Lecture 18

Classes

Announcements for This Lecture

Assignments

- **A4 Thursday** at midnight
  - Hopefully you are on Task 5
  - Will have a follow-up lab!
- Will post **A5** on Friday
  - Written assignment like A2
  - Needs material from next Tues
- Will also post **A6** Friday.
  - Not due until November 15
  - But you need to **start it first**!

Optional Videos

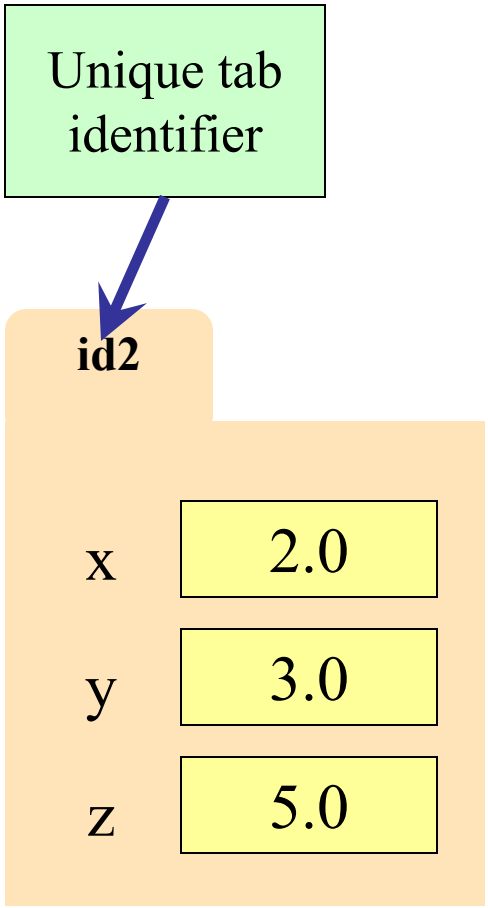
- **Videos 20.1-20.8** today
- **Videos 20.9-20.10** next time
- Also **Lesson 21** next time

Exams

- Last week for regrades
  - Limit them to valid issues
- We will do them *eventually*

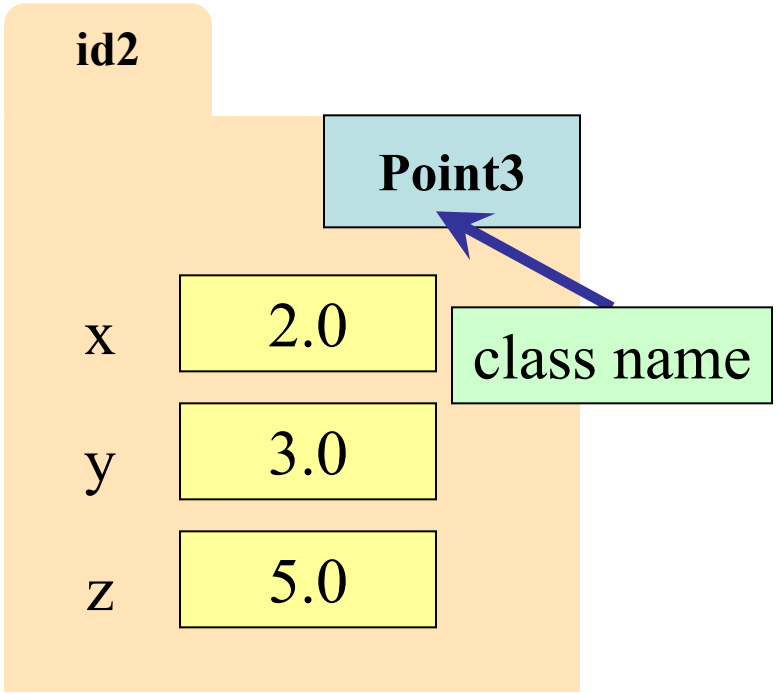
Recall: Objects as Data in Folders

- 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

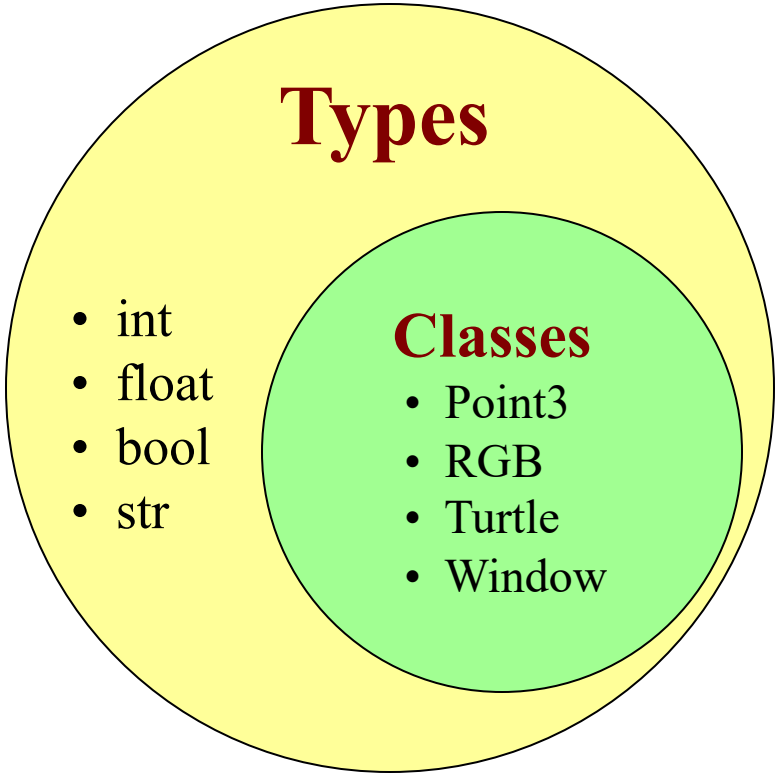


Recall: Classes are Types for Objects

- Values must have a type
  - An **object** is a **value**
  - A **class** is its **type**

