Prepared by Julian García, based on material by
David Albrecht and María García de la Banda

Lecture 15
Variables and Scoping

FIT 1008
Introduction to Computer Science

Objectives

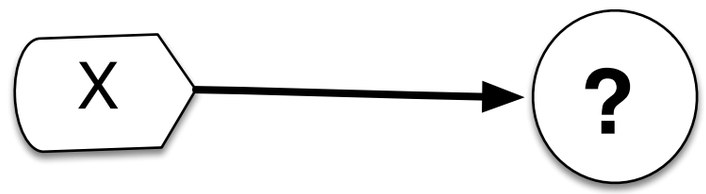
- To revise how **variables and values** are represented internally in **Python**

- To understand names and scopes.

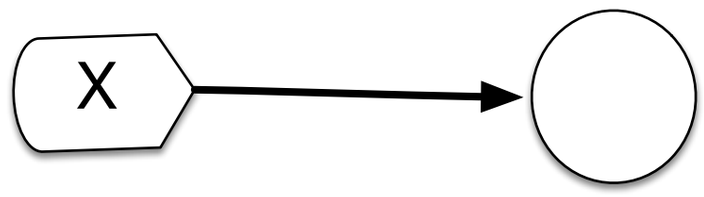
Variable representation

- What is a **variable**?
  *A name (**identifier**) of "something"*

- The name (in almost all languages) refers to a memory address. That memory address contains…"something



Variable representation



- The content depends … on the language!

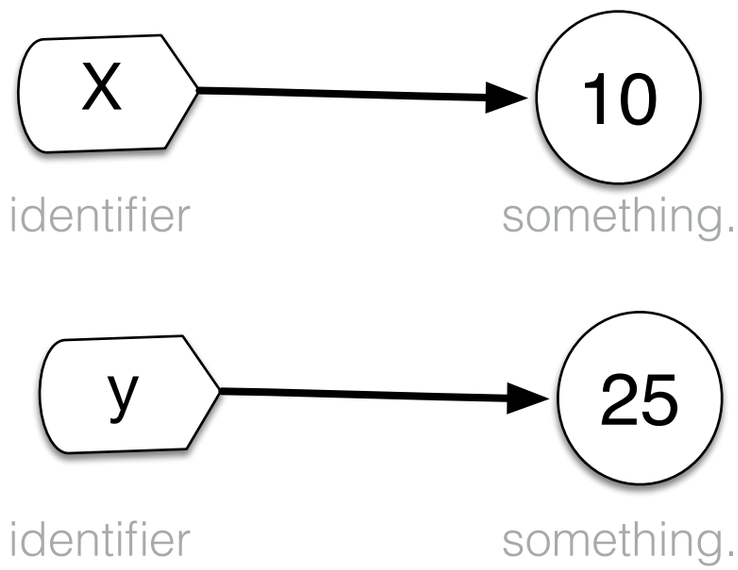
- In Python: it is **a label** reference to the memory location containing

  - The **data**
  - The **type of the data**
  - Other stuff…

  } The “object”

Variable representation in Python

```
>>> x = 10
>>> y = 25
```

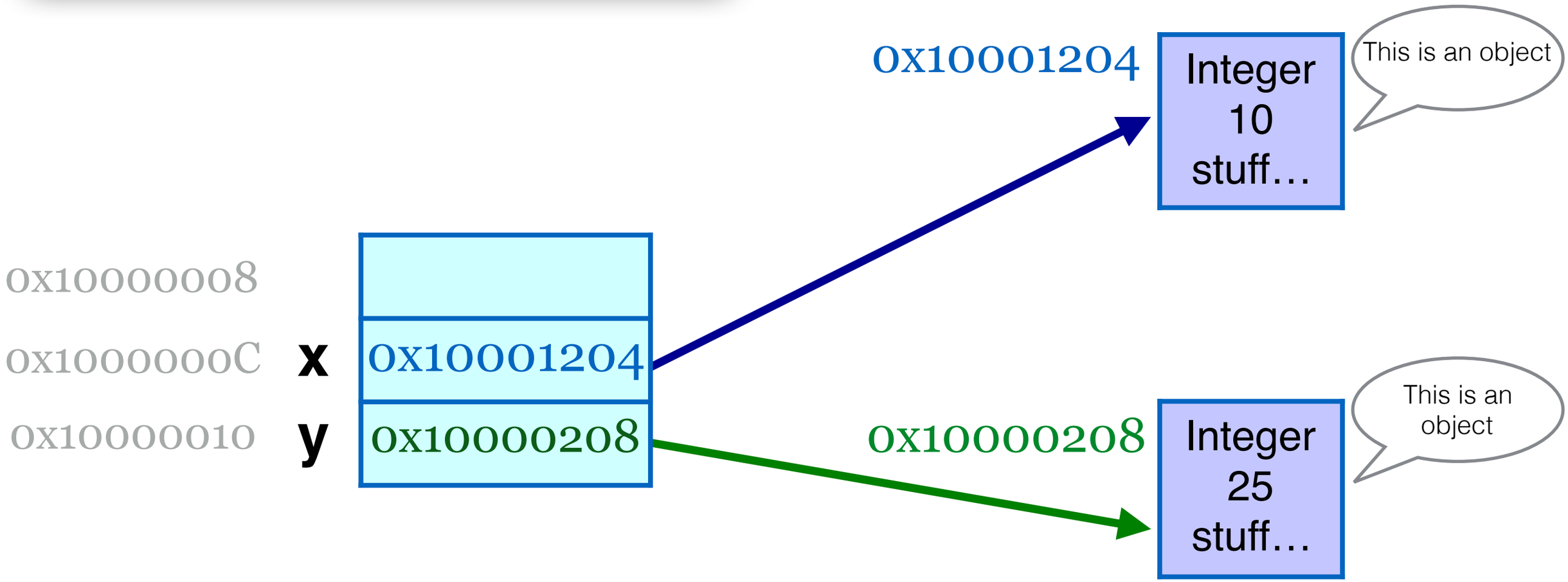


Variable representation in Python

```
>>> x = 10
>>> y = 25
```

- The **data**
- The **type of the data**
- Other stuff…

} The "object"

