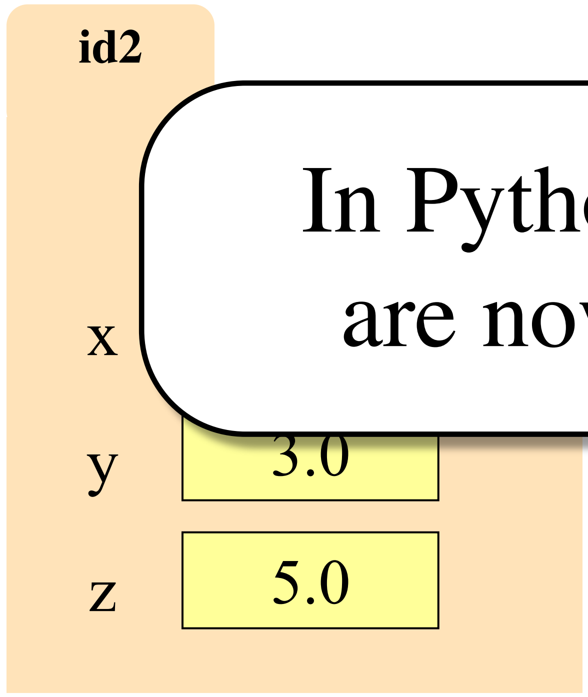
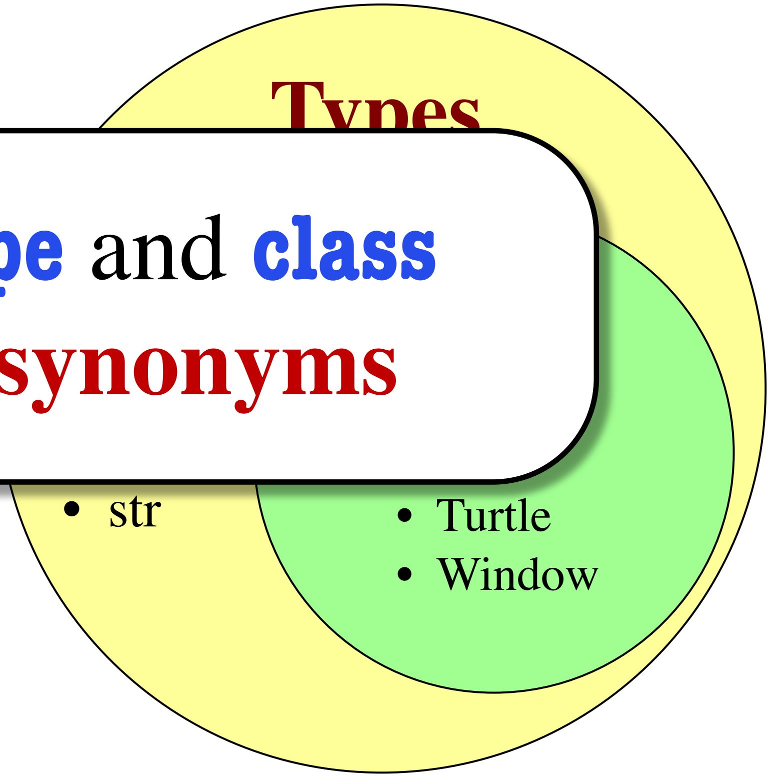




In Python3, **type** and **class** are now both **synonyms**

It is Time to Define Classes

- Remember how we learned about functions
  - Learned to use (**call**) them first
  - Then we learned how to define them
- Now going to do the same for classes
  - Learned how to use (**instantiate**) them first
  - Will now learn how to define them
- First, let's look at the **syntax**
  - Will look at what it means later

The Class Definition

```
class <class-name>(object):
    """Class specification"""
    <function definitions>
    <assignment statements>
    <any other statements also allowed>
```

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

Goes inside a module, just like a function definition.

The Class Definition

keyword class
Beginning of a class definition

```
class <class-name>(object):
    """Class specification"""
    <function definitions>
    <assignment statements>
    <any other statements also allowed>
```

Do not forget the colon!