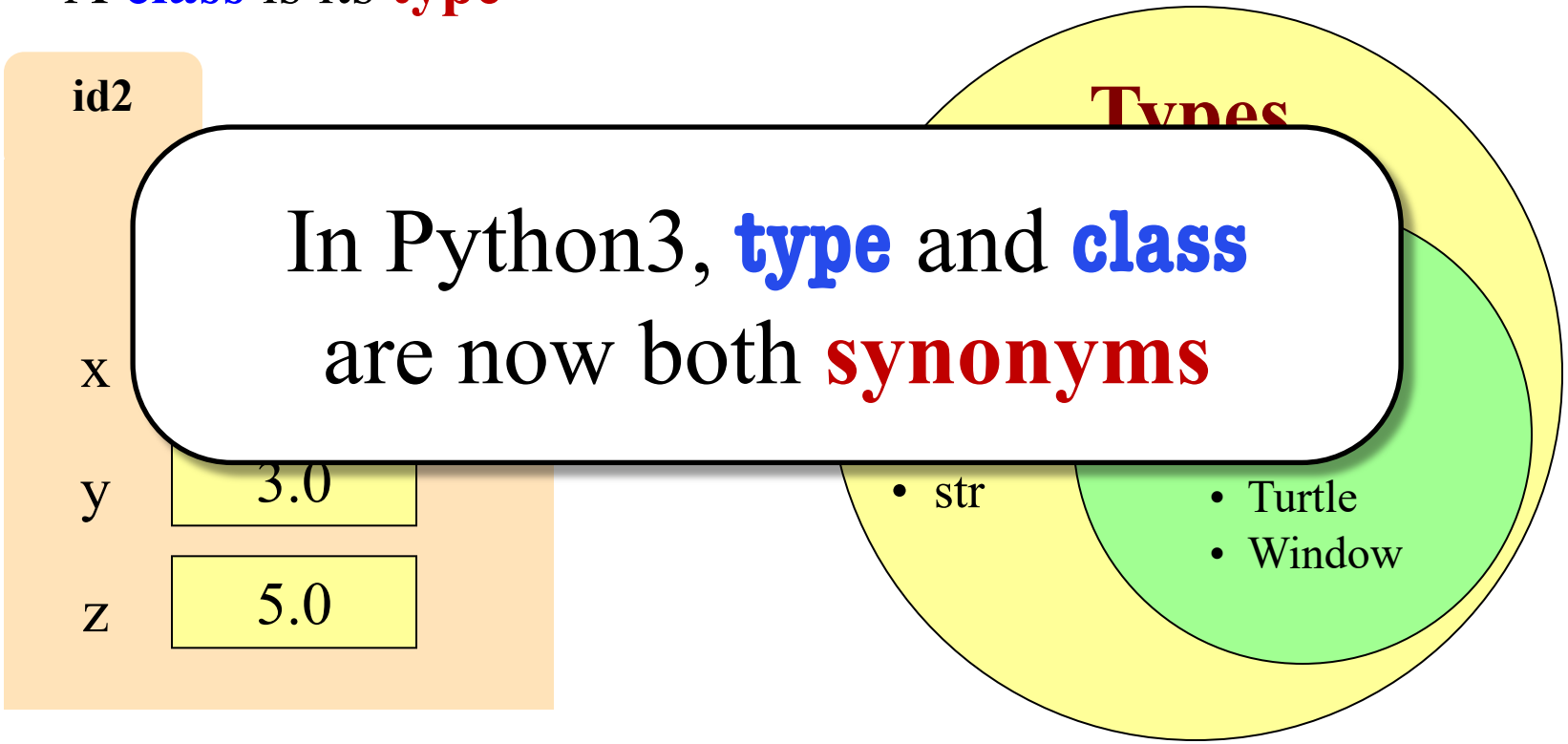


- Classes are how we add new types to Python



Recall: Classes are Types for Objects

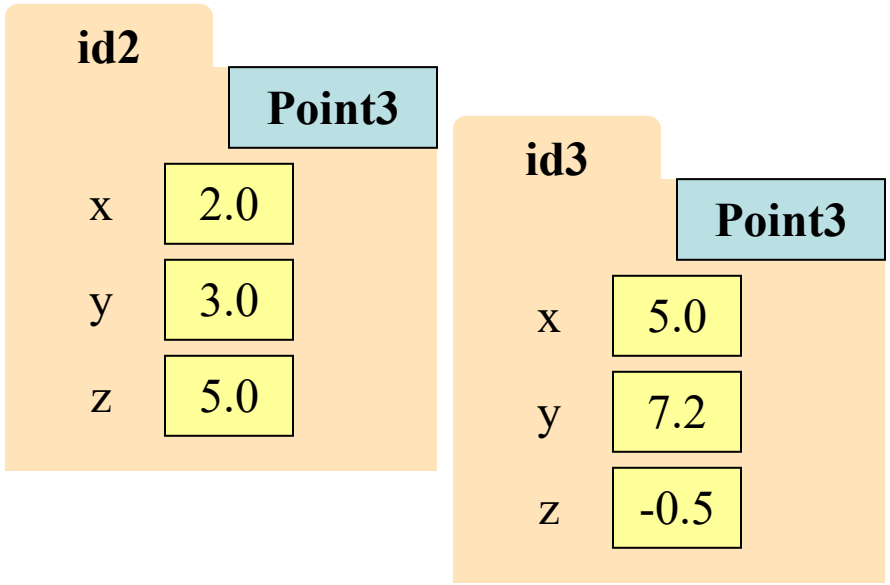
- Values must have a type
  - An **object** is a **value**
  - A **class** is its **type**
- Classes are how we add new types to Python



