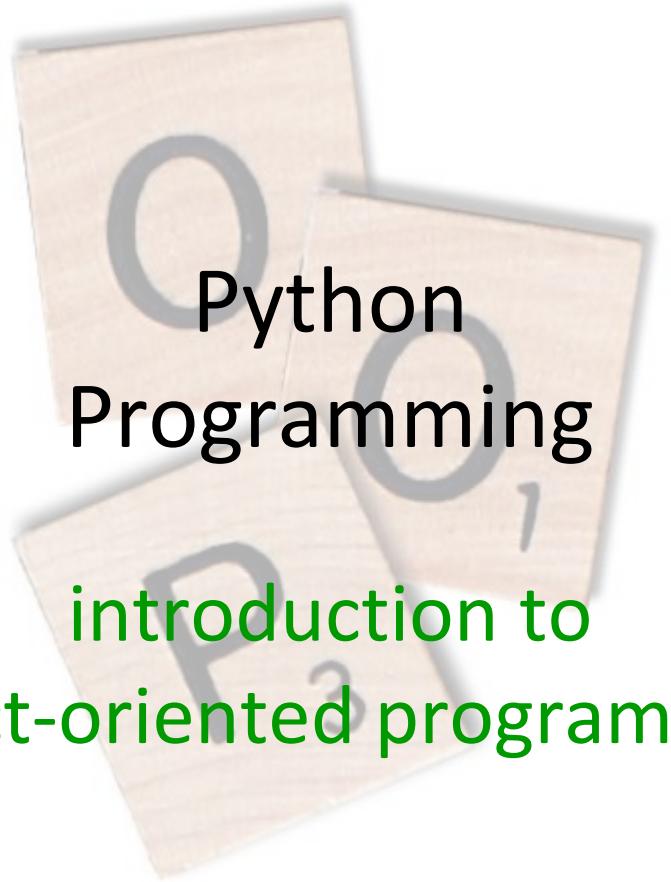
Ghent University
Faculty of Sciences



Python Programming

introduction to object-oriented programming

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@dawyndt

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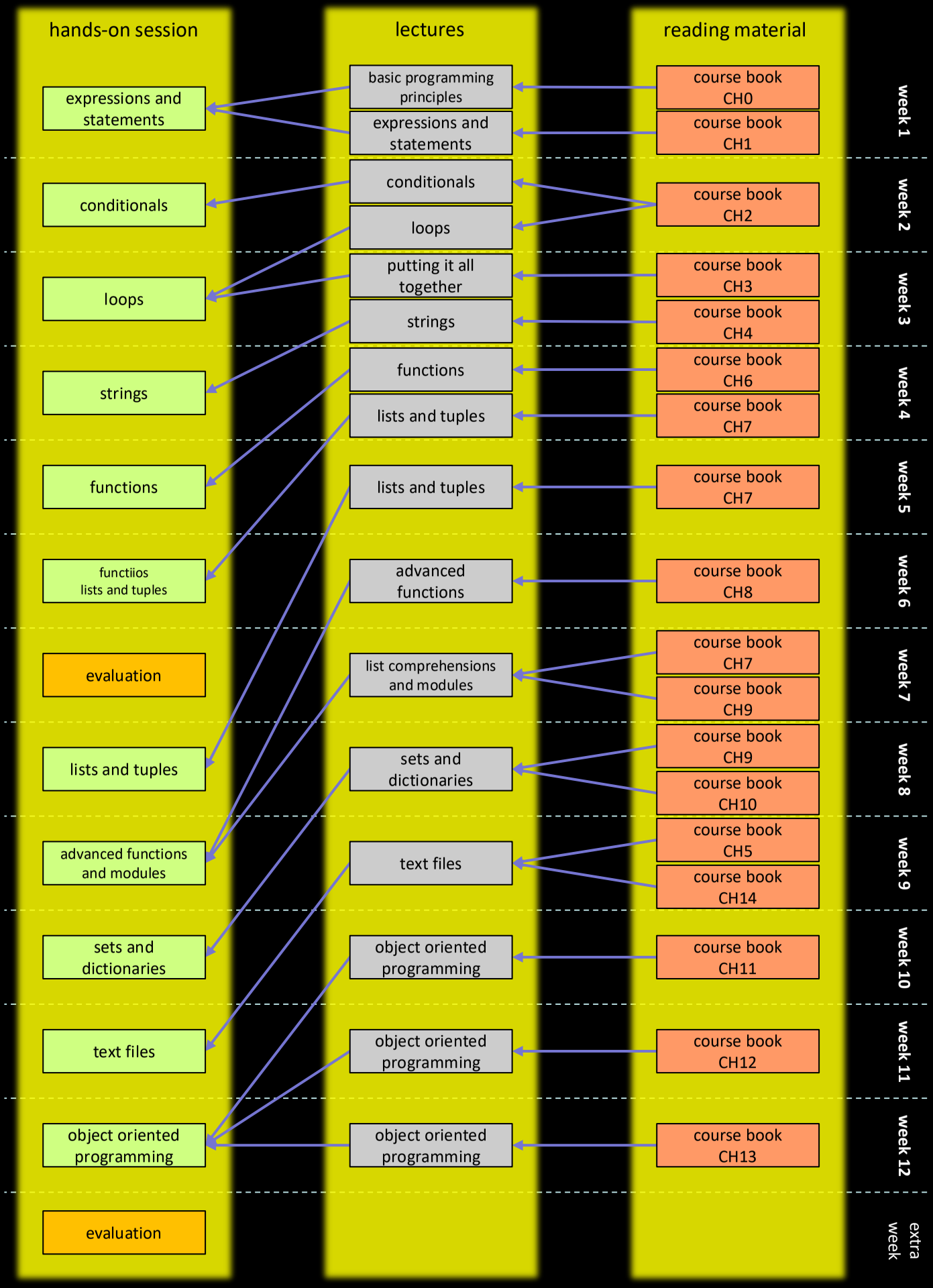
hands-on session
lectures
reading material
week 1
week 2
week 3
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week 9
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week 11
week 12
extra week
expressions and statements
conditionals
loops
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evaluation
lists and tuples
advanced functions and modules
sets and dictionaries
text files
