

# Object oriented programming

- classes, objects
- self
- construction
- encapsulation

# Object Oriented Programming

- **Programming paradigm**, other paradigms are e.g.
  - *functional programming* where the focus is on functions, lambda's and higher order functions, and
  - *imperative programming* focusing on sequences of statements changing the state of the program
- Core concepts are **objects**, **methods** and **classes**,
  - allowing one to construct *abstract data types*, i.e. *user defined types*
  - objects have states
  - methods manipulate objects, defining the interface of the object to the rest of the program
- OO supported by many programming languages, including Python

# Object Oriented Programming - History

(selected programming languages)

## Mid 1960's **Simula 67**

(Ole-Johan Dahl and Kristen Nygaard, Norsk Regnesentral Oslo)  
Introduced classes, objects, virtual procedures

## 1970's **Smalltalk** (Alan Kay, Dan Ingalls, Adele Goldberg, Xerox PARC)

Object-oriented programming, fully dynamic system  
(opposed to the static nature of Simula 67 )

## 1985 **Eiffel** (Bertrand Meyer, Eiffel Software)

Focus on software quality, capturing the full software cycle

## 1985 **C++** (Bjarne Stroustrup [MSc Aarhus 1975], AT&T Bell Labs)

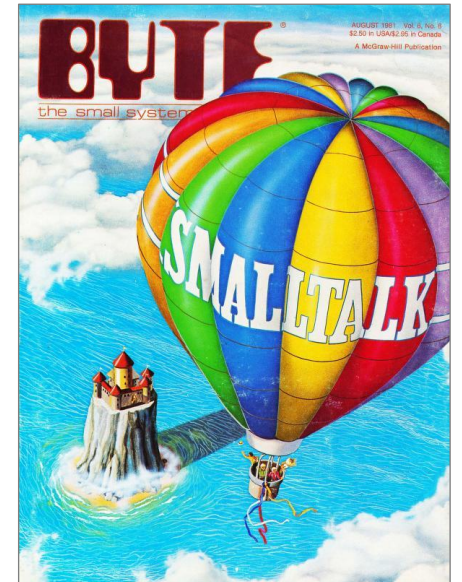
## 1995 **Java** (James Gosling, Sun)

## 2000 **C#** (Anders Hejlsberg (studied at DTU) et al., Microsoft)

## 1991 **Python** (Guido van Rossum)

Multi-paradigm programming language, fully dynamic system

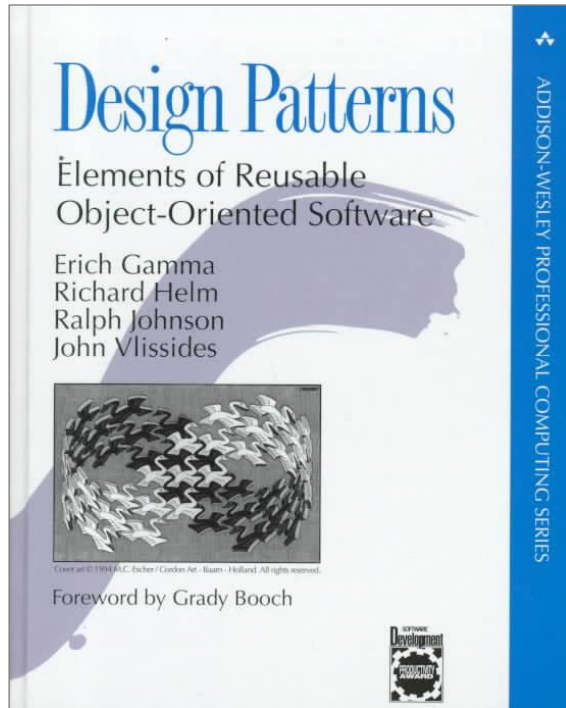
**Note:** Java, C++, Python, C# are among Top 5 on TIOBE March 2024 index of popular languages (only non OO language among Top 5 was C)