Classes Have Folders Too

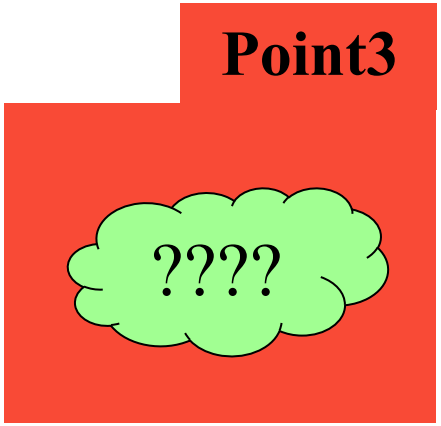
Object Folders

- Separate for each *instance*



Class Folders

- Data common to all instances



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*>

Example

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

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!

more on this later

Specification (similar to one for a function)

"""Class specification"""

<*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
```

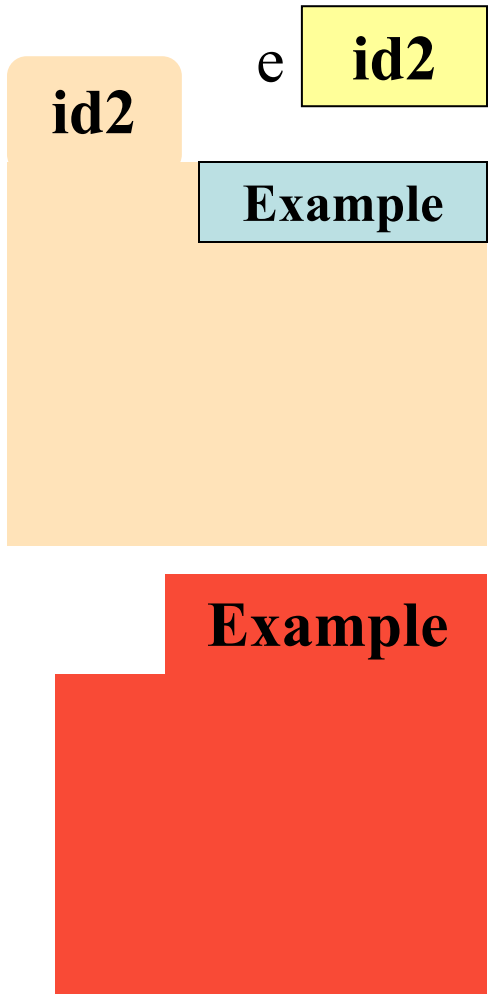
Example

Python creates after reading the class definition

Recall: Constructors

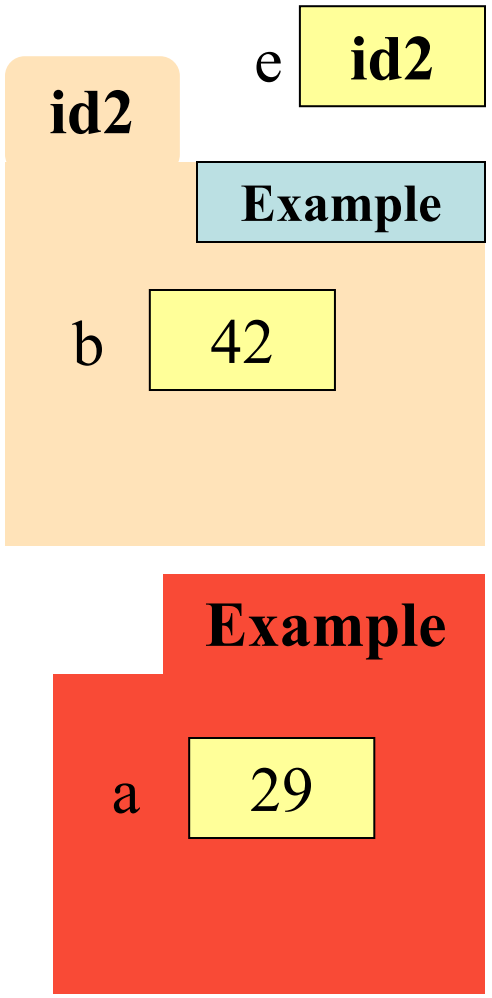
- Function to create new instances
  - Function name == class name
  - Created for you automatically
- Calling the constructor:
  - Makes a new object folder
  - Initializes attributes
  - Returns the id of the folder
- By default, takes no arguments
  - `e = Example()`

Will come back to this



Instances and Attributes

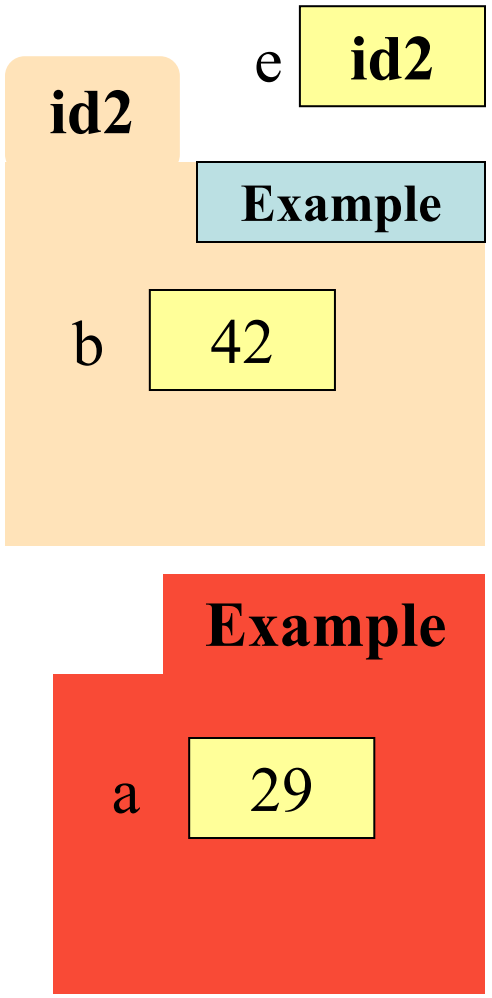