more on this later

Specification (similar to one for a function)

to define **methods**

…but not often used

to define **attributes**

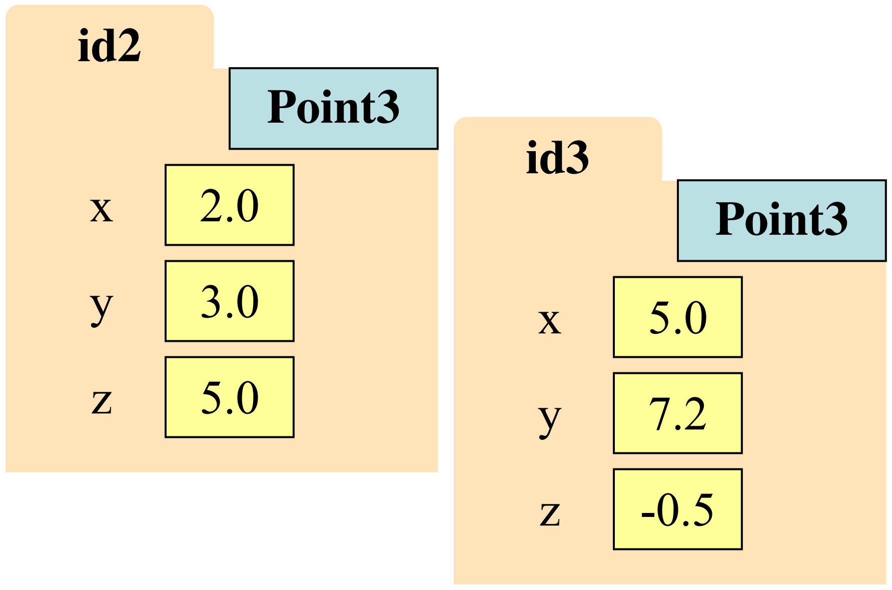
```
class Example(object):
    """The simplest possible class."""
    pass
```

Goes inside a module, just like a function definition.