object oriented programming
evaluation
basic programming principles
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putting it all together
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lists and tuples
advanced functions
list comprehensions and modules
sets and dictionaries
text files
object oriented programming
object oriented programming
object oriented programming
course book CH0
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course book CH13

Object-oriented programming

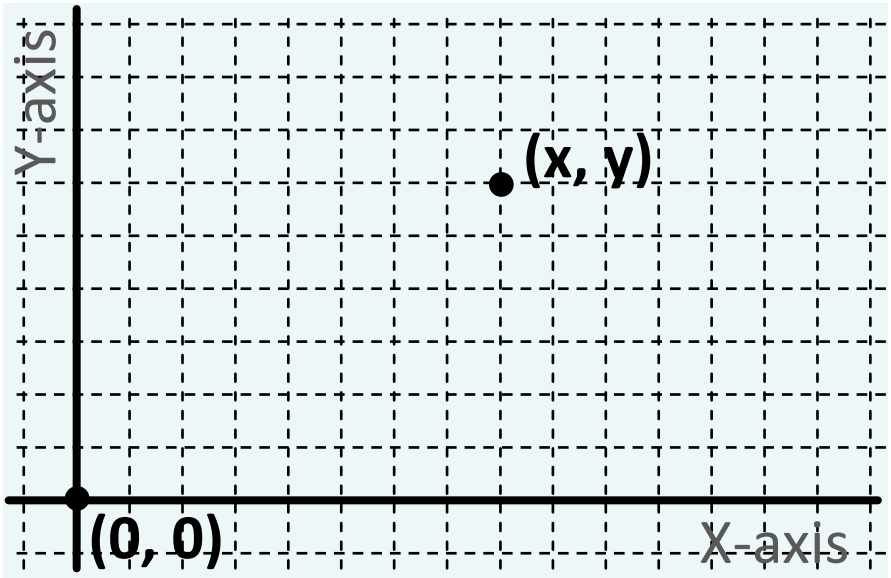
- Python is an object-oriented programming language
  - popular programming paradigm since mid 1980s
  - handles rapidly increasing size and complexity of software