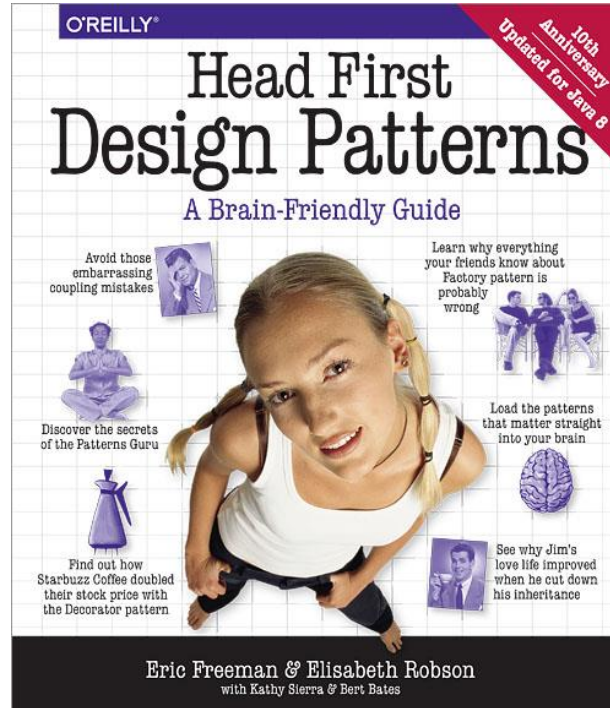
Byte Magazine,  
August 1981

# Design Patterns (not part of this course)

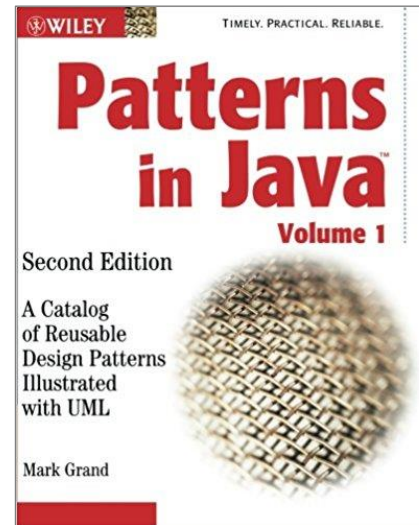
## *reoccurring patterns in software design*



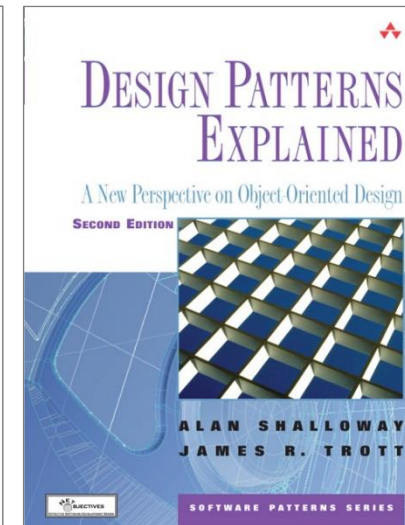
**The Classic book 1994**  
(C++ cookbook)



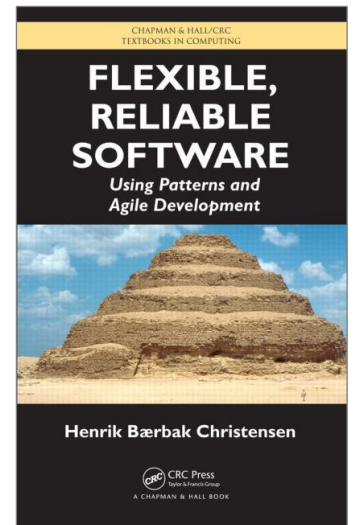
**A very alternative book 2004**  
(Java, very visual)