Classes Have Folders Too

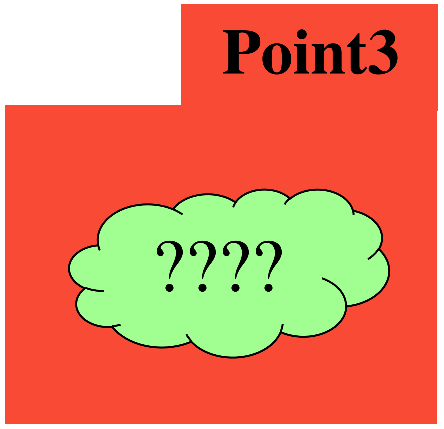
Object Folders

- Separate for each *instance*



Class Folders

- Data common to all instances

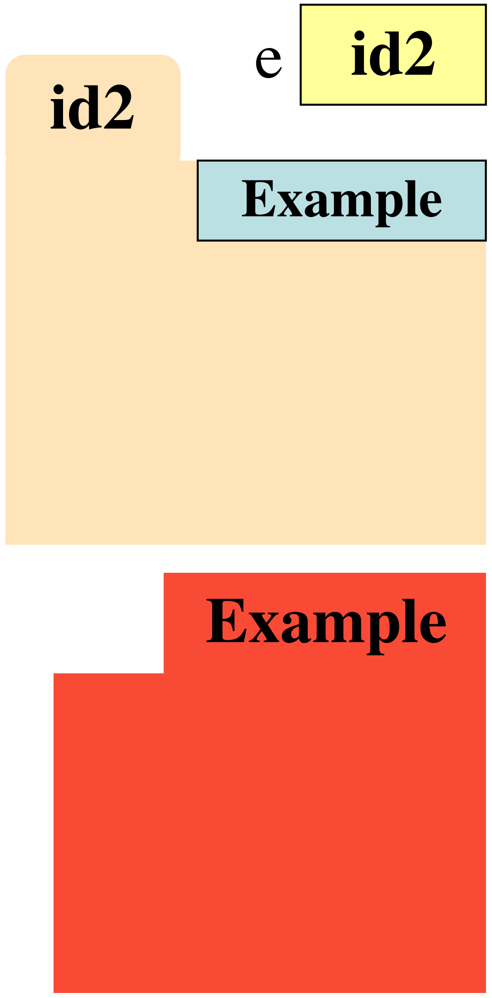


Created by class defintion

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

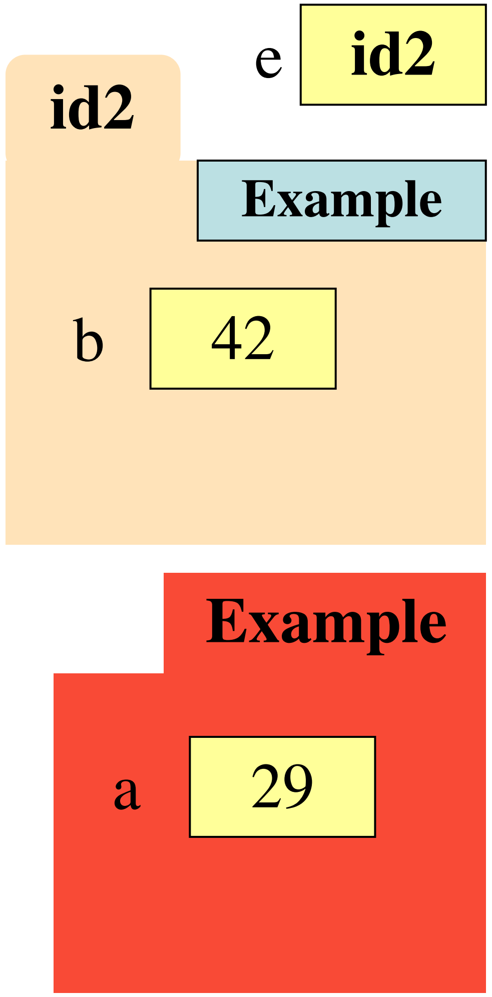


Folder Observations

- By default, the folders are empty
  - Nothing inside of the class folder
  - Nothing inside each object folder either
- We have to write code to put stuff there
  - Empty definition = empty folders
- Code must provide the features objects have
  - **Attributes**, or variables inside of folder
  - **Methods**, or functions inside of folder

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



Instances and Attributes

- Assignments add object attributes
  - <object>.<att> = <expression>
  - **Example**: `e.b = 42`

Not how usually done

- Assignments can add class attributes
  - <class>.<att> = <expression>
  - **Example**: `Example.a = 29`
- Objects can access class attributes
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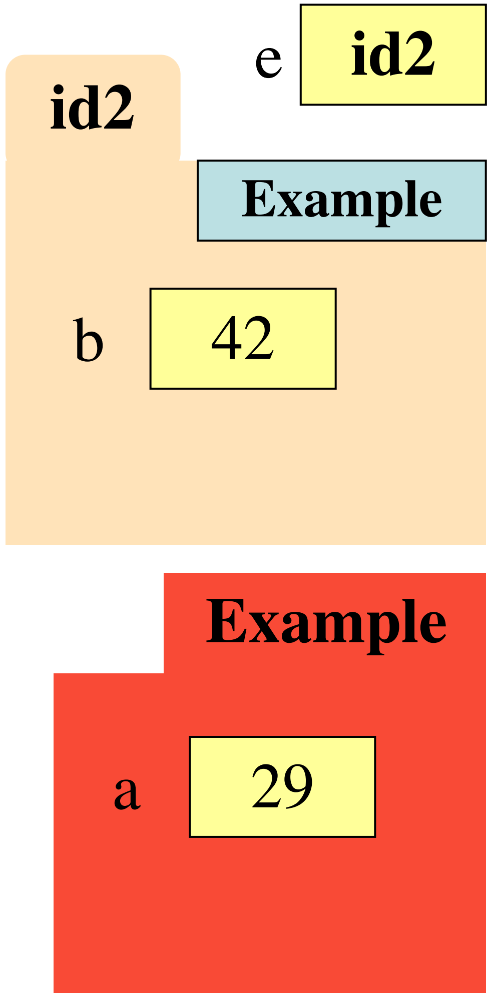

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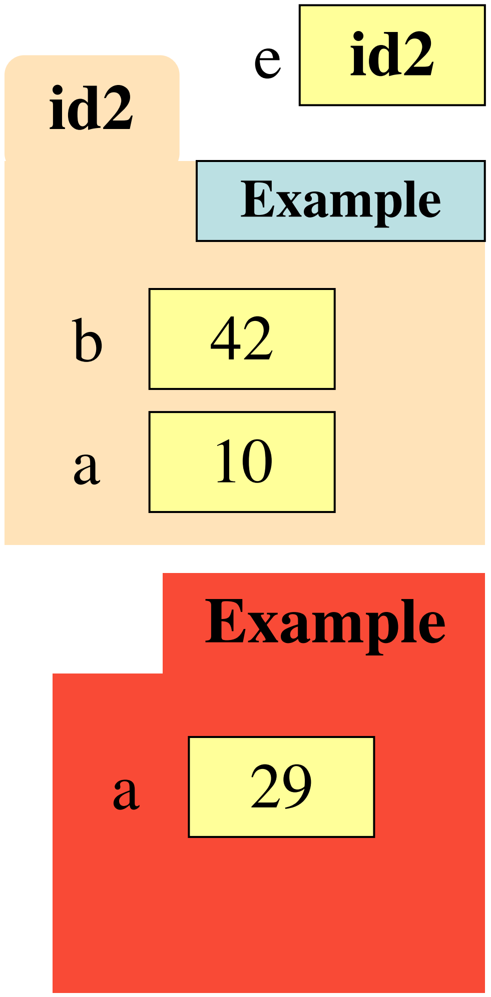
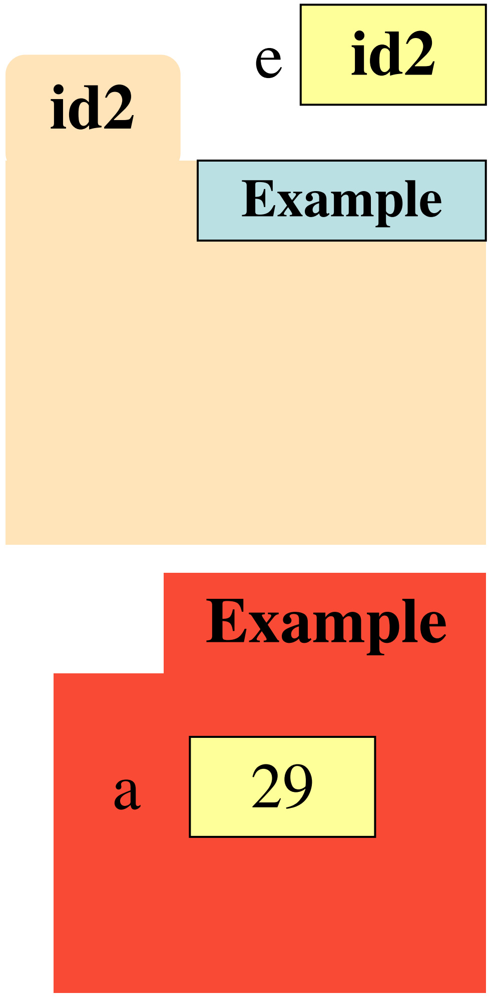