- Assignments add object attributes
  - <object>.<att> = <expression>
  - **Example**: `e.b = 42`
- Assignments can add class attributes
  - <class>.<att> = <expression>
  - **Example**: `Example.a = 29`
- Objects can access class attributes
  - **Example**: `print(e.a)`
  - But assigning it creates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



Instances and Attributes

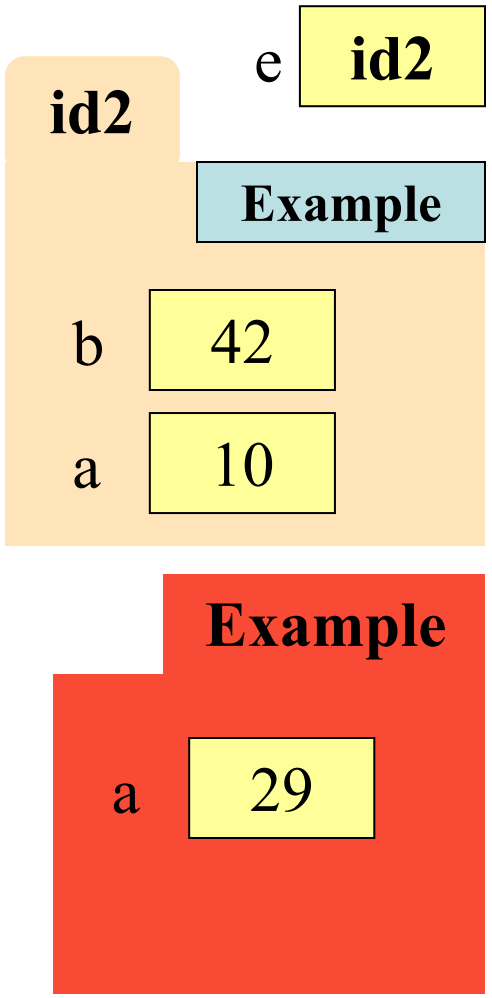
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  - **Example**: `print(e.a)`
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- **Rule**: check object first, then class

Not how usually done



Instances and Attributes

- Assignments add object attributes
  - <object>.<att> = <expression>
  - **Example**: e.b = 42
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  - **Example**: print(e.a)
  - But assigning it creates object attribute
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- **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**:
  - 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