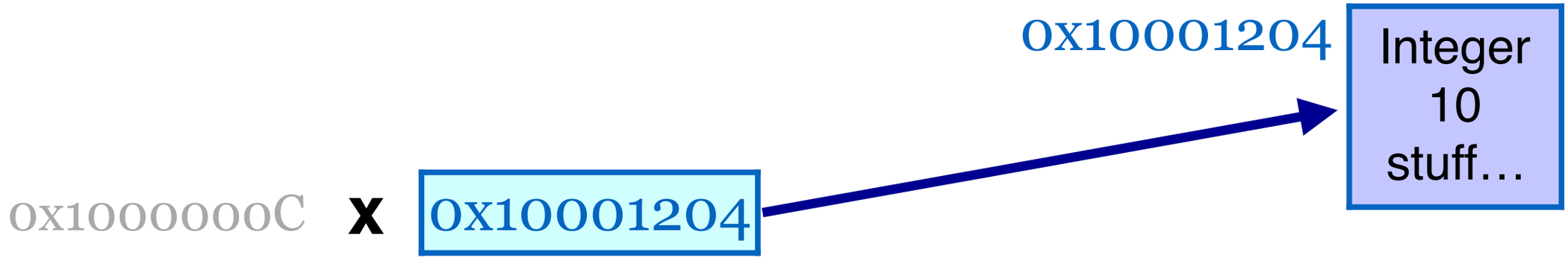


Creating variables in Python

- A variable is **created** when you first **assign** it a **value**
- In many other languages, variables can be created without a value (“declared”)

```
>>> x = 10
```

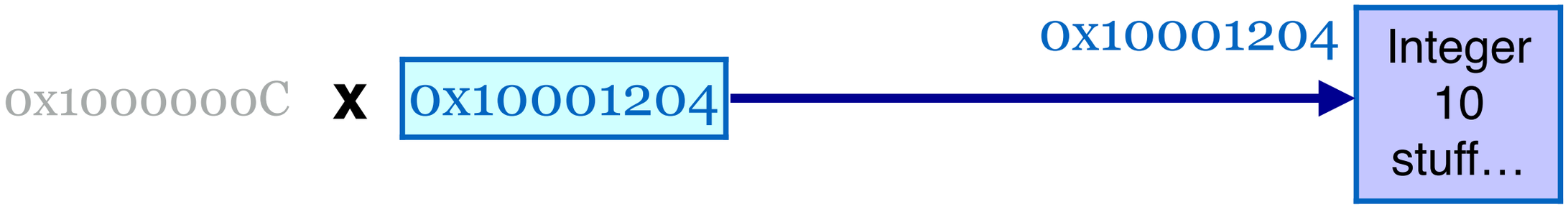
1. **Creates an object** to represent 10, starting at some address
2. Creates the variable **x** if it does not exist
3. **Links it** with the object created (assigns the address to **x**)



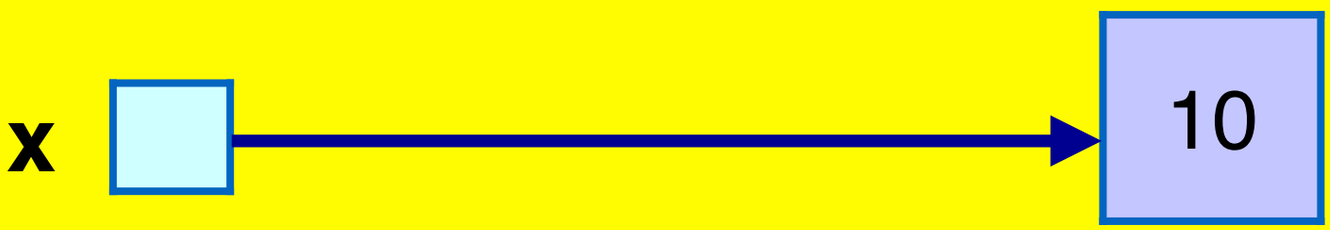
Consequence:
Variables do not have a type. Types are associated with values (i.e., with object)

You can assign values of different types to the same variable

Our visualisation of objects in Python



- We will only display values within the object
- Ignore the exact value of the references (i.e., the address)



And once variables are created?

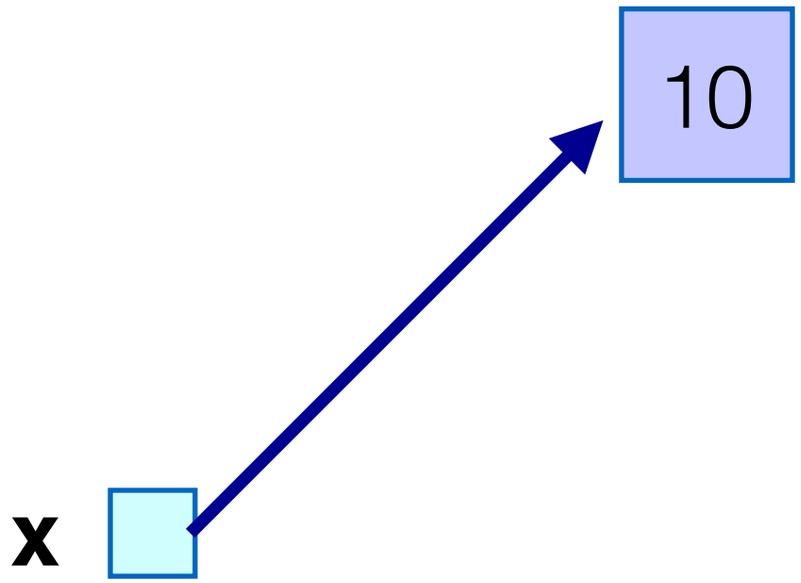
- Variables are **always** labels to where in the memory the objects are stored.