How it Fits in a Definition

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


    # A class attribute
    a = 29
```

Puts variable in class folder, not object folder



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**:
  - Point3 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):
    """A class representing a worker in a certain organization

     Instance has basic worker info, but no salary information.

    Attribute lname: The worker last name
    Invariant: lname is a string

    Attribute ssn: The Social Security number
    Invariant: ssn is an int in the range 0..999999999

    Attribute boss: The worker's boss
    Invariant: boss is an instace of Worker, or None if no boss"""
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Short summary

More detail

Description

Invariant

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Warning: New format since 2019.
Old exams will be very different.

Recall: Objects can have Methods

- 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
```

Method Definitions

- Looks like a function def
  - Indented *inside* class
  - First param is always self
  - But otherwise the same
- In a **method call**:
  - One less argument in ()
  - Obj in front goes to self
- **Example**: a.distance(b)

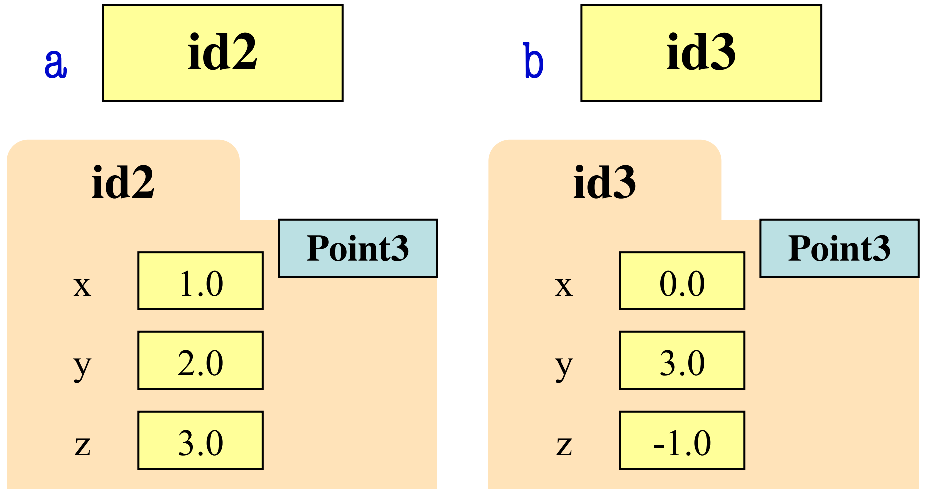
self

q

```
class Point3(object):
    """Class for points in 3d space
    Invariant: x is a float
    Invariant y is a float
    Invariant z is a float     """
    def distance(self,q):
        """Returns dist from self to q
        Precondition: q a Point3"""
        assert type(q) == Point3
        sqrdst = ((self.x-q.x)**2 +
                  (self.y-q.y)**2 +
                  (self.z-q.z)**2)
        return math.sqrt(sqrdst)
```

Methods Calls

- **Example**: a.distance(b)