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

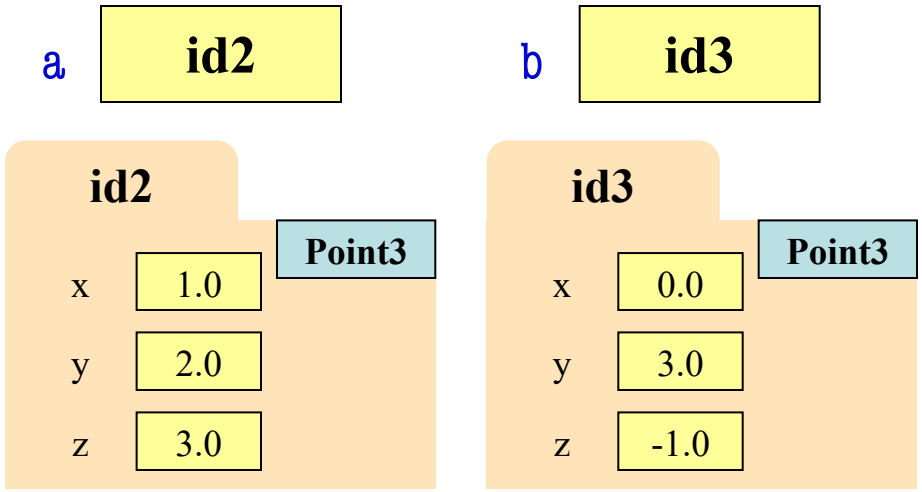
- Looks like a function def
  - Indented *inside* class
  - First param is always self
  - But otherwise the same
- In a **method call**:
  - One less argument in ()
  - Obj in front goes to self
- **Example**: a.distance(b)




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

Methods Calls

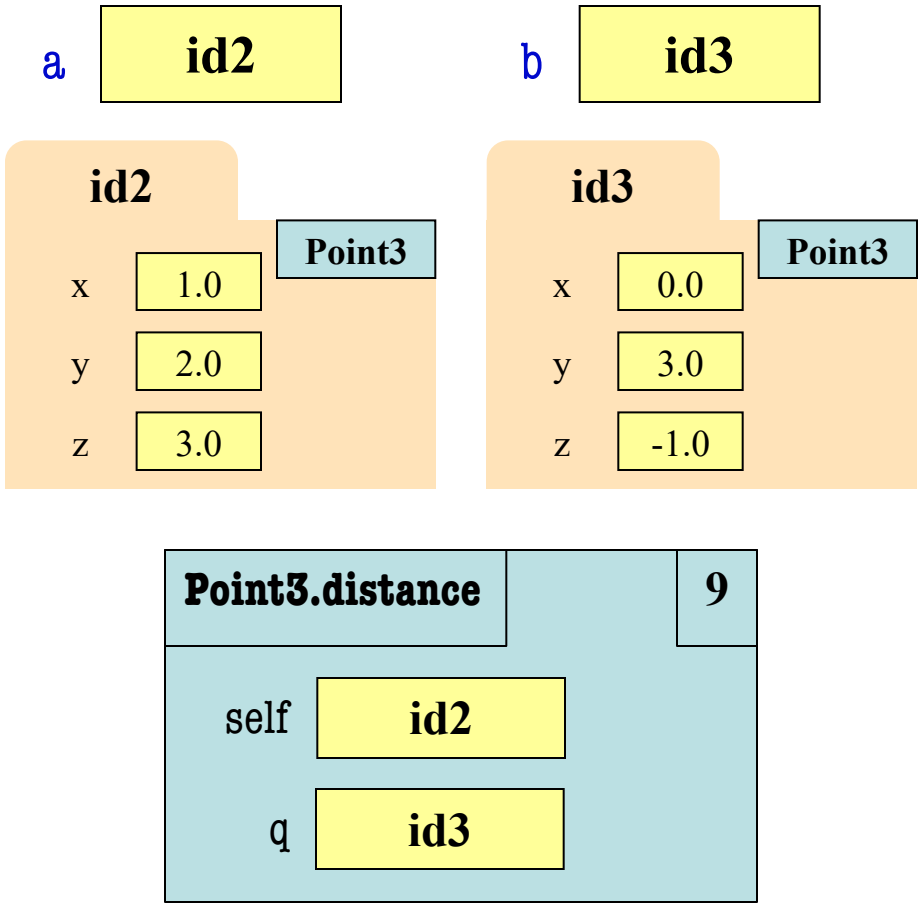
- **Example**: a.distance(b)




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Methods Calls

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

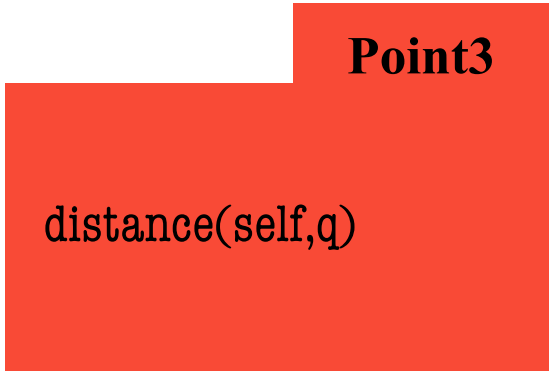



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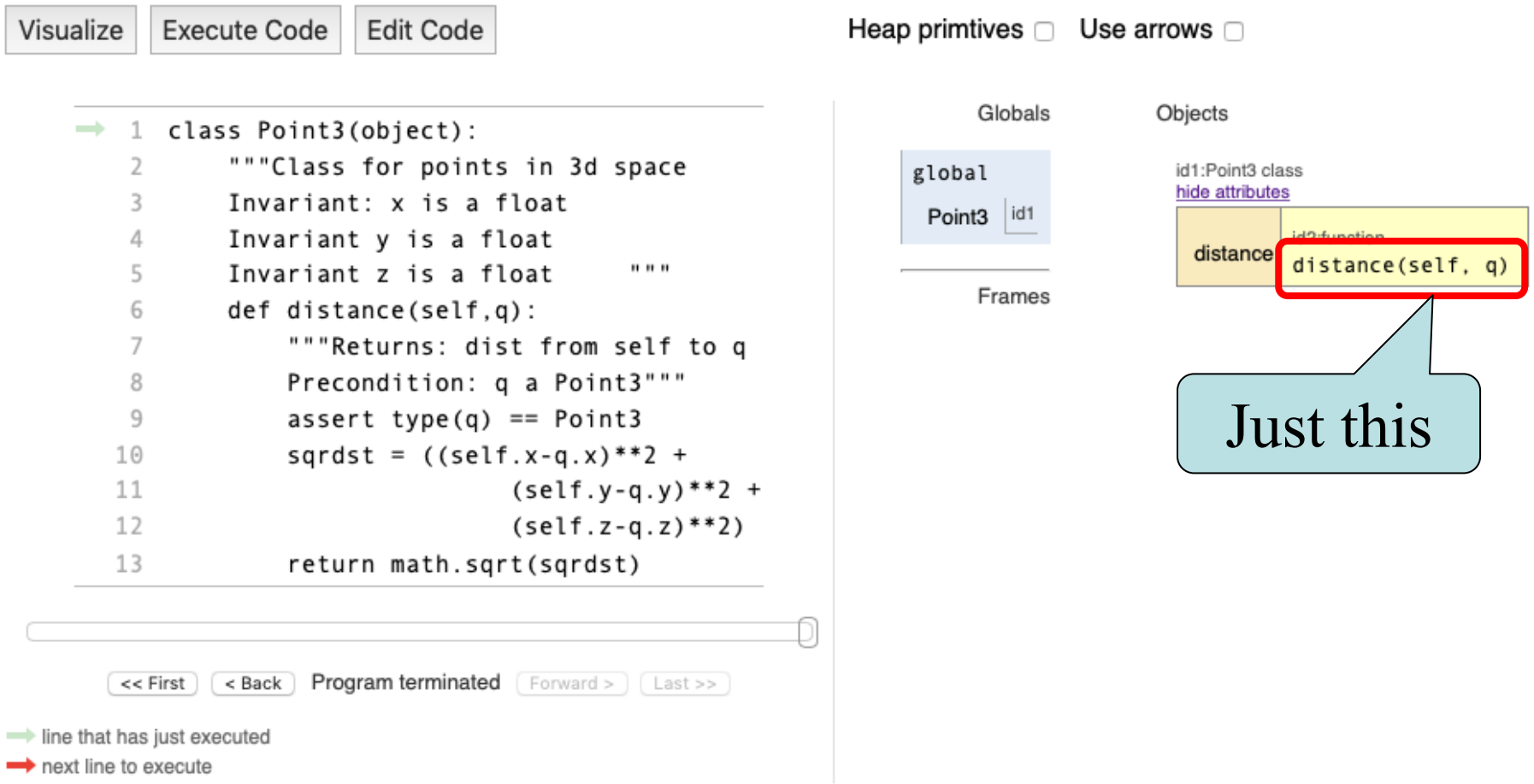
Methods and Folders

- 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!

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2.      """Class for points in 3d space
3.      Invariant: x is a float
4.      Invariant y is a float
5.      Invariant z is a float    """
6.      def distance(self,q):
        ....
```