- Assignments do not alter the object itself. They only alter the reference.

- The variable will refer to a different object.

```
>>> x = 10
>>> x = x + 3
```

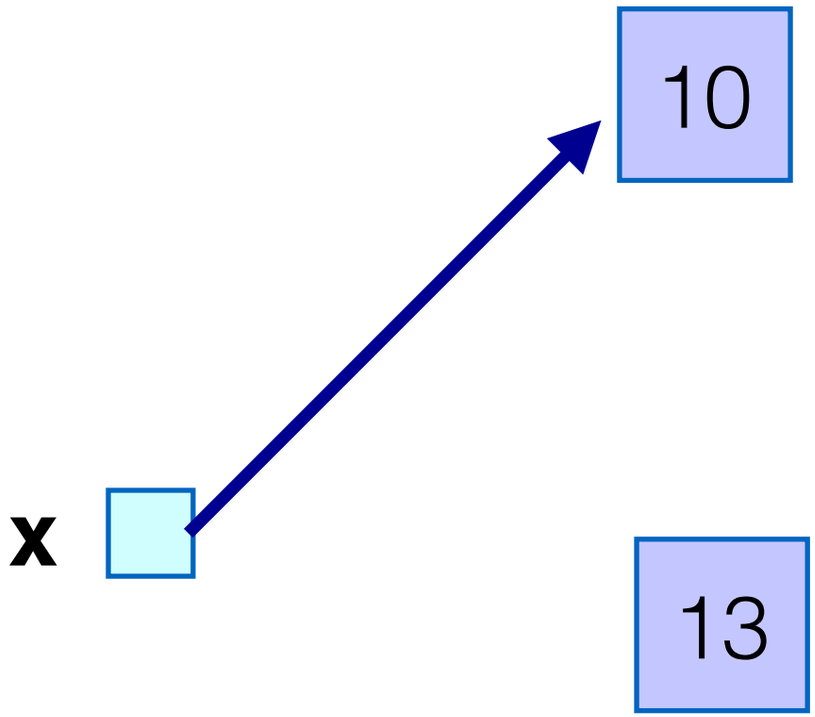
1. Creates object **10** somewhere
2. Creates variable **x**
3. Links **x** to **10**
4. Evaluates **x + 3**



A variable in an expression is immediately **replaced** with the object it currently refers to. Then the expression is evaluated.

```
>>> x = 10
>>> x = x + 3
```

1. Creates object **10** somewhere
2. Creates variable **x**
3. Links **x** to **10**
4. Evaluates **x + 3**
5. Creates object **13**

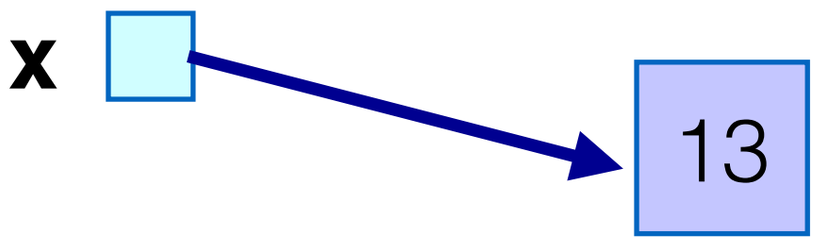


```
>>> x = 10
>>> x = x + 3
```

Garbage collection:
Automatically removes objects that are not referenced.

10

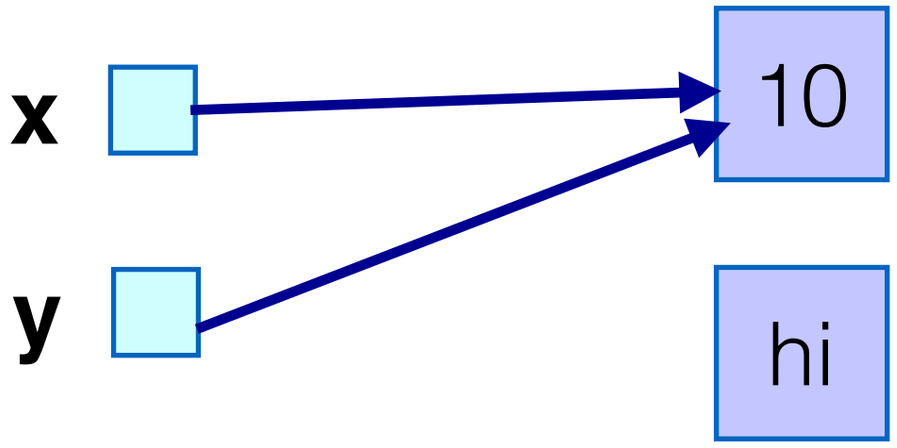
1. Creates object **10** somewhere
2. Creates variable **x**
3. Links **x** to **10**
4. Evaluates **x + 3**
5. Creates object **13**
6. Links **x** to **13**



- Every time a new value is created, Python creates a new object (a chunk of memory) to represent it.

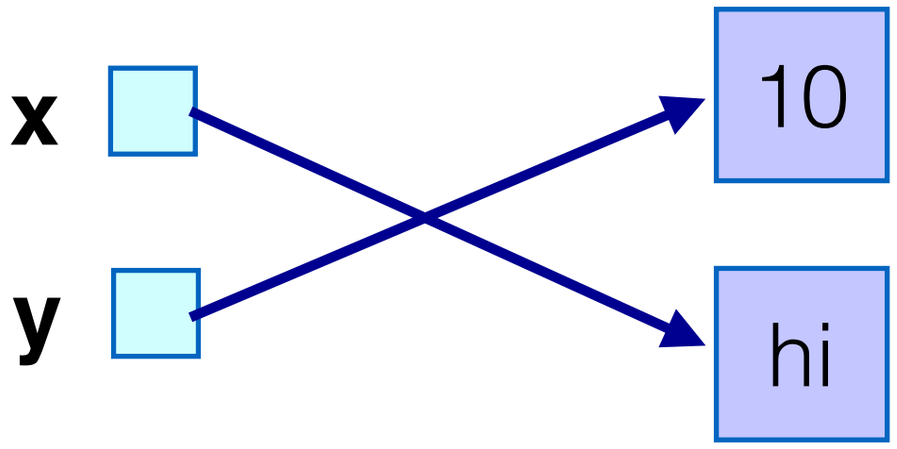
- **What about assigning a variable to another variable?**

```
>>> x = 10
>>> y = x
>>> x = 'hi'
```