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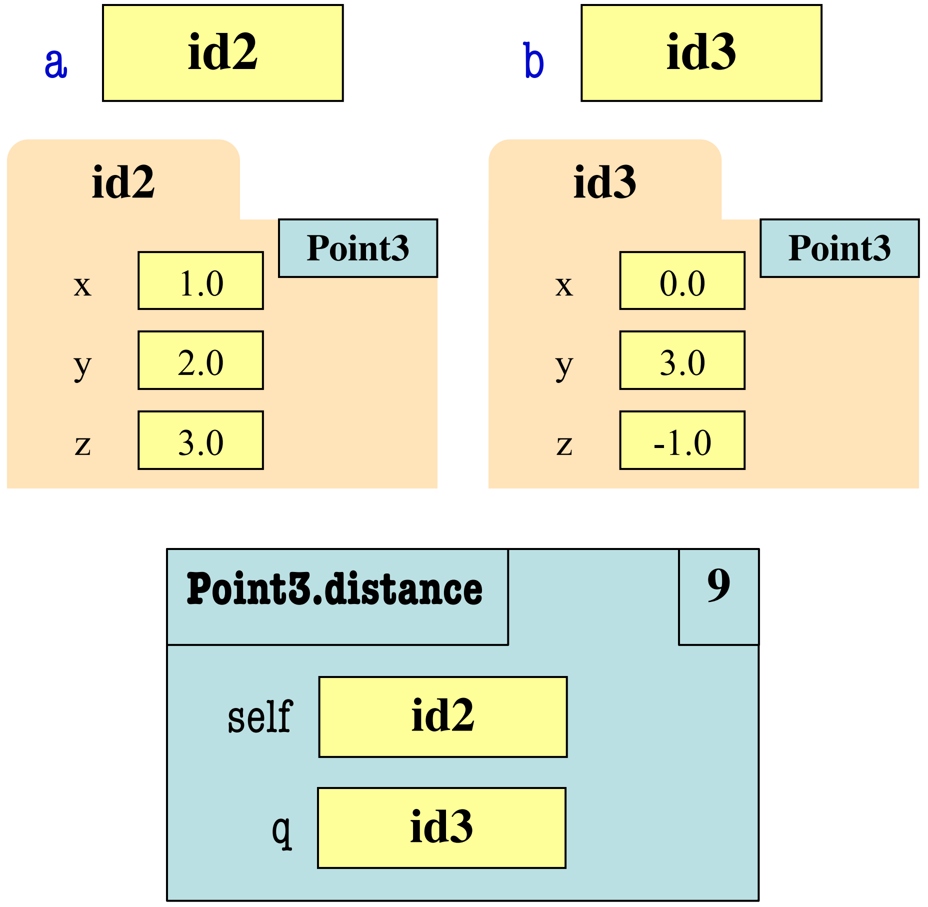

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11.                       (self.y-q.y)**2 +
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13.         return math.sqrt(sqrdst)
```

Methods and Folders

- Function definitions…
  - make a folder in heap
  - assign name as variable
  - variable in global space
- Methods are similar...
  - Variable in **class folder**
  - But otherwise the same
- **Rule of this course**
  - Put header in class folder
  - Nothing else!