**Java cookbook 2003**



**Java textbook 2004**



**Java textbook 2010**

...and many more books on the topic of Design Patterns, also with Python

# Some known classes, objects, and methods

Type / class	Objects	Methods (examples)
int	0 -7 42 1234567	.__add__(x), .__eq__(x), .__str__()
str	"" 'abc' '12_a'	.isdigit(), .lower(), .__len__()
list	[] [1,2,3] ['a', 'b', 'c']	.append(x), .clear(), .__mul__(x)
dict	{'foo': 42, 'bar': 5}	.keys(), .get(), .__getitem__(x)
NoneType	None	.__str__()

## Example:

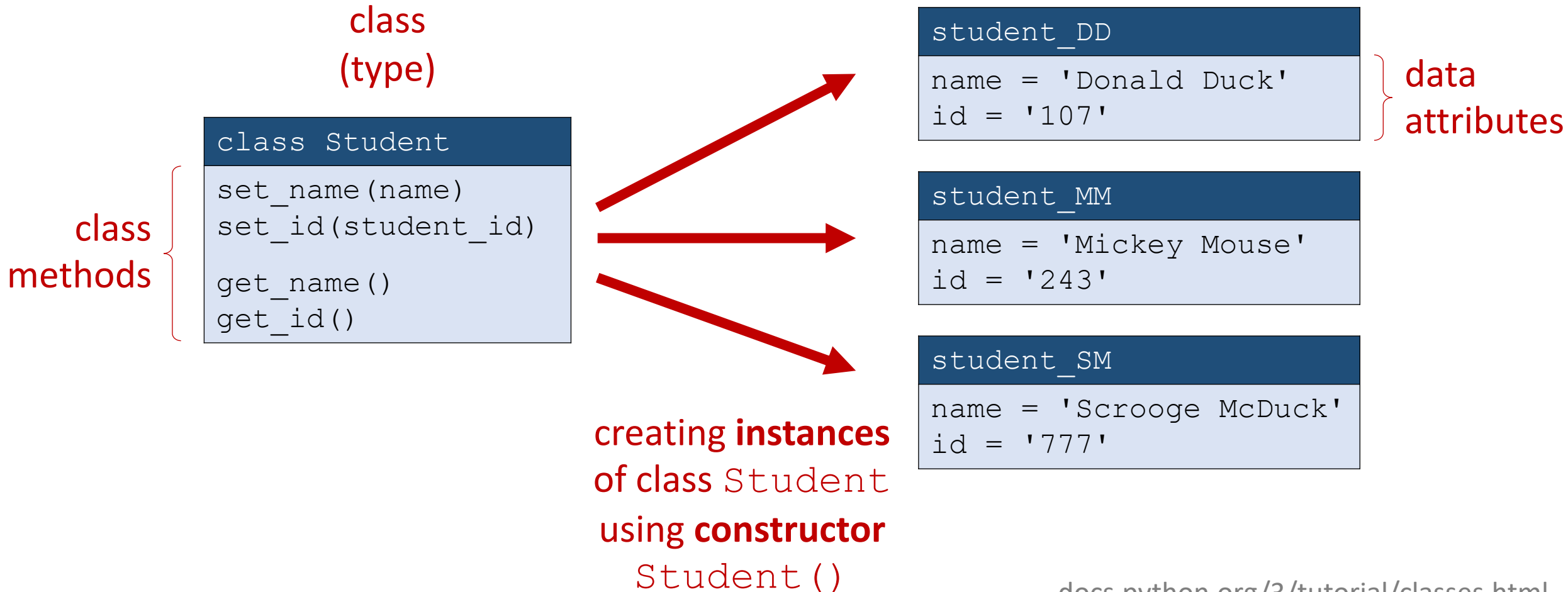
The function `str(obj)` calls the methods  
`obj.__str__()` or `obj.__repr__()`, if  
`obj.__str__` does not exist.

`print` calls `str`.