Methods and Folders



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__

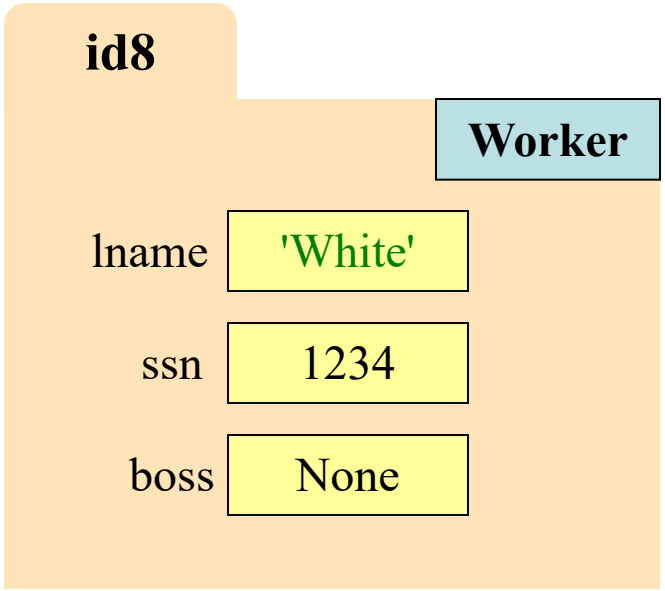
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w = Worker('White', 1234, None)
```

```
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

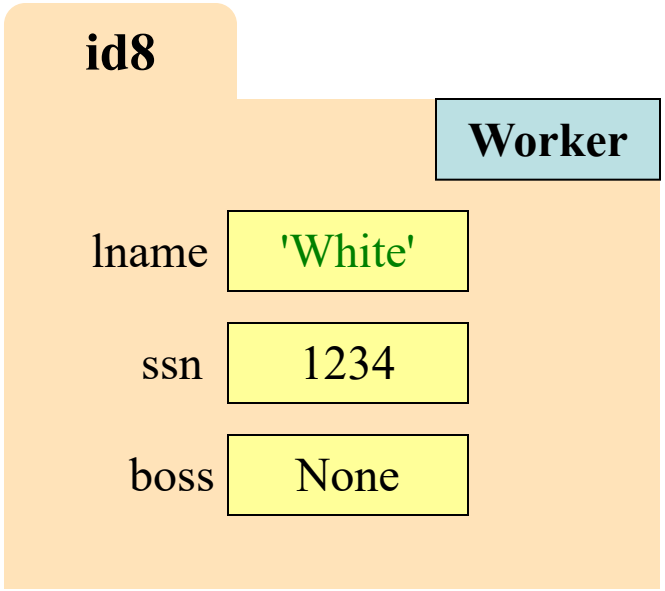
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```