1. Creates object **10** somewhere
2. Creates variable **x**
3. Links **x** to **10**
4. Creates variable **y**
5. Links it to the object pointed to by **x**
6. Creates the object **‘hi’**

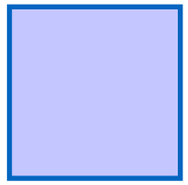
```
>>> x = 10
>>> y = x
>>> x = 'hi'
```



1. Creates object **10** somewhere
2. Creates variable **x**
3. Links **x** to **10**
4. Creates variable **y**
5. Links it to the object pointed to by **x**
6. Creates the object **‘hi’**
7. Links **x** to this object.

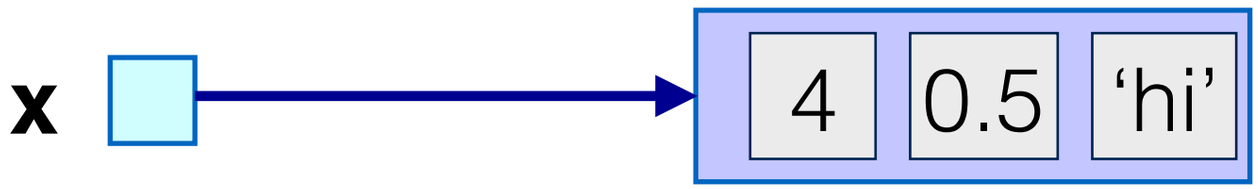
reference

object

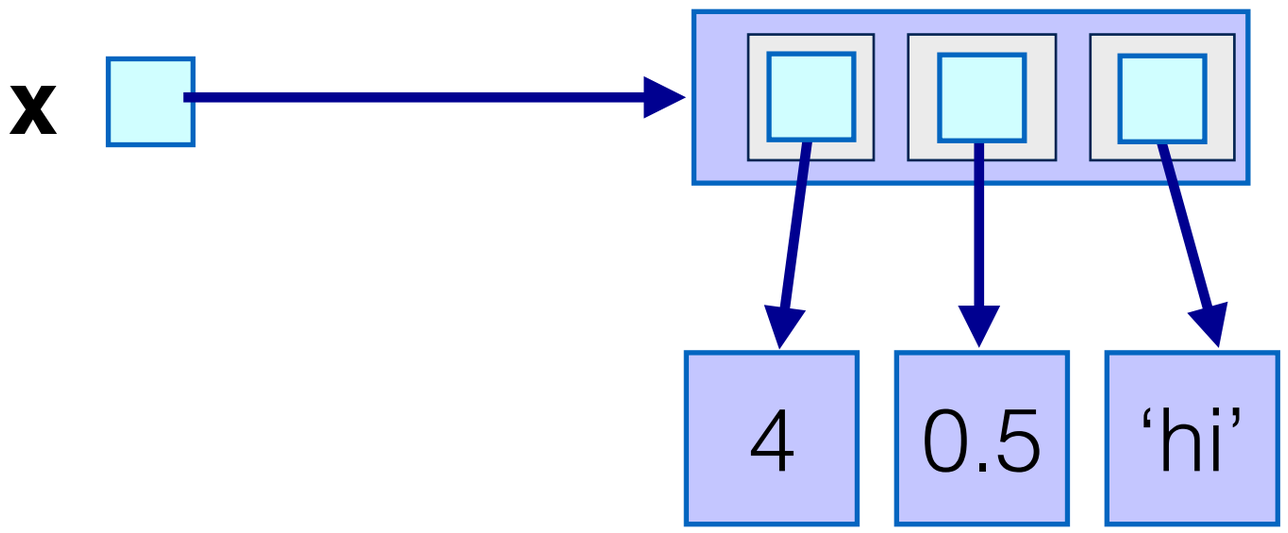


```
>>> x = [4, 0.5, 'hi']
>>>
```

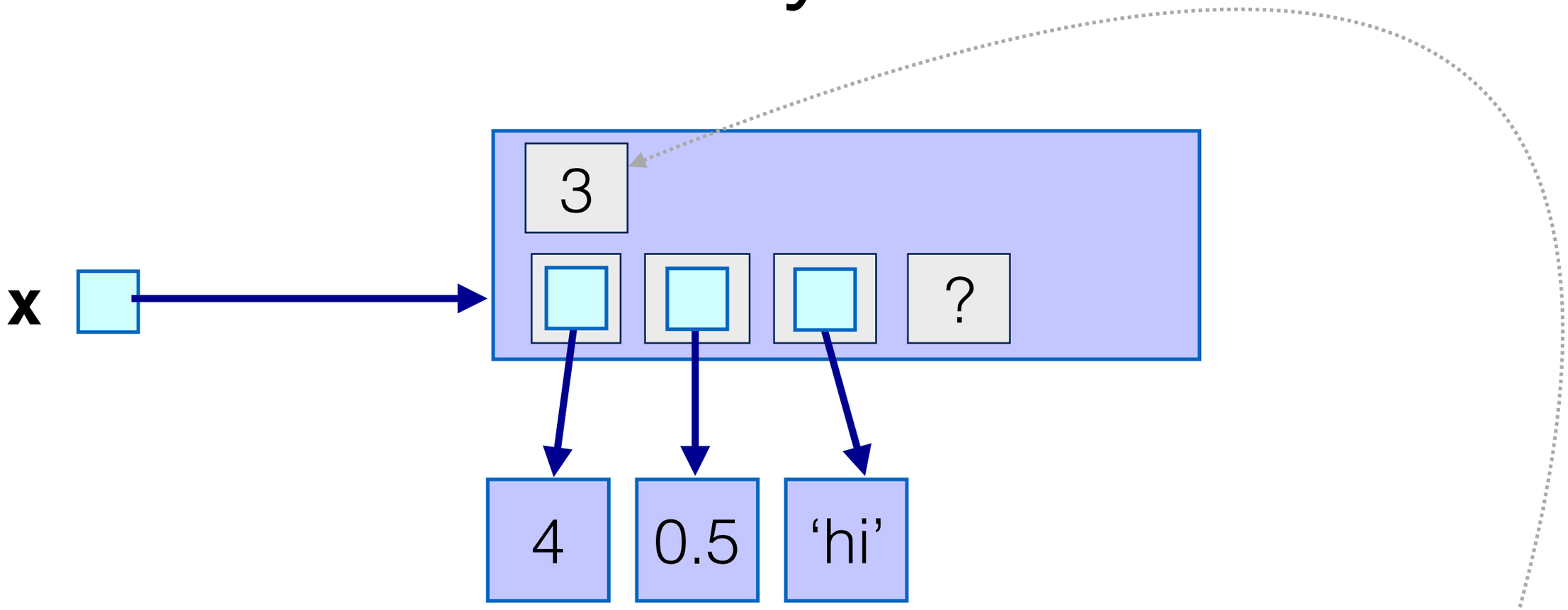
Like this?