## Python shell

```
> 5 + 7 # + calls .__add__(7)
| 12
> (5).__add__(7) # eq. to 5 + 7
| 12
> (7).__eq__(7) # eq. to 7 == 7
| True
> 'aBCd'.lower()
| 'abcd'
> 'abcde'.__len__()
| 5
# .__len__() called by len(...)
> ['x', 'y'].__mul__(2)
| ['x', 'y', 'x', 'y']
> {'foo': 42}.__getitem__('foo')
| 42
# eq. to {'foo': 42}['foo']
> None.__str__() # used by str(...)
| 'None'
> 'abc'.__str__(), 'abc'.__repr__()
| ('abc', "'abc'")
```

# Classes and Objects



# Using the Student class

## student.py

```
student_DD = Student()
student_MM = Student()
student_SM = Student()

student_DD.set_name('Donald Duck')
student_DD.set_id('107')
student_MM.set_name('Mickey Mouse')
student_MM.set_id('243')
student_SM.set_name('Scrooge McDuck')
student_SM.set_id('777')

students = [student_DD, student_MM, student_SM]

for student in students:
    print(student.get_name(),
          'has id',
          student.get_id())
```

## Python shell

```
| Donald Duck has id 107
| Mickey Mouse has id 243
| Scrooge McDuck has id 777
```

Call **constructor** for class Student. Each call returns a new Student object.

Call class methods to set data attributes

Call class methods to read data attributes



# class Student

class definitions start with the keyword `class`

often called **mutator methods**, since they change the state of an object

often called **accessor methods**, since they only read the state of an object

class method definitions start with keyword `def` (like normal function definitions)

```
student.py
class Student:
    '''Documentation of class'''

    def set_name(self, name):
        self.name = name

    def set_id(self, student_id):
        self.id = student_id

    def get_name(self):
        return self.name

    def get_id(self):
        return self.id
```

name of class

docstring containing documentation for class

the first argument to all class methods is a reference to the object called upon, and by convention the first argument should be named `self`.


use `self.` to access an attribute of an object or class method (attribute reference)

**Note** In other OO programming languages the explicit reference to `self` is not required (in Java and C++ `self` is the keyword `this`)



# When are object attributes initialized ?

Python shell

```
> x = Student()
> x.set_name("Gladstone Gander")
> x.get_name()
| 'Gladstone Gander'
> x.get_id()
| 
| AttributeError: 'Student' object has no attribute 'id'
```

- Default behaviour of a class is that instances are created with no attributes defined, but has access to the attributes / methods of the class
- In the previous class `Student` both the `name` and `id` attributes were first created when set by `set_name` and `set_id`, respectively

# Class construction and `__init__`

- When an object is created using `class_name()` its initializer method `__init__` is called.
- To initialize objects to contain default values, (re)define this function.

**student.py**

```
class Student:
    def __init__(self):
        self.name = None
        self.id = None

    ... previous method definitions ...
```

# Question – What is printed ?


Python shell

```
> class C:
    def __init__(self):
        self.v = 0
    def f(self):
        self.v = self.v + 1
        return self.v

> x = C()
> print(x.f() + x.f())
```

a) 1

b) 2

 c) 3

d) 4

e) 5

f) Don't know

# `__init__` with arguments

- When creating objects using `class_name(args)` the initializer method is called as `__init__(args)`
- To initialize objects to contain default values, (re)define this function to do the appropriate initialization

## student.py

```
class Student:
    def __init__(self, name=None, student_id=None):
        self.name = name
        self.id = student_id

... previous method definitions ...
```

## Python shell

```
> p = Student('Pluto')
> print(p.get_name())
| Pluto
> print(p.get_id())
| None
```

# Are accessor and mutator methods necessary ?

No - but good programming style

## Python shell

```
> p = Pair(3, 5)
> p.sum()
| 8
> p.set_a(4)
> p.sum()
| 9
> p.a      # access object attribute
| 4
> p.b = 0  # update object attribute
> p.sum()
| 9      # the_sum not updated
```