```
class Point3(object):
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    def distance(self,q):
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```
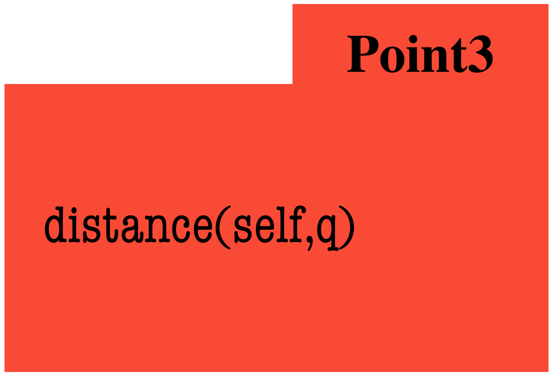
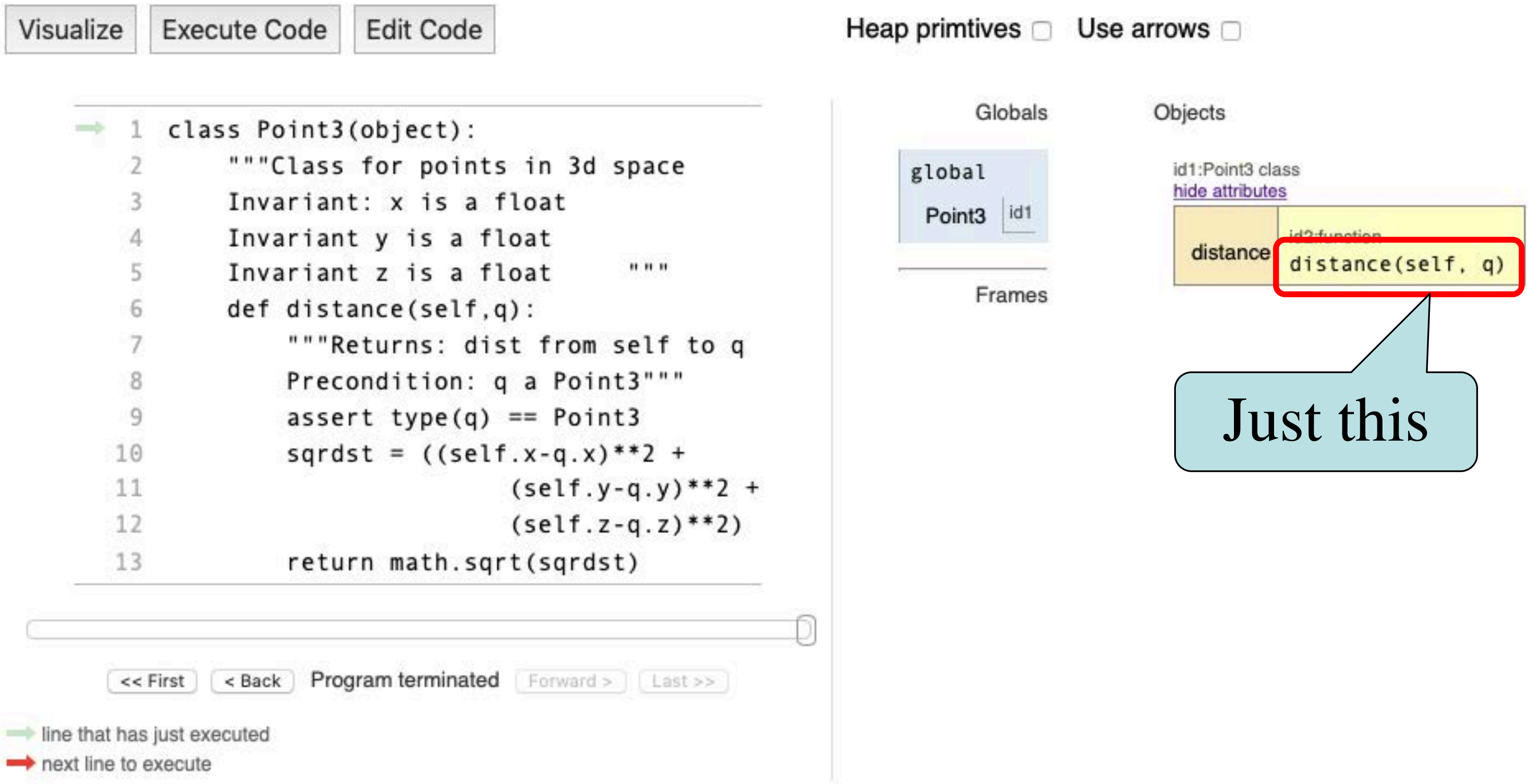



Methods and Folders



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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__

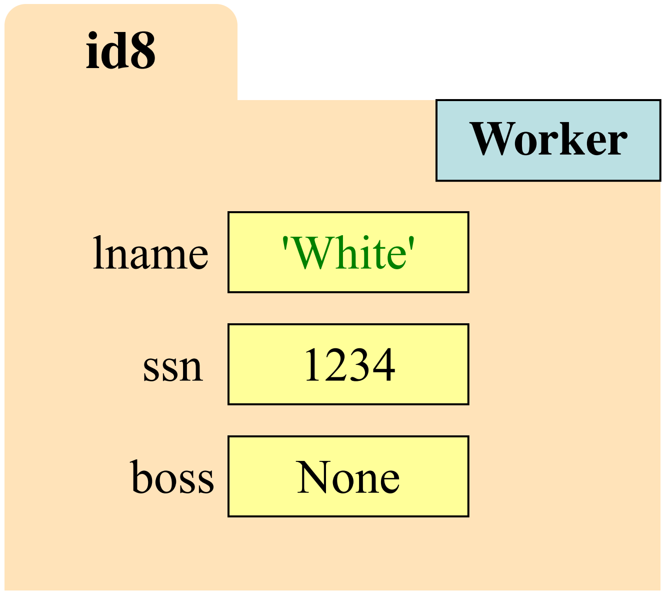
```
w = Worker('White', 1234, None)
```

```
def  __init__(self, n, s, b):
    """Initializes a Worker object

    Has last name n, SSN s, and boss b

    Precondition: n a string,
    s an int in range 0..999999999,
    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('White', 1234, None)
```