use self to assign attributes

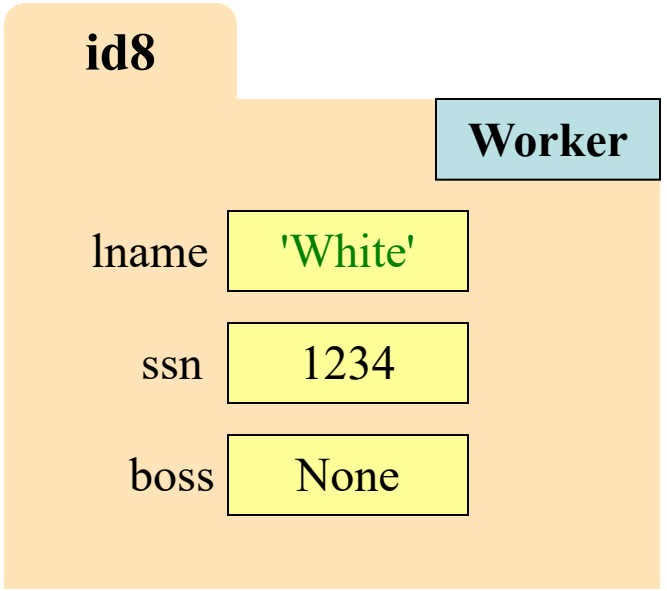
Called by the constructor



Evaluating a Constructor Expression

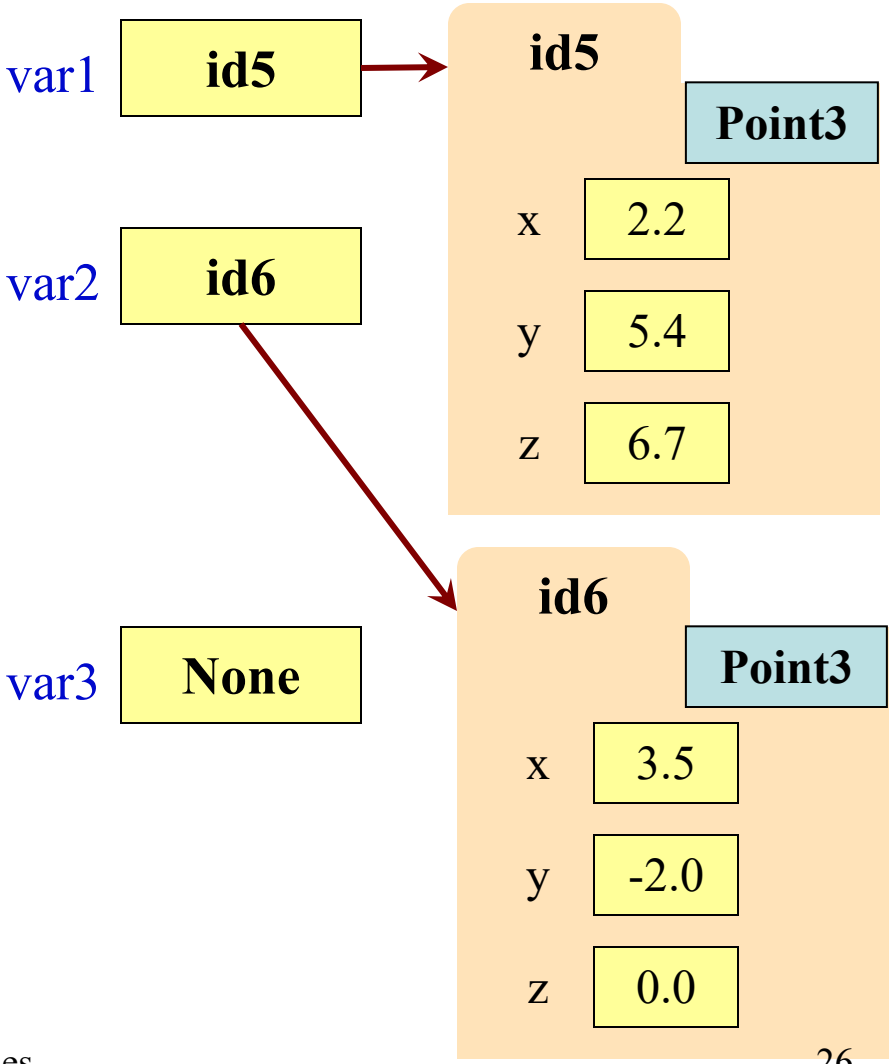
```
Worker('White', 1234, None)
```

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?



A Class Definition

```
class Example(object):


    def __init__(self,x):
        self.x = x

    def foo(self,y):
        x = self.bar(y+1)
        return x

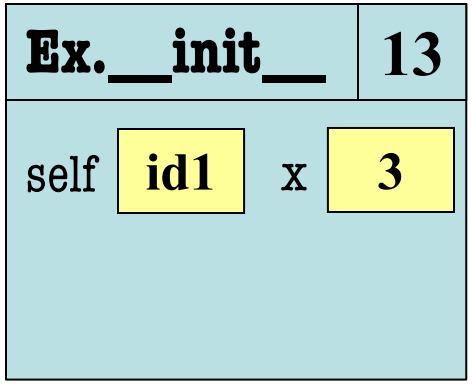
    def bar(self,y):
        self.x = y-1
        return self.x
```

```
>>> a = Example(3)
```

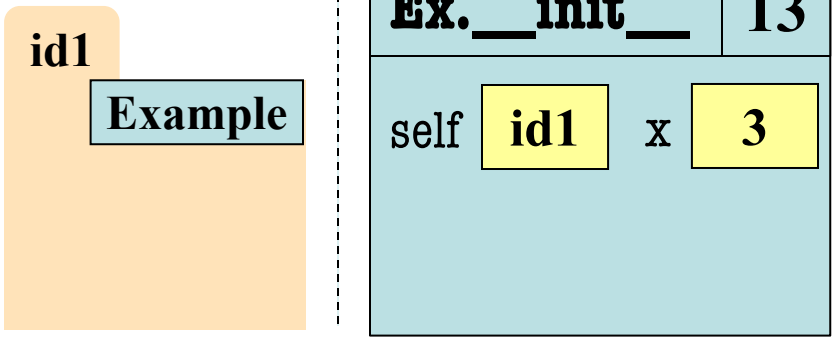
Ignoring the **class folder** what does the **call stack** and the **heap** look like?

Which One is Closest to Your Answer?

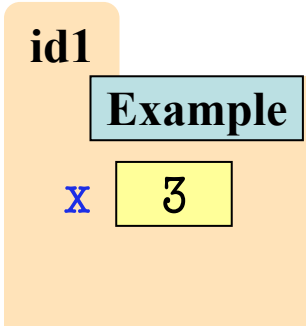
A:



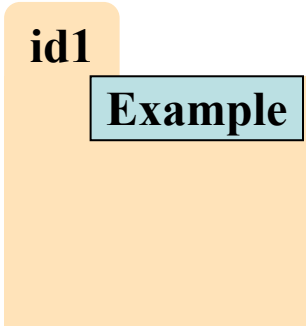
B:



C:



D:



A Class Definition

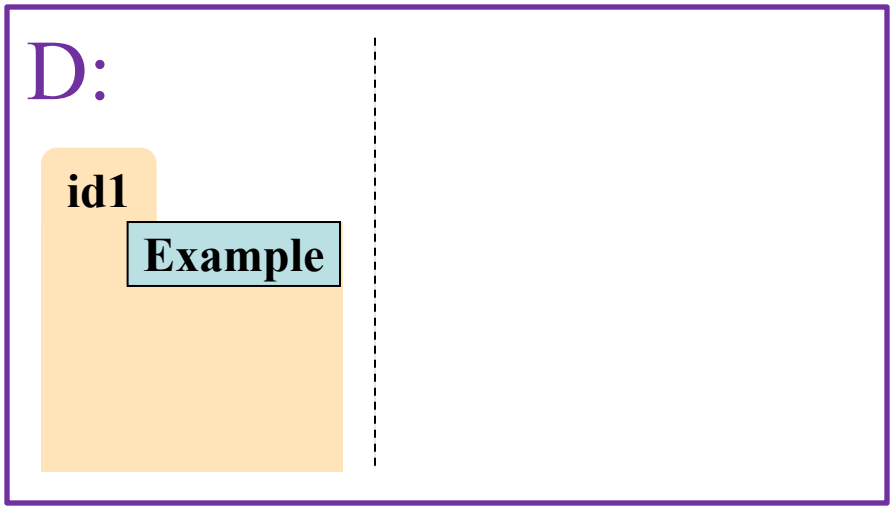
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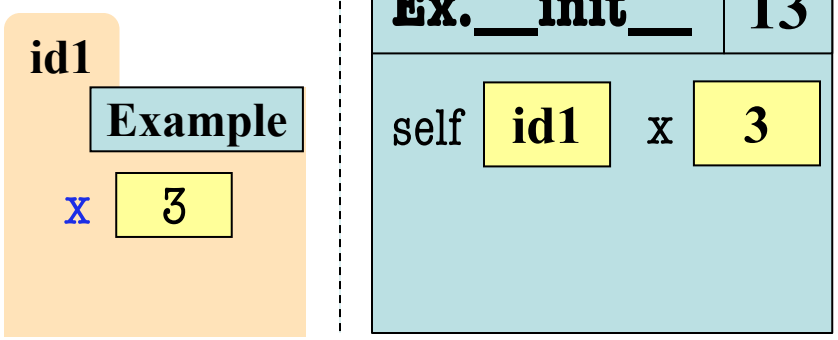
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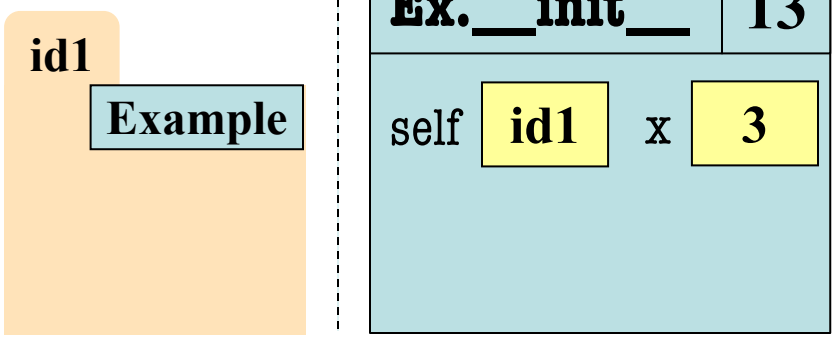
What is the **next step**?