## pair.py

```
class Pair:
    """ invariant: the_sum = a + b """

    def __init__(self, a, b):
        self.a = a
        self.b = b
        self.the_sum = self.a + self.b

    def set_a(self, a):
        self.a = a
        self.the_sum = self.a + self.b

    def set_b(self, b):
        self.b = b
        self.the_sum = self.a + self.b

    def sum(self):
        return self.the_sum
```

# Defining order on instances of a class (sorting)

- To define an order on objects, define the “<” operator by defining `__lt__`
- When “<” is defined a list `L` of students can be sorted using `sorted(L)` and `L.sort()`

**student.py**

```
class Student:
    def __lt__(self, other):
        return self.id < other.id

    ... previous method definitions ...
```

**Python shell**

```
> student_DD < student_MM
| True
> [x.id for x in students]
| ['243', '107', '777']
> [x.id for x in sorted(students)]
| ['107', '243', '777']
```

# Converting objects to `str`

- To be able to convert an object to a string using `str(object)`, define the method `__str__`
- `__str__` is e.g. used by `print`

## Student\_constructor.py

```
class Student:
    def __str__(self):
        return f"Student('{self.name}', '{self.id}')"
    ... previous method definitions ...
```

## Python shell

```
> print(student_DD)    # without __str__
| <__main__.Student object at 0x03AB6B90>
> print(student_DD)    # with __str__
| Student('Donald Duck', '107')
```



# Nothing is private in Python

- Python does not support **hiding information** inside objects
- Recommendation is to start attributes with underscore, if these should be used only locally inside a class, i.e. be considered "private"
- **PEP8**: "Use one leading underscore only for non-public methods and instance variables"

## private\_attributes.py

```
class My_Class:
    def set_xy(self, x, y):
        self._x = x
        self._y = y

    def get_sum(self):
        return self._x + self._y

obj = My_Class()
obj.set_xy(3, 5)

print('Sum =', obj.get_sum())
print('_x =', obj._x)
```

## Python shell

```
| Sum = 8
| _x = 3
```

# C++ private, public

## C++ vs Python

1. argument types
2. return types
3. `void = NoneType`
4. `private` / `public` access specifier
5. types of data attributes
6. data attributes must be defined in class
7. object creation
8. no `self` in class methods

`private_attributes.cpp`

```
#include <iostream>
using namespace std;

class My_Class {
private: ④
    ⑤int x, y; ⑥
public: ④
    ②③void set_xy(int a, int b) { ①
        x = a;
        y = b;
    }; ⑧
    ②int get_sum() {
        return x + y;
    };
};

main() {
    ⑦My_Class obj;
    obj.set_xy(3, 5);
    cout << "Sum = " << obj.get_sum() << endl;
    cout << "x = " << obj.x << endl;
}
```



invalid reference


# Java private, public

## Java vs Python

1. argument types
2. return types
3. void = NoneType
4. `private` / `public` access specifier
5. types of data attributes
6. data attributes must be defined in class
7. object creation
8. no `self` in class methods

private\_attributes.java

```
class My_Class {  
    ④ private ⑤ int x, y; ⑥  
    ④ public ②③ void set_xy(int a, int b) { ①  
        x = a; y = b;  
    }  
    ④ public ② int get_sum() ⑧ { return x + y; };  
};  
  
class private_attributes {  
    public static void main(String args[]){  
        ⑦ My_Class obj = new My_Class();  
        obj.set_xy(3, 5);  
        System.out.println("Sum = " + obj.get_sum());  
        System.out.println("x = " + obj.x);  
    }  
}
```

invalid reference 

# Name mangling (partial privacy)

- Python handles references to class attributes inside a class definition with *at least two leading underscores and at most one trailing underscore* in a special way: `__attribute` is textually replaced by `__classname__attribute`
- Note that [Guttag, p. 200] states “that attribute is not visible outside the class” – which only is partially correct (see example)