Close, but not quite…



What about Python lists?



- The **object** list also contains other information, i.e., **length**.
- The **key point** is that **they are arrays of references**.

Mutable/Immutable

- Lists are **mutable**:
  - In other words: objects of type list in Python can be changed without creating a new object.

- Integers are **immutable:**
  - Once created they **cannot be changed**
  - I can create a new one, but not modify an already created one.

- List are **mutable**:
  - In other words: objects of type list in Python can be changed.

- Integers are **immutable:**
  - Once created they **cannot be changed**
  - I can create a new one, but not modify an already created one.
- Strings are **immutable**.

Names

- First remember, in Python **all identifiers are names**: variables, functions, methods, modules, types, …

- This means, **a name can only refer to one thing** at a time!

- Careful when reusing names then…

```
>>> a_name = 10*6
>>> a_name
60
>>> def a_name(x):
...     return x*100
...
>>> a_name
<function a_name at 0x100520560>
>>>

>>> a_name = 'hello'
>>> a_name
'hello'
>>> class a_name:
...     i = 8
...
>>> a_name
<class '__main__.a_name'>
```

Example

Single variable…
one name for different objects

Namespaces (or environments)

- A **namespace** is a mapping of names to objects: like a dictionary
- When the interpreter starts, it creates a namespace with the names of the built-in functions
- Each file (also called **module**) has its own namespace.
  - Don't put two classes or two functions with the same name in a file
  - They share the same namespace, so the result can be surprising. With two functions, the second definition overwrites the first.
- **Functions** have their namespace too. When a function is called, Python creates a local namespace for it. This namespace is forgotten once the function finishes.
- **Names** belong to the namespace in which they are bound.

```python
class Point:
    def __init__(self, x, y):
        self.x_coordinate = x
        self.y_coordinate = y

    def shift(self, x_increment, y_increment):
        self.x_coordinate = self.x_coordinate + x_increment
        self.y_coordinate = self.y_coordinate + y_increment
```

```
>>> import point
```

```python
class Point:
    def __init__(self, x, y):
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```

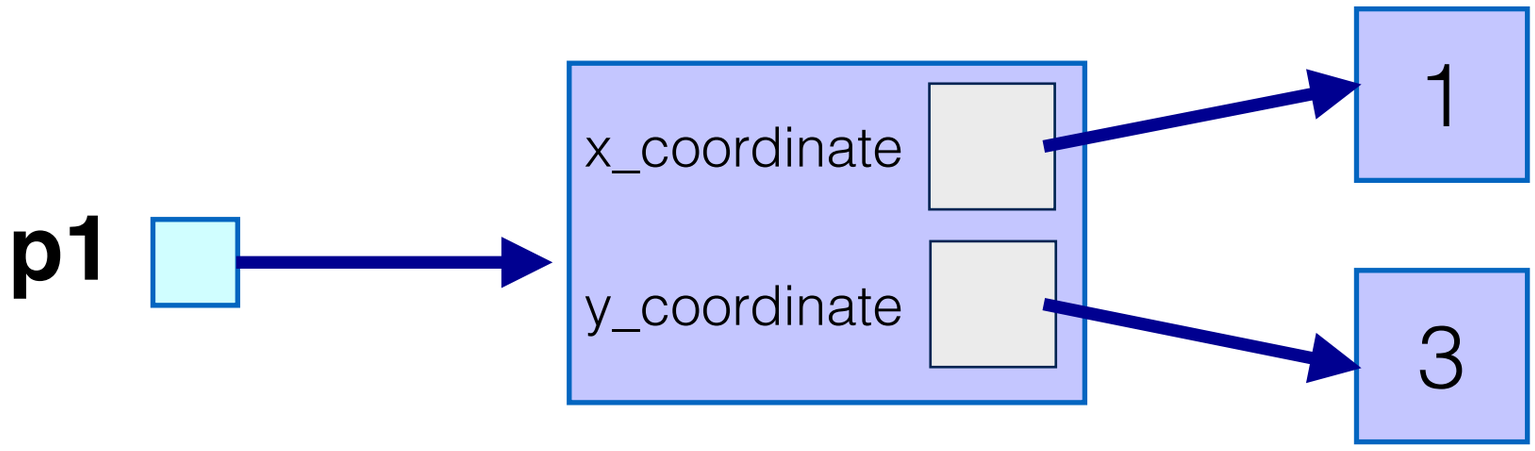