create objects that bundle both data and functionality

write functions that operate on data

User-defined compound types

- **class**: defines a new (compound) data type
  - extension to built-in data types




```
class Point:
    pass
```

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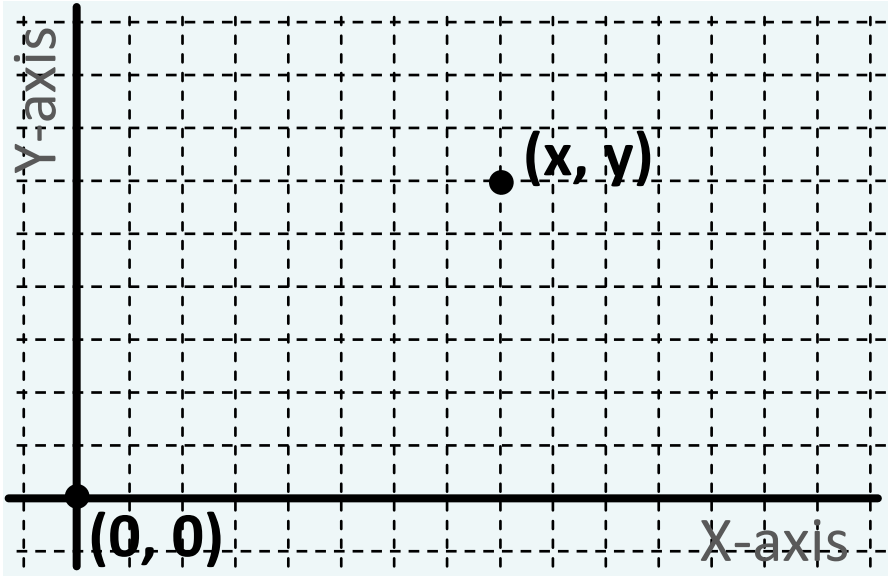
User-defined compound types

- **class**: defines a new (compound) data type
  - extension to built-in data types




```
class Point:
    '''Representation of two-dimensional points'''
```

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User-defined compound types

- **class**: defines a new (compound) data type
  - Python enables creation of *abstract data types* (ADTs)
    - "abstract" because they hide implementation details
    - programmers interact with them through a limited set of operations (*methods*), rather than by manipulating data directly (*encapsulation*)
      - fewer thing can go wrong (at least in theory)
      - resulting code is easier to read
      - makes code easier to maintain, since internals can be changed without changing calling code