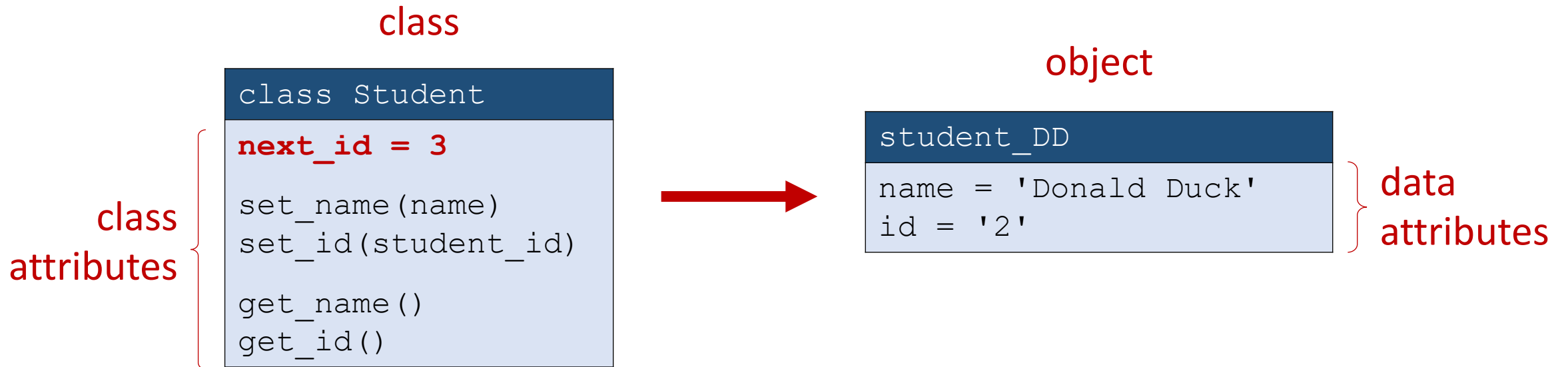
**name\_mangling.py**

```
class MySecretBox:  
    def __init__(self, secret):  
        self.__secret = secret
```

**Python shell**

```
> x = MySecretBox(42)  
> print(x.__secret)  
| AttributeError: 'MySecretBox'  
  object has no attribute  
    '__secret'  
> print(x.__MySecretBox__secret)  
| 42
```

# Class attributes



- `obj.attribute` first searches the objects attributes to find a match, if no match, continuous to search the attributes of the class
- Assignments to `obj.attribute` are always to the objects attribute (possibly creating the attribute)
- Class attributes can be accessed directly as `class.attribute` (or `obj.__class__.attribute`)

# Class data attribute

- `next_id` is a class attribute
- Accessed using `Student.next_id`
- The lookup ① can be replaced with `self.next_id`, since only the class has this attribute, looking up in the object will be propagated to a lookup in the class attributes
- In the update ② it is crucial that we update the class attribute, since otherwise the incremented value will be assigned as an object attribute (What will the result be?)

student\_auto\_id.py

```
class Student:
    next_id = 1 # class attribute
    def __init__(self, name):
        self.name = name
        self.id = str(Student.next_id) ①
        ② Student.next_id += 1
    def get_name(self):
        return self.name
    def get_id(self):
        return self.id

students = [Student('Scrooge McDuck'),
            Student('Donald Duck'),
            Student('Mickey Mouse')]

for student in students:
    print(student.get_name(),
          "has student id",
          student.get_id())
```

Python shell

```
| Scrooge McDuck has student id 1
| Donald Duck has student id 2
| Mickey Mouse has student id 3
```