don't forget self

```
def __init__(self, n, s, b):
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    self.lname = n
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```
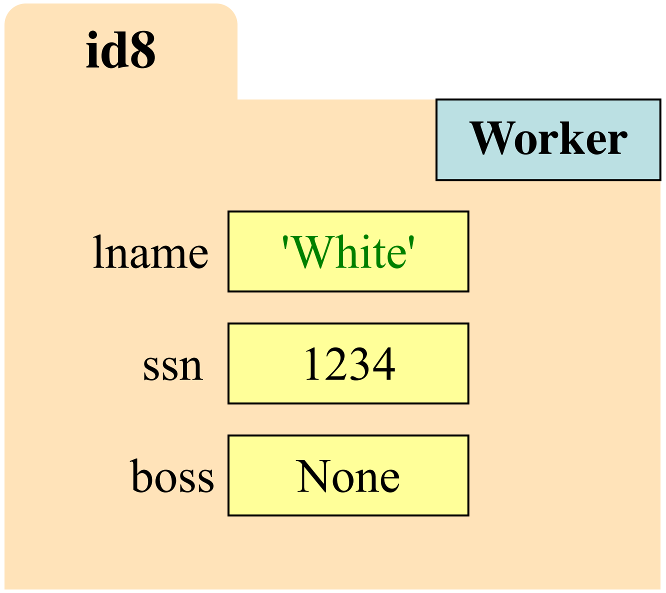

use self to assign attributes

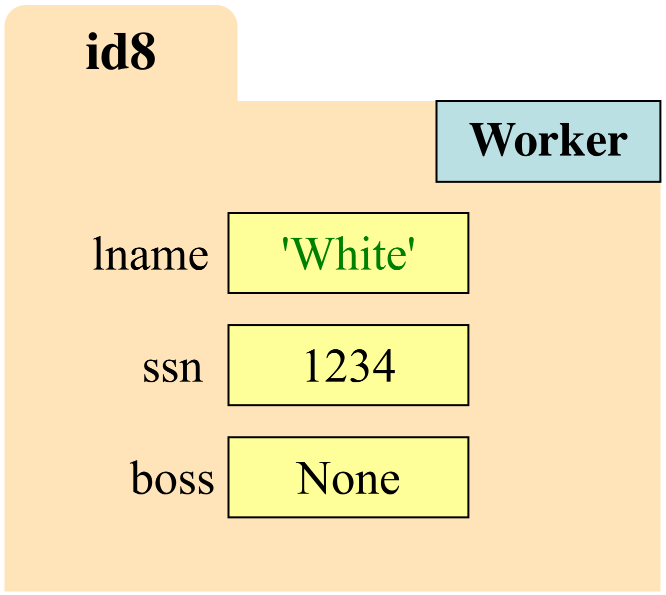
Called by the constructor



Evaluating a Constructor Expression

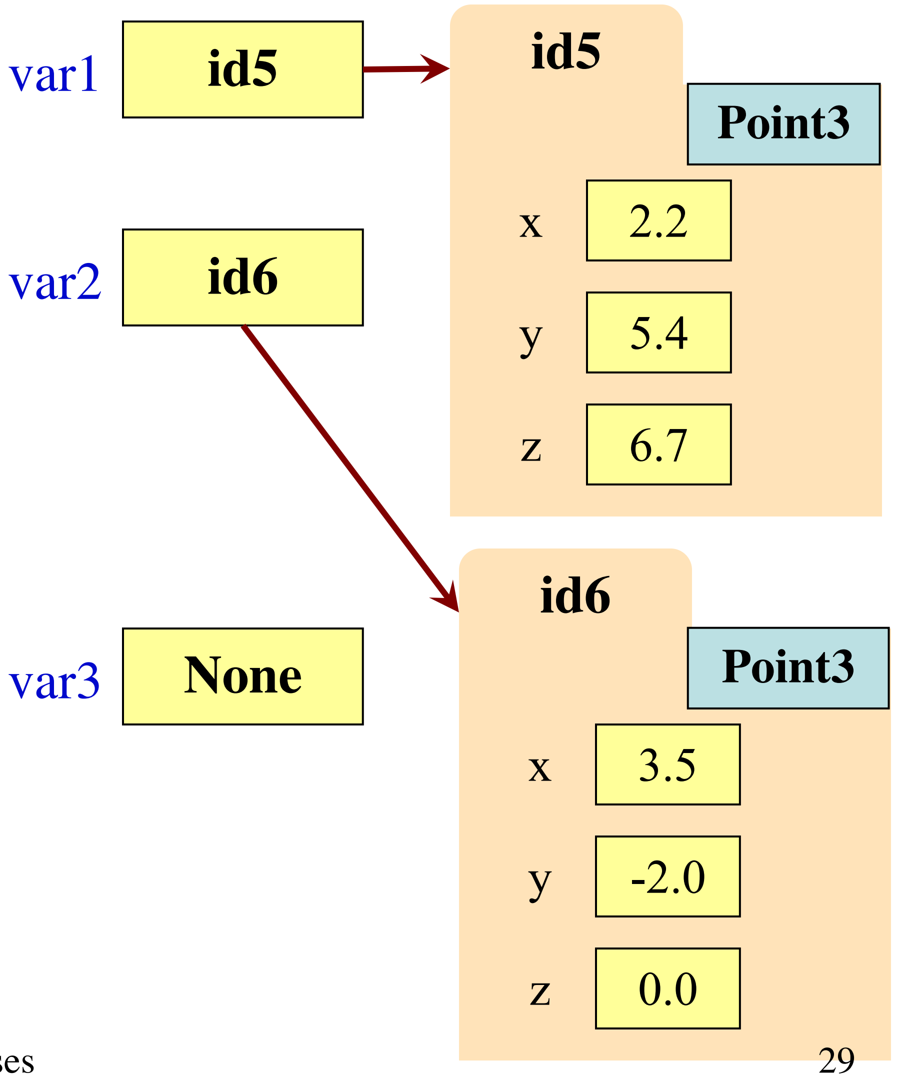
```
Worker('White', 1234, None)
```

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 Point3 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 = Point3() # (0,0,0)
  - p = Point3(1,2,3) # (1,2,3)
  - p = Point3(1,2) # (1,2,0)
  - p = Point3(y=3) # (0,3,0)
  - p = Point3(1,z=2) # (1,0,2)