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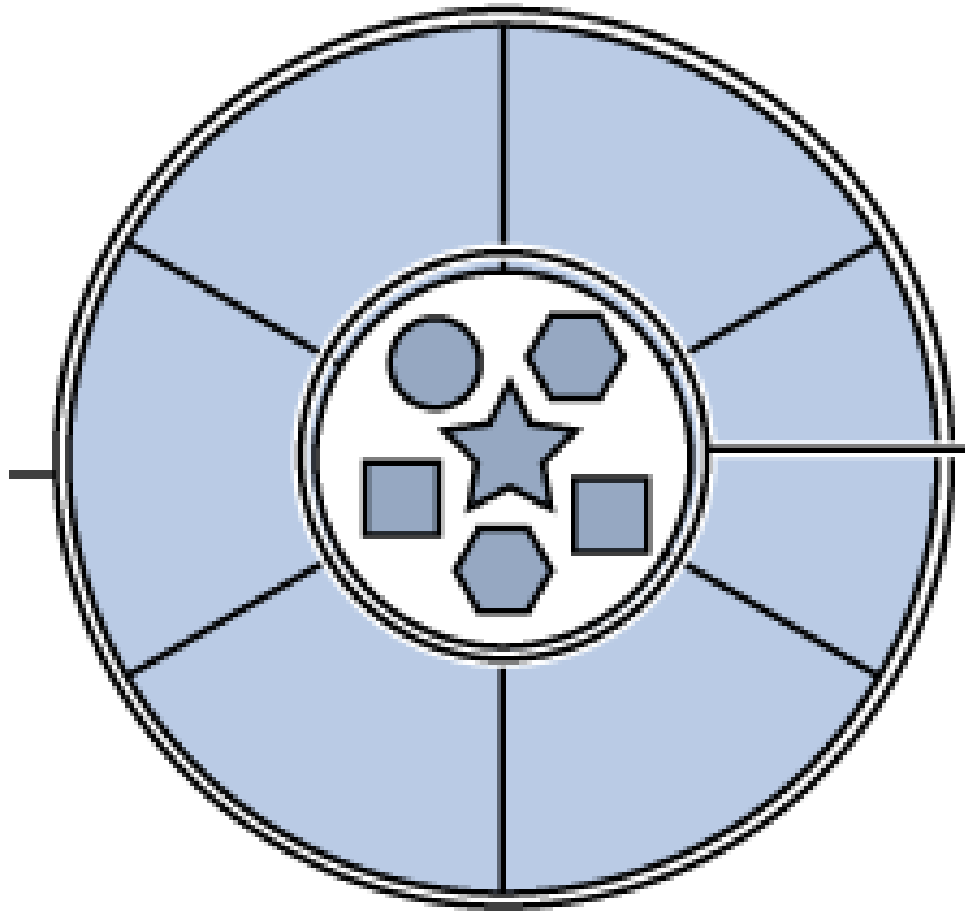
```
class Point:
    '''Representation of two-dimensional points'''
```

User-defined compound types



methods (behavior)

properties (status)