# Question – What does `obj.get()` return ?

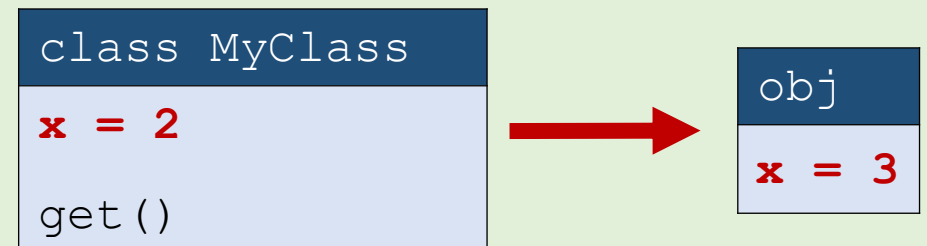
Python shell

```
> class MyClass:
    x = 2

    def get(self):
        self.x = self.x + 1
        return MyClass.x + self.x

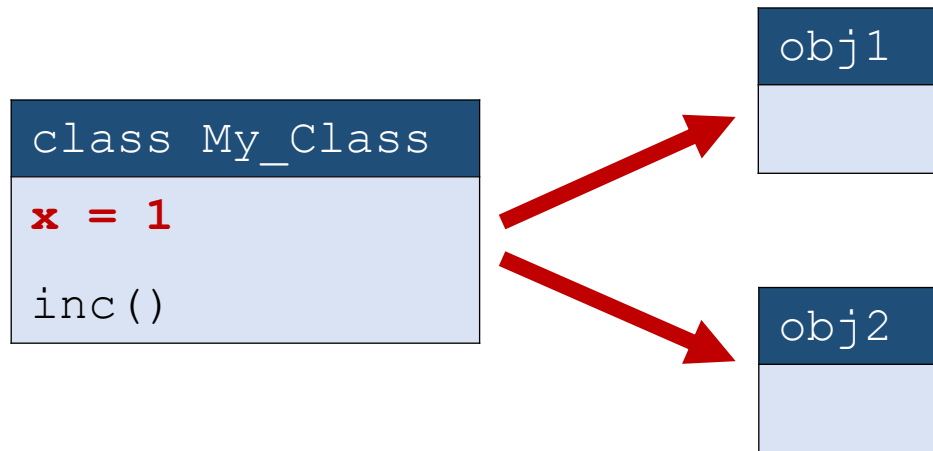
> obj = MyClass()
> print(obj.get())
| ?
```

- a) 4
- 😊 b) 5
- c) 6
- d) UnboundLocalError
- e) Don't know





# Class data attribute example (in Python)



**class\_attributes.py**

```
class My_Class:
    x = 1 # class attribute
    def inc(self):
        My_Class.x = self.x + 1

obj1 = My_Class()
obj2 = My_Class()
obj1.inc()
obj2.inc()
print(obj1.x, obj2.x)
```

**Python shell**

| 3 3

- Note that `My_Class.x` and `self.x` refer to the same class attribute (since `self.x` has never been assigned a value)

dict, name and class

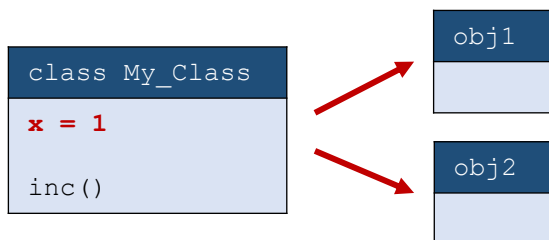
# Python shell

```
> MM = Student('Mickey Mouse')  
> MM.__dict__ # objects attributes  
| {'name': 'Mickey Mouse', 'id': '1'}  
> MM.__class__ # objects class (reference to object of type class)  
| <class '__main__.Student'>  
> Student.__name__ # class name (string)  
| 'Student'  
> Student.__dict__ # class attributes  
| mappingproxy({  
|   '__module__': '__main__',  
|   'next_id': 2,  
|   '__init__': <function Student.__init__ at 0x000002831344CD30>,  
|   'get_name': <function Student.get_name at 0x000002831344CE50>,  
|   'get_id': <function Student.get_id at 0x000002831344CEE0>,  
|   '__dict__': <attribute '__dict__' of 'Student' objects>,  
|   '__weakref__': <attribute '__weakref__' of 'Student' objects>,  
|   '__doc__': None  
| })
```

```
# module where class defined  
# class data attriute  
# class method  
# class method  
# class method  
# attributes of class  
# (for garbage collecting)  
# docstring
```