Which One is Closest to Your Answer?

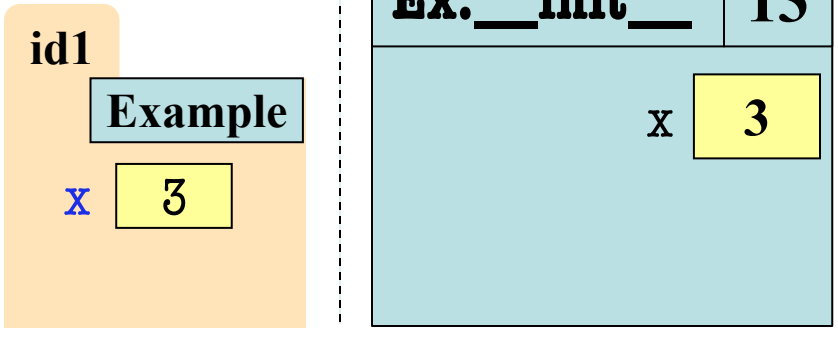
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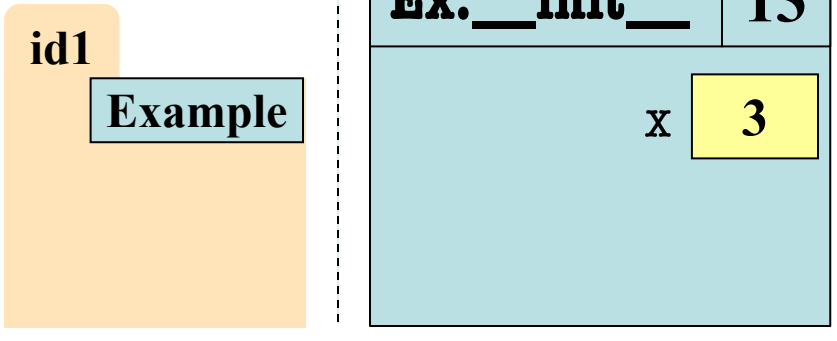
B:



C:



D:



A Class Definition

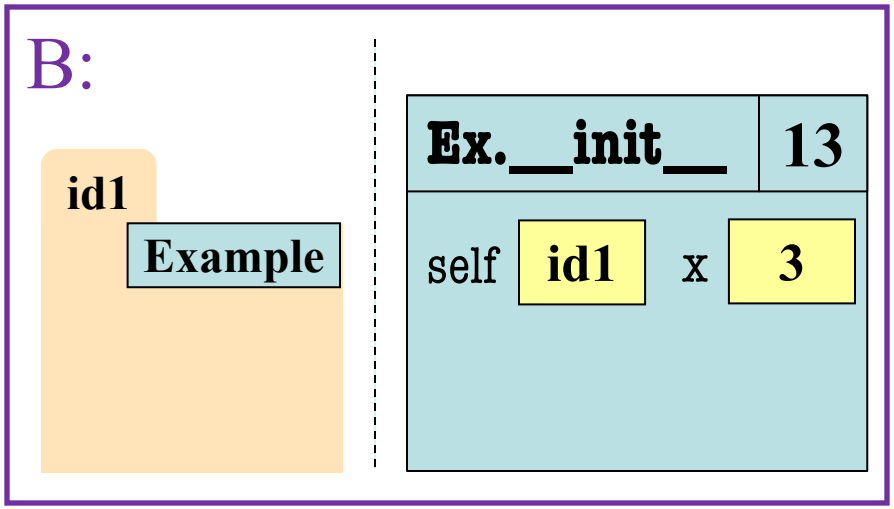
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```

```
>>> a = Example(3)
```



What is the **next step**?

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)

```
1.  class Point3(object):
2.      """Class for points in 3d space
3.      Invariant: x is a float
4.      Invariant y is a float
5.      Invariant z is a float     """
6.
7.      def __init__(self,x=0,y=0,z=0):
8.          """Initializes a new Point3
9.          Precond: x,y,z are numbers"""
10.         self.x = x
11.         self.y = y
12.         self.z = z
13.     ...
```

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

Assigns in order

Use parameter name when out of order

Can mix two approaches

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7.      def __init__(self,x=0,y=0,z=0):
8.          """Initializes a
9.
10.
12.             .z = z
            ...
```

Not limited to methods. Can do with any function.