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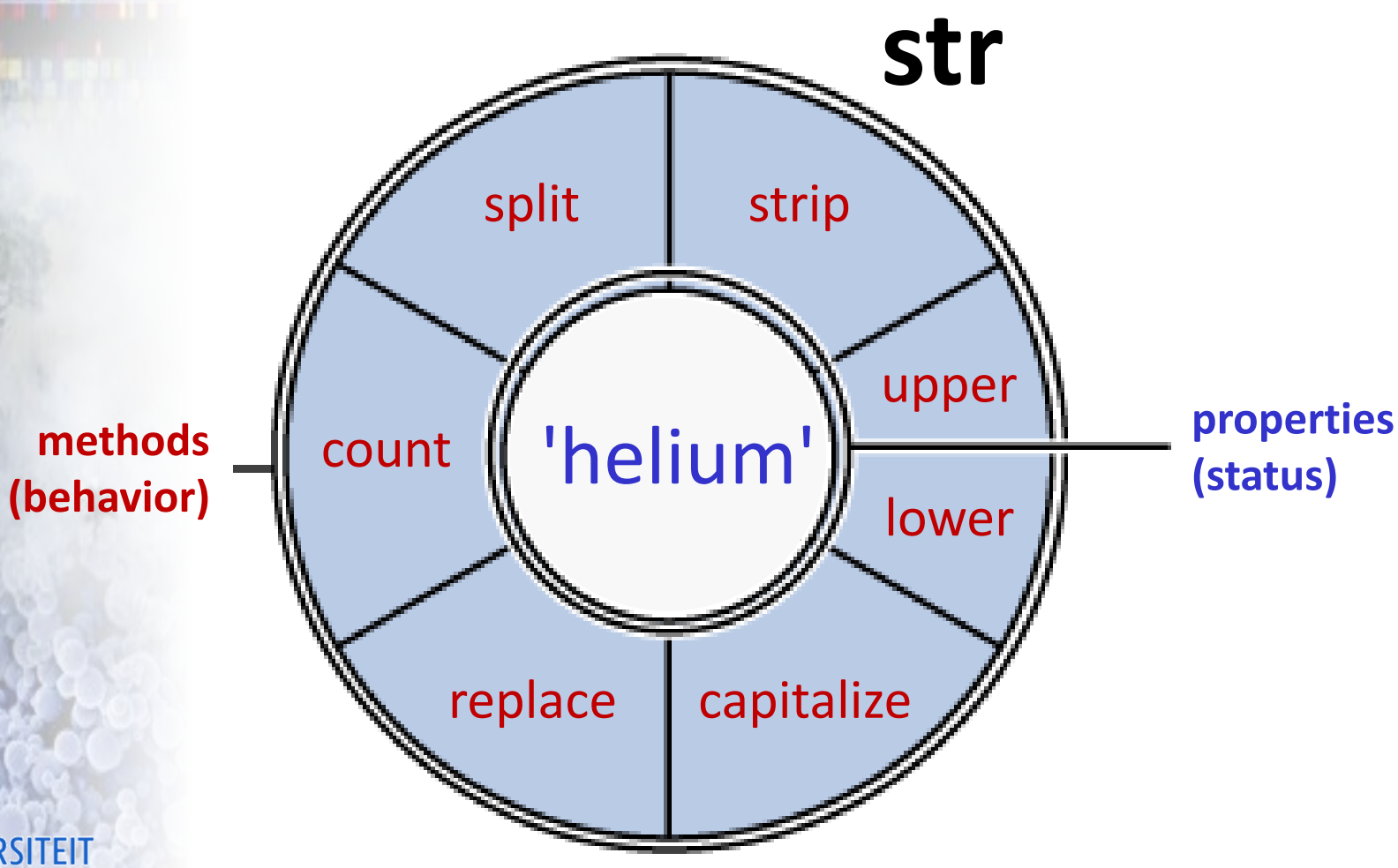
User-defined compound types