# Java static

- In Java *class attributes*, i.e. attribute values shared by all instances, are labeled **static**
- Python allows both class and instance attributes with the same name – in Java at most one of them can exist



## static\_attributes.java

```
class My_Class {
    public static int x = 1;
    public void inc() { x += 1; };
}

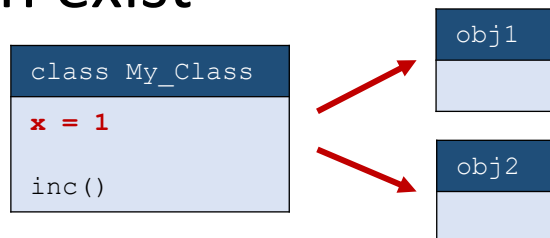
class static_attributes {
    public static void main(String args[]){
        My_Class obj1 = new My_Class();
        My_Class obj2 = new My_Class();
        obj1.inc();
        obj2.inc();
        System.out.println(obj1.x);
        System.out.println(obj2.x);
    }
}
```

## Java output

```
| 3
| 3
```

# C++ static

- In C++ *class attributes*, i.e. attribute values shared by all instances, are labeled **static**
- ISO C++ forbids in-class initialization of non-const static member
- Python allows both class and instance attributes with the same name – in C++ at most one of them can exist



## static\_attributes.cpp

```
#include <iostream>
using namespace std;

class My_Class {
public:
    static int x; // "= 1" is not allowed
    void inc() { x += 1; };
};

int My_Class::x = 1; // class initialization

int main() {
    My_Class obj1;
    My_Class obj2;
    obj1.inc();
    obj2.inc();
    cout << obj1.x << endl;
    cout << obj2.x << endl;
}
```

## C++ output

```
| 3
| 3
```

# Constants

- A simple usage of class data attributes is to store a set of constants (but there is nothing preventing anyone to change these values)

```
Python shell
> class Color:
    RED    = "ff0000"
    GREEN  = "00ff00"
    BLUE   = "0000ff"
> Color.RED
| 'ff0000'
```

# PEP8 Style Guide for Python Code (some quotes)

- Class names should normally use the **CapWords** convention.
- Always use **self** for the first argument to instance methods.
- Use one **leading underscore** only for **non-public methods and instance variables**.
- For **simple public data attributes**, it is best to expose just the attribute name, **without complicated accessor/mutator methods**.
- Always decide whether a class's methods and instance variables (collectively "attributes") should be **public** or **non-public**. If in doubt, choose non-public; it's easier to make it public later than to make a public attribute non-public.

# Some methods many classes have

Method	Description
<code>__eq__(self, other)</code>	Used to test if two elements are equal Two elements where <code>__eq__</code> is true must have equal <code>__hash__</code>
<code>__str__(self)</code>	Used by <code>str</code> and <code>print</code>
<code>__repr__(self)</code>	Used by <code>repr</code> , e.g. for printing to the IDE shell (usually something that is a valid Python expression for <code>eval()</code> )
<code>__len__(self)</code>	Length (integer) of object, e.g. lists, strings, tuples, sets, dictionaries
<code>__doc__</code>	The docstring of the class
<code>__hash__(self)</code>	Returns hash value (integer) of object Dictionary keys and set values must have a <code>__hash__</code> method
<code>__lt__(self, other)</code>	Comparison (less than, <code>&lt;</code> ) used by <code>sorted</code> and <code>sort()</code>
<code>__init__(self, ...)</code>	Class initializer