```
>>> import point
>>> p1 = point.Point(1,3)
```

```
class Point:
    def __init__(self, x, y):
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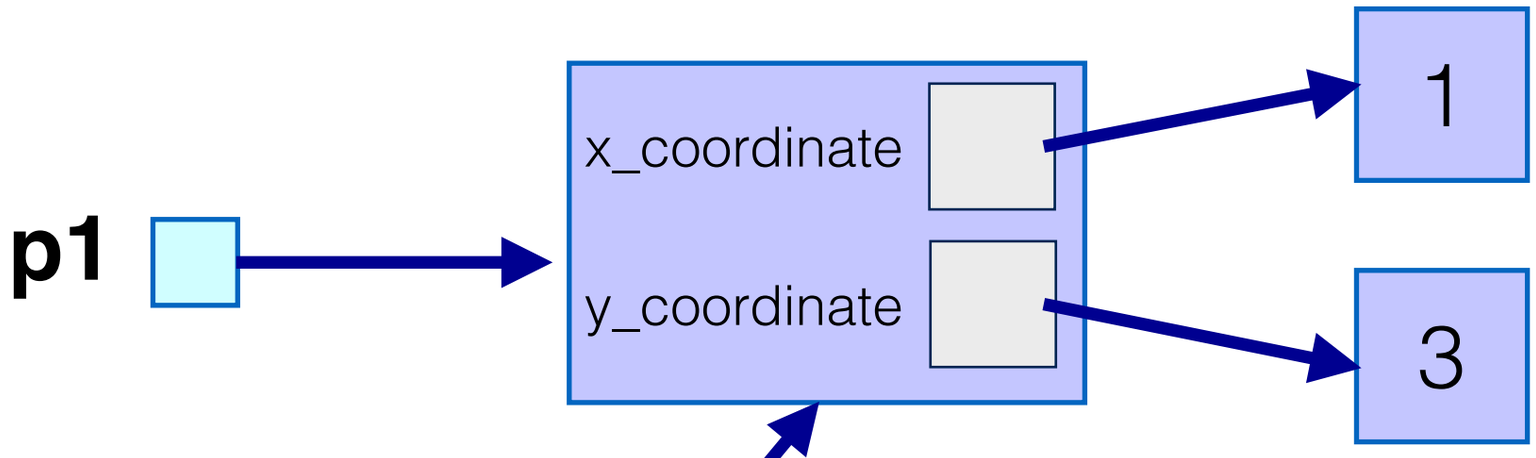
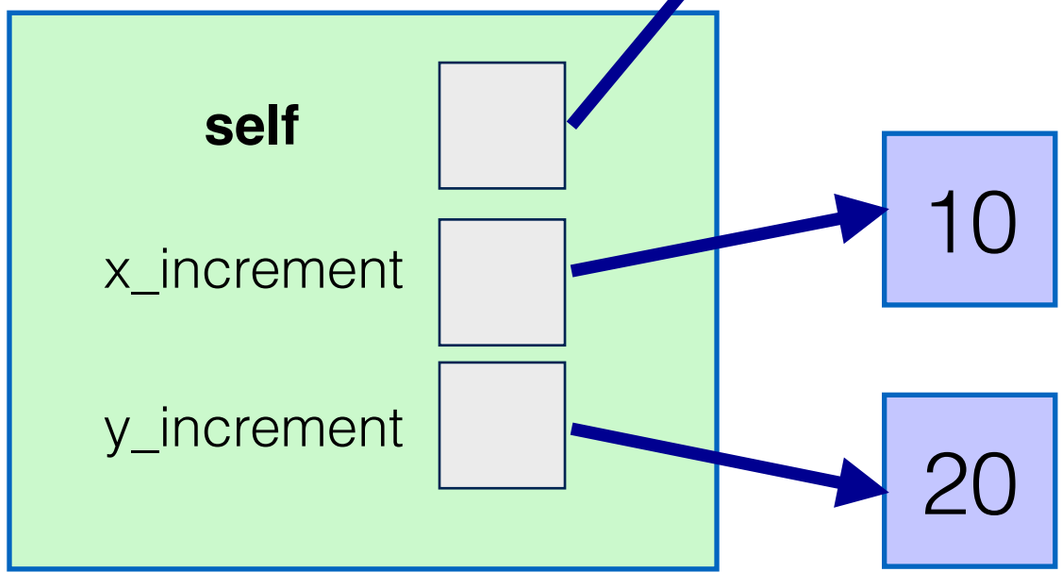


Namespace for p1.shift(10,20)