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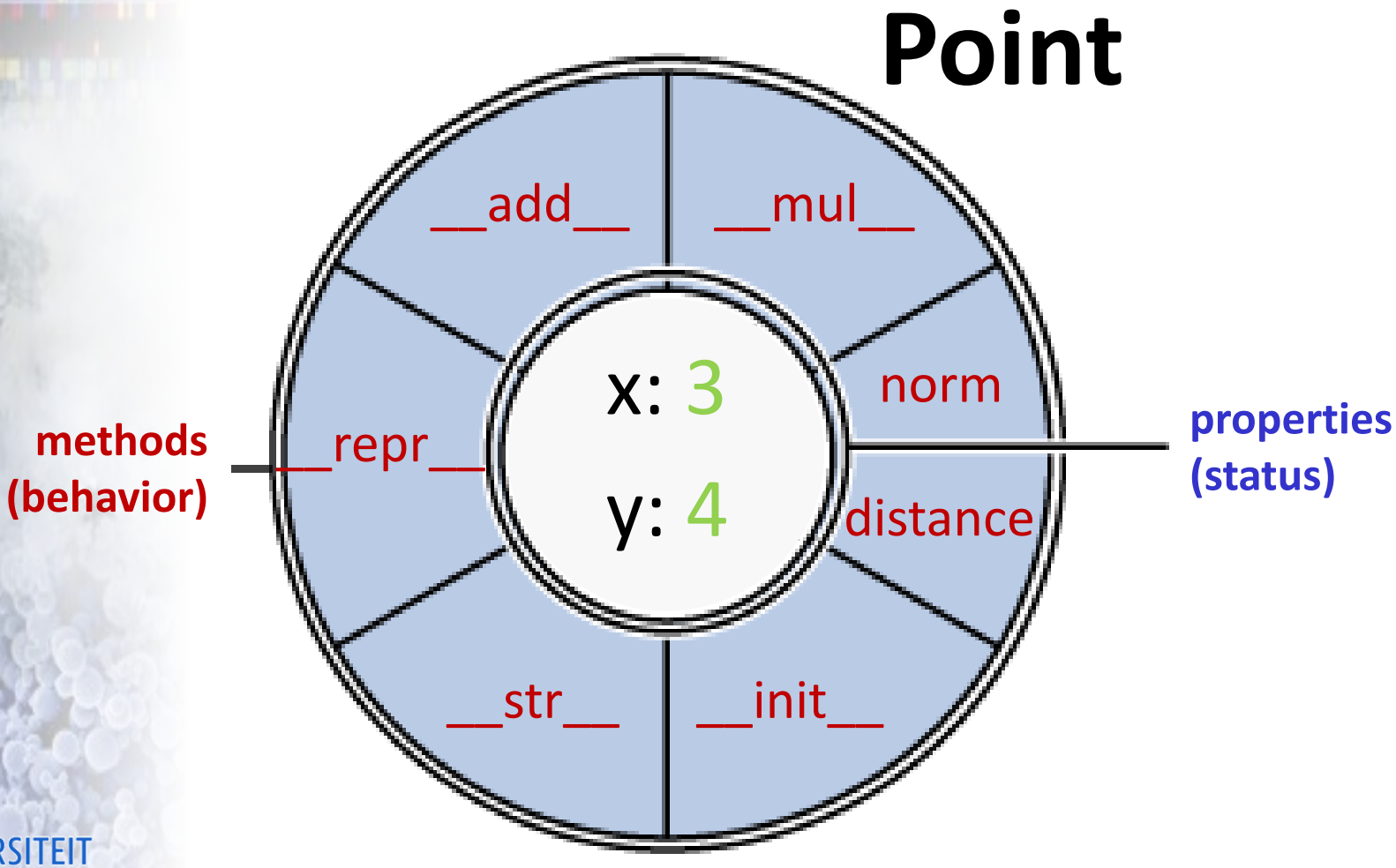
User-defined compound types