```
class Point3(object):
    """Class for points in 3d space
    Invariant: x is a float
    Invariant y is a float
    Invariant z is a float    """

    def __init__(self,x=0,y=0,z=0):
        """Initializes a new Point3
        Precond: x,y,z are numbers"""
        self.x = x
        self.y = y
        self.z = z
    ...
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Assigns in order

Use parameter name when out of order

Can mix two approaches

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        """Initializes a n
        P

          z = z
    …
```

Not limited to methods.
Can do with any function.

Recall: The __init__ Method

two underscores

```
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,
    b either a Worker or None.   """
    self.lname = n
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```
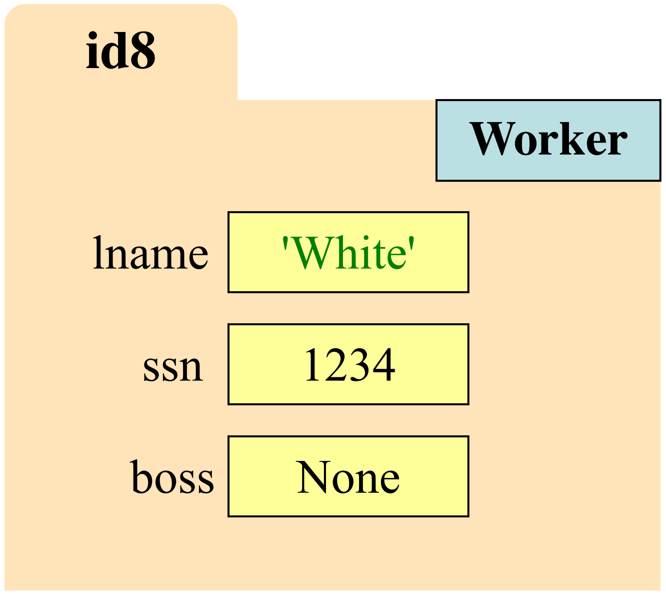

Called by the constructor



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```

Are there other special methods that we can use?

Example: Converting Values to Strings

str() Function

- **Usage**: str(<expression>)
  - Evaluates the expression
  - Converts it into a string
- How does it convert?
  - str(2) → '2'
  - str(True) → 'True'
  - str('True') → 'True'
  - str(Point3()) → '(0.0,0.0,0.0)'

repr() Function

- **Usage**: repr(<expression>)
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What type is this value?

repr() Function

-

repr() is for *unambigious* representation

- How does it co
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The value's type is clear

What Does str() Do On Objects?

- Does **NOT** display contents

```
>>> p = Point3(1,2,3)
>>> str(p)
'<Point3 object at 0x1007a90>'
```

- Must add a special method
  - __str__ for str()
  - __repr__ for repr()
- Could get away with just one
  - repr() requires __repr__
  - str() can use __repr__ (if __str__ is not there)

```
class Point3(object):
    """Class for points in 3d space"""
    …
    def __str__(self):
        """Returns: string with contents"""
        return '('+str(self.x) + ',' +
                    str(self.y) + ',' +
                    str(self.z) + ')'

    def __repr__(self):
        """Returns: unambiguous string"""
        return str(self.__class__)+
                str(self)
```

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```

Gives the class name

`__repr__` using `__str__` as helper