Exists while the function is executing

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>>> p1 = point.Point(1,3)
>>> p1.shift(10,20)
```

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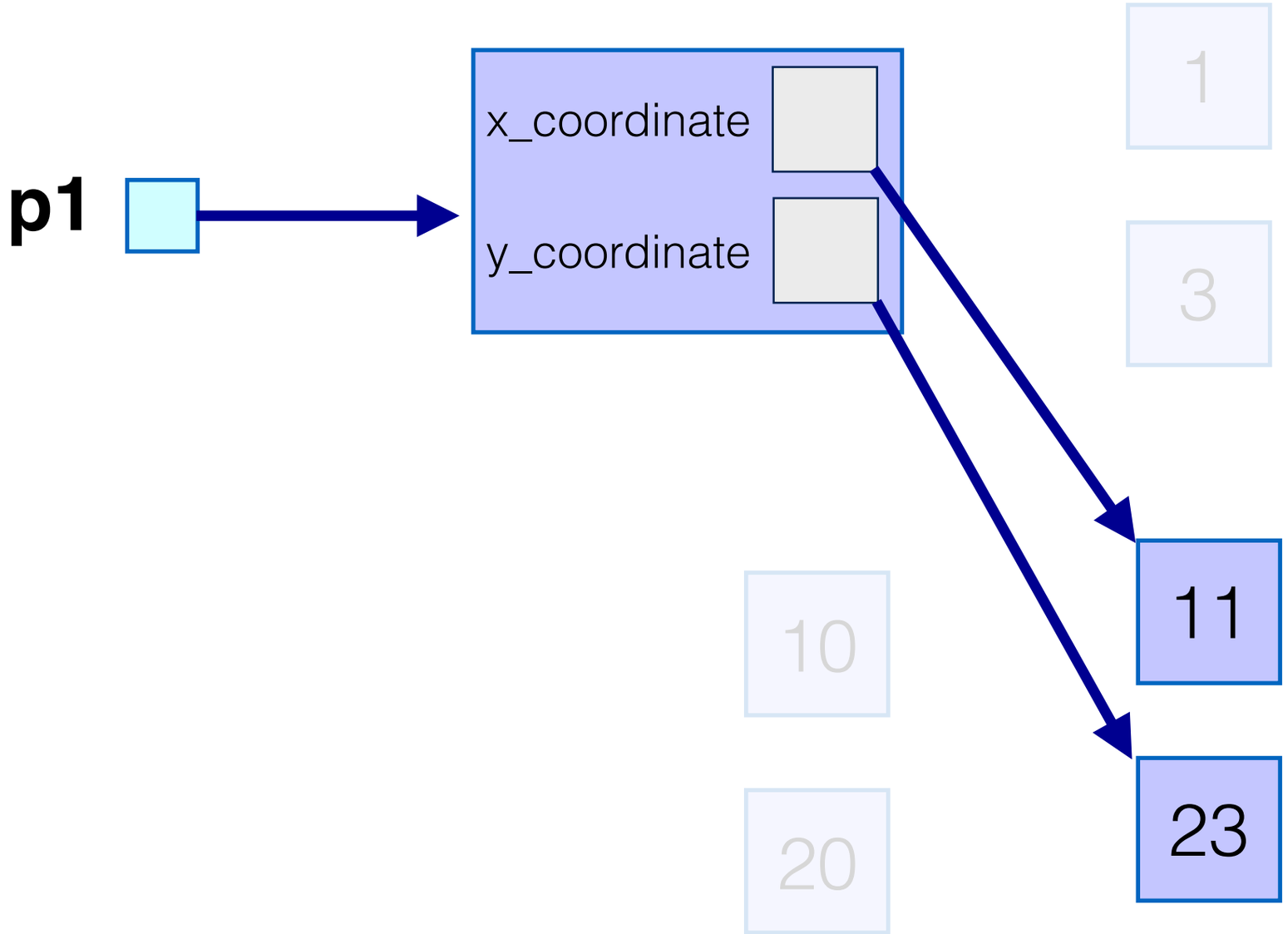
```



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```
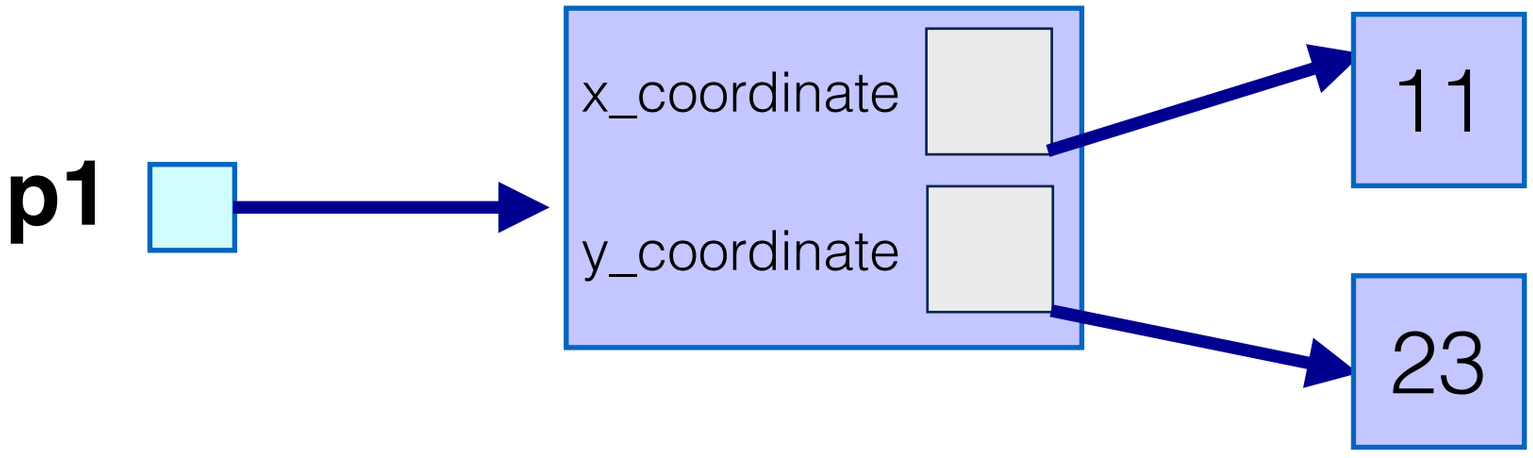




```
>>> p1.x_coordinate
11
>>> p1.y_coordinate
23
>>>
```

Once the function finishes executing the function **namespace** is gone.

Binding a name

- There are many ways to **bind a name** in Python
- For example, by:
  - **Assigning** to a variable (x = 13)
  - Receiving an **argument** (e.g., for *x_increment* and *y_increment*)
  - Importing a **module** (**import x**)
  - Importing a variable (from y import x)
  - Defining a **function** (**def x**(foo): ...)
  - **Defining a class** (class x: ...)
  - Writing a for loop (for x in y: ...)
  - Writing an except clause (try: ... except x: ...)
- If any of these appears inside a function. It makes the name local to the function