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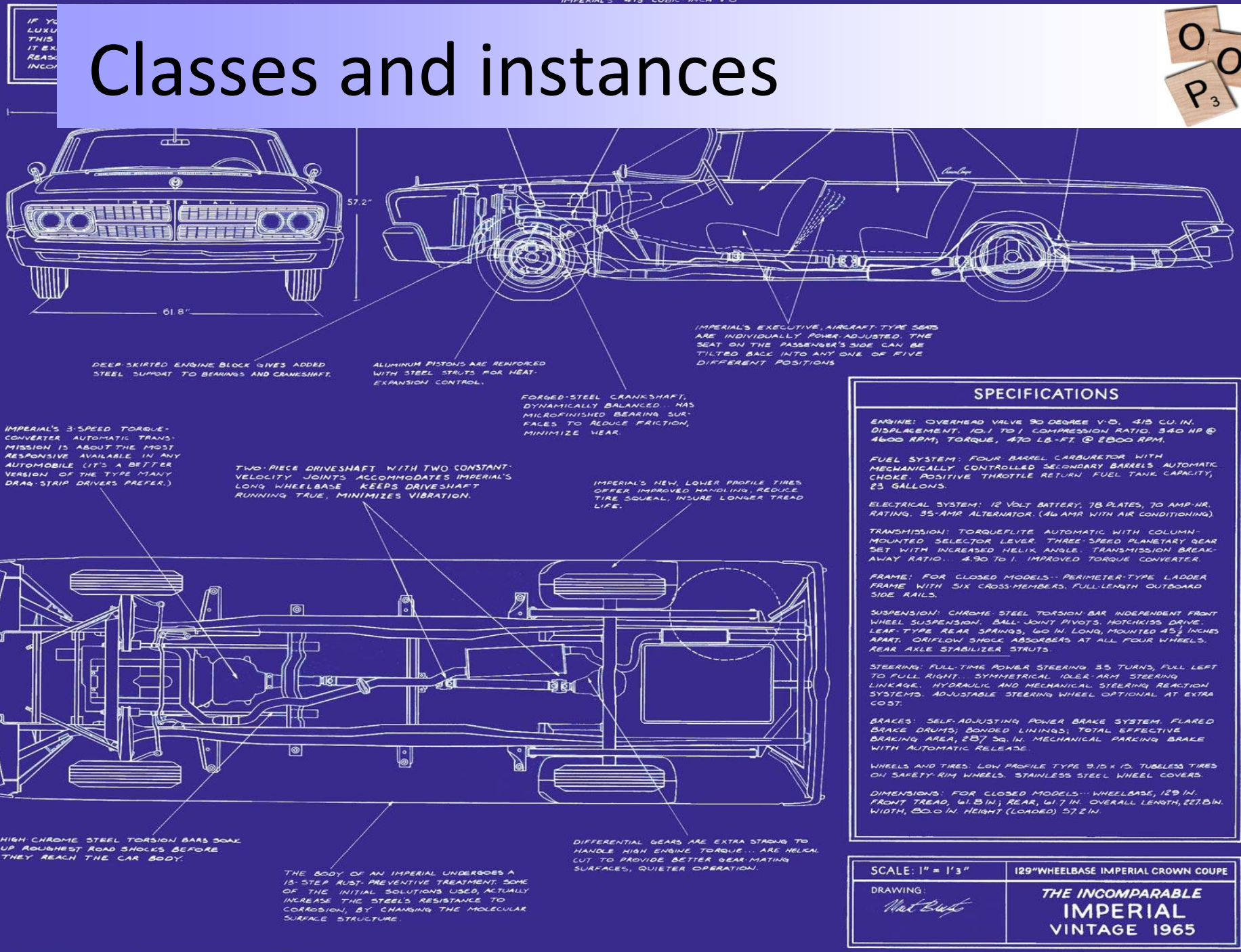
Classes and instances



Classes and instances

- ADT usually created by defining a *class* that specifies
  - how it stores state (*properties*)
  - what it can do (*methods*)
  - classes are also objects themselves, just like functions
- *objects* are created as *instances* of a class
  - each object of a particular ADT shares the class's methods, but usually has its own properties
  - changes to one object thus do not affect the state of others

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```
class Point:
    '''Representation of two-dimensional points'''
```

Classes and instances

- class **`Point`** defines a new data type: **`Point`**
  - *instantiation*: creating a new instance of a class
    - done by calling the class name as if it were a function
    - classes are *callable* just like functions
  - members of a data type: *instances* or *objects*

```
>>> class Point:
...     pass
...
>>> type(Point)
<class 'type'>
>>> p = Point()
>>> type(p)
<class '__main__.Point'>
```

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Classes and instances

- think of a class as a blueprint for making objects
  - s **`Point`** is a factory for making points
  - cl s **`Point`** isn't an instance of a point, but it
    he machinery to make point instances


```
>>> class Point:
...     pass
...
>>> type(Point)
<class 'type'>
>>> p = Point()
>>> type(p)
<class '__main__.Point'>
```

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Properties

- object instances both have state and behavior
  - attributes of an instance determine its state
  - instances have their own *namespace* (just like modules)
  - *attribute*: name in namespace (instances and modules)
    - use *dot notation* to access name from namespace
    - similar to module syntax: **`math.pi`**, **`string.uppercase`**

```
>>> class Point:
...     pass
...
>>> p = Point()
>>> p.x = 3
>>> p.y = 4
```

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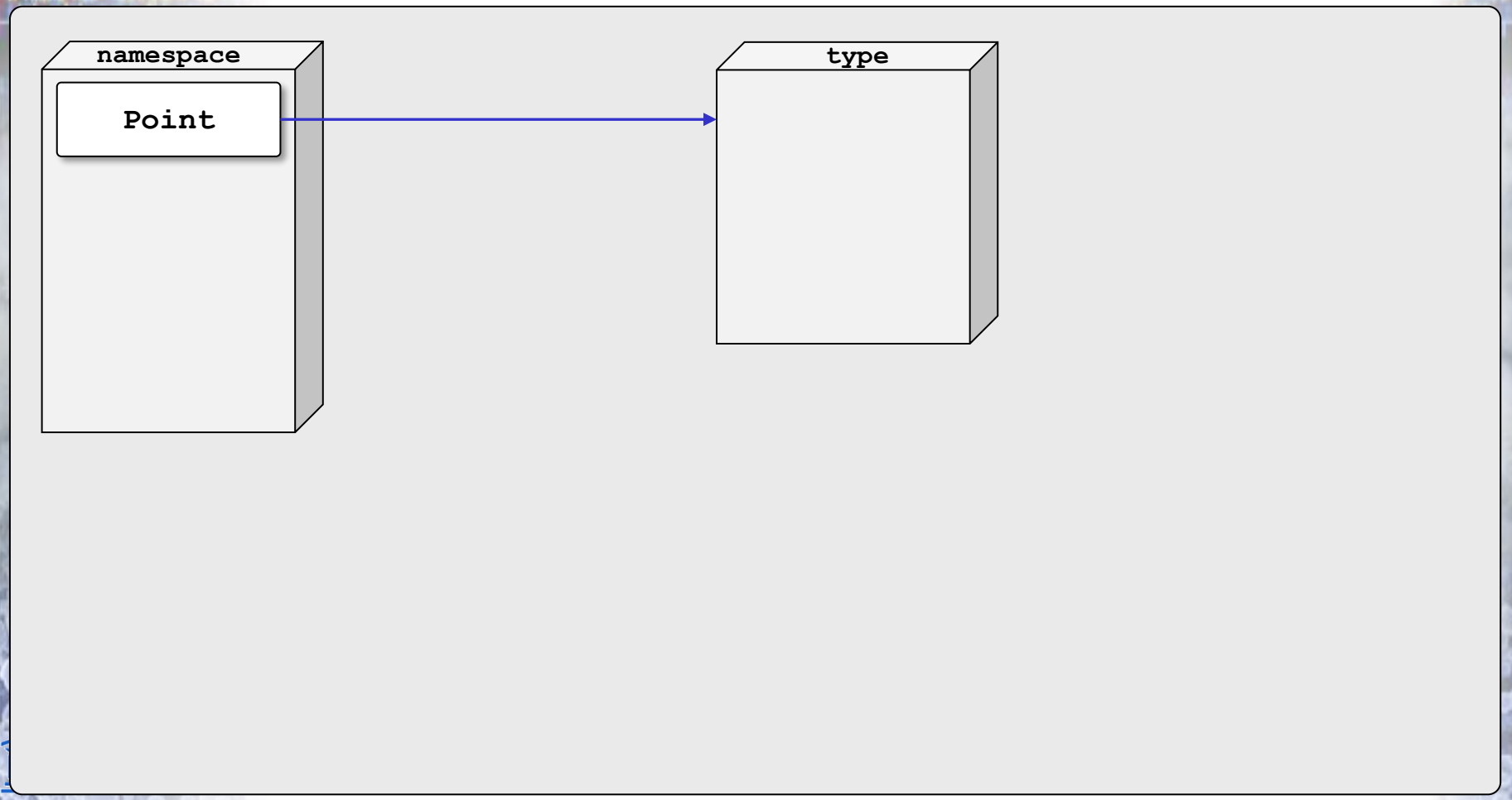