Scoping

- **Scope**: block of text where a namespace is directly accessible. That is, where there is no need to “qualify” the name.

```
>>> import point
>>> p1 = point.Point(1,3)
```

qualify a name

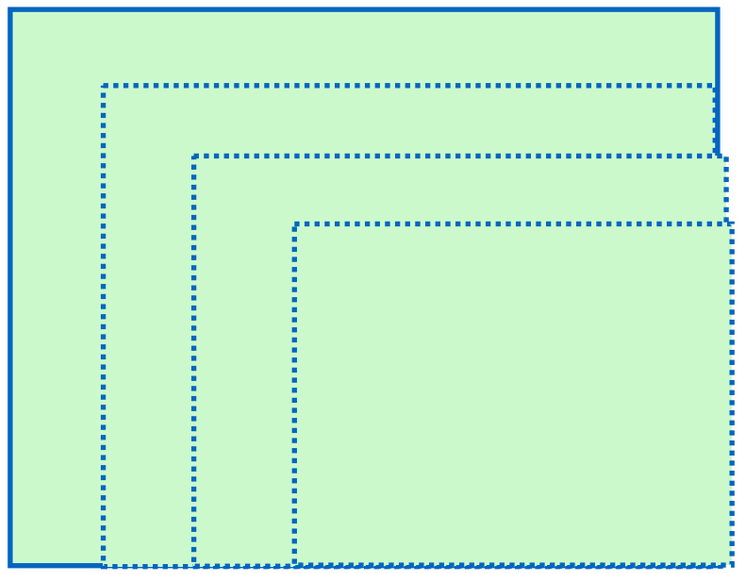
```
>>> from point import Point
>>> p1 = Point(1,3)
```

Brings Point to the **current namespace**
Then, there is **no need** for *point.Point*

```
>>> p1.x_coordinate
11
```

qualify a name

- Often there are **several scopes in operation**:
  - The scope of the **method** that is executing
  - The scope of the **class** where the method is defined
  - The scope of the **module** where the class is defined
  - The scope of the **interpreter** that is executing

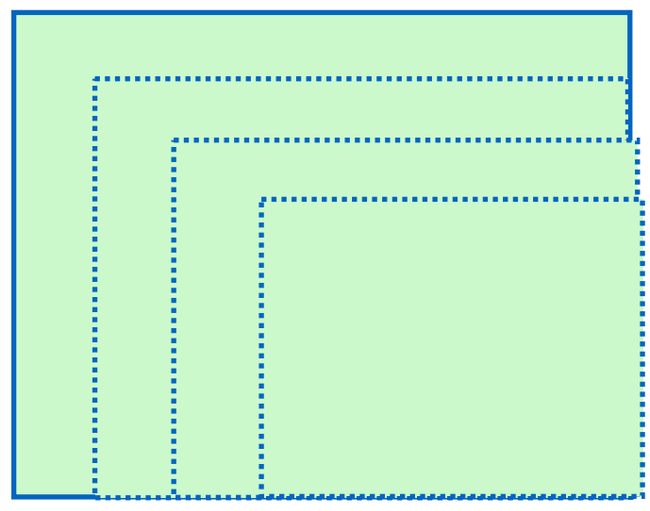


- Scope is **determined statically** but **used dynamically**
  - Statically: that you can always determine the scope of any name by looking at the program
  - Dynamically: that it is at run-time that Python searches for names

Scoping Rules

- **Names belong to the namespace** where they are bound. The scope of a name does not change while the program is running.

- During execution, Python searches for names as follows:
  - First, in the **innermost** scope
    - Contains all the local names (those in the method's namespace)
  - Then, in the scopes of any **enclosing** functions:
    - Searched from the nearest-to-outer enclosing scope
    - Contains nonlocal and nonglobal names
  - Then the current **module's global names**
    - That is, those in the module's namespace
  - Last, the namespace containing **built-in names**



- Programmers can change the scope of identifiers. But we are not going to see this.

"Qualifying"

```
class Point:
    def __init__(self, x, y):
        self.x_coordinate = x
        self.y_coordinate = y
```

Why is **.point** needed?

The name **Point** is not directly accessible from the current code, i.e., not in its namespace or in any one where Python will search for it

Qualifying it by **point.** allows us to access the namespace of module **point.** which contains the name **Point**

```
>>> import point
>>> p1 = point.Point(1,3)
>>> p1.x_coordinate
1
>>> p1.y_coordinate
3
>>> p2 = point.Point(-4,7)
>>> p2.x_coordinate
-4
>>> p2.y_coordinate
7
>>> p1.__class__
<class 'point.Point'>
```

Class variables

Variables whose values are shared by **all instances** of the class

Defined in the body of a class, but **outside** any methods.

```
>>> class Silly:
...     i = 8
...
```

Class variables

Variables whose values are shared by **all instances** of the class

```
>>> class Silly:
...     i = 8
...
>>> Silly.i
8
```

Defined in the body of a class, but **outside** any methods.

Belongs to the **class**. It exists without the object. Values are accessed through the **class**.

Class variables

Variables whose values are shared by **all instances** of the class

Defined in the body of a class, but **outside** any methods.

```
>>> class Silly:
...     i = 8
...
>>> Silly.i
8
>>> s1 = Silly()
>>> s1.i
8
```

Belongs to the **class**. It exists without the object. Values are accessed through the **class**.

Can also be accessed through instances.

Class variables

Variables whose values are shared by **all instances** of the class

```
>>> class Silly:
...     i = 8
...
>>> Silly.i
8
>>> s1 = Silly()
>>> s1.i
8
>>> s2 = Silly()
>>> s2.i
8
```

Defined in the body of a class, but **outside** any methods.

Belongs to the **class**. It exists without the object. Values are accessed through the **class**.

Can also be accessed through instances.

All instances share the same value.

Class variables

```
>>> Silly.i = 11
>>> s1.i
11
>>> s2.i
11
>>> s1.i = 6
>>> s1.i
6
>>> s2.i
11
```

You can modify the value of a **class variable**

All instances will share the new value

Modifying the value of a **class variable through the instance**?

?

Names and scoping!

Summary

- We have seen how to **draw memory diagrams** for code involving:
  - Variable **assignments**
  - **Mutable** types
  - **Immutable** types
  - Assigning variables to other variables (“**variable aliasing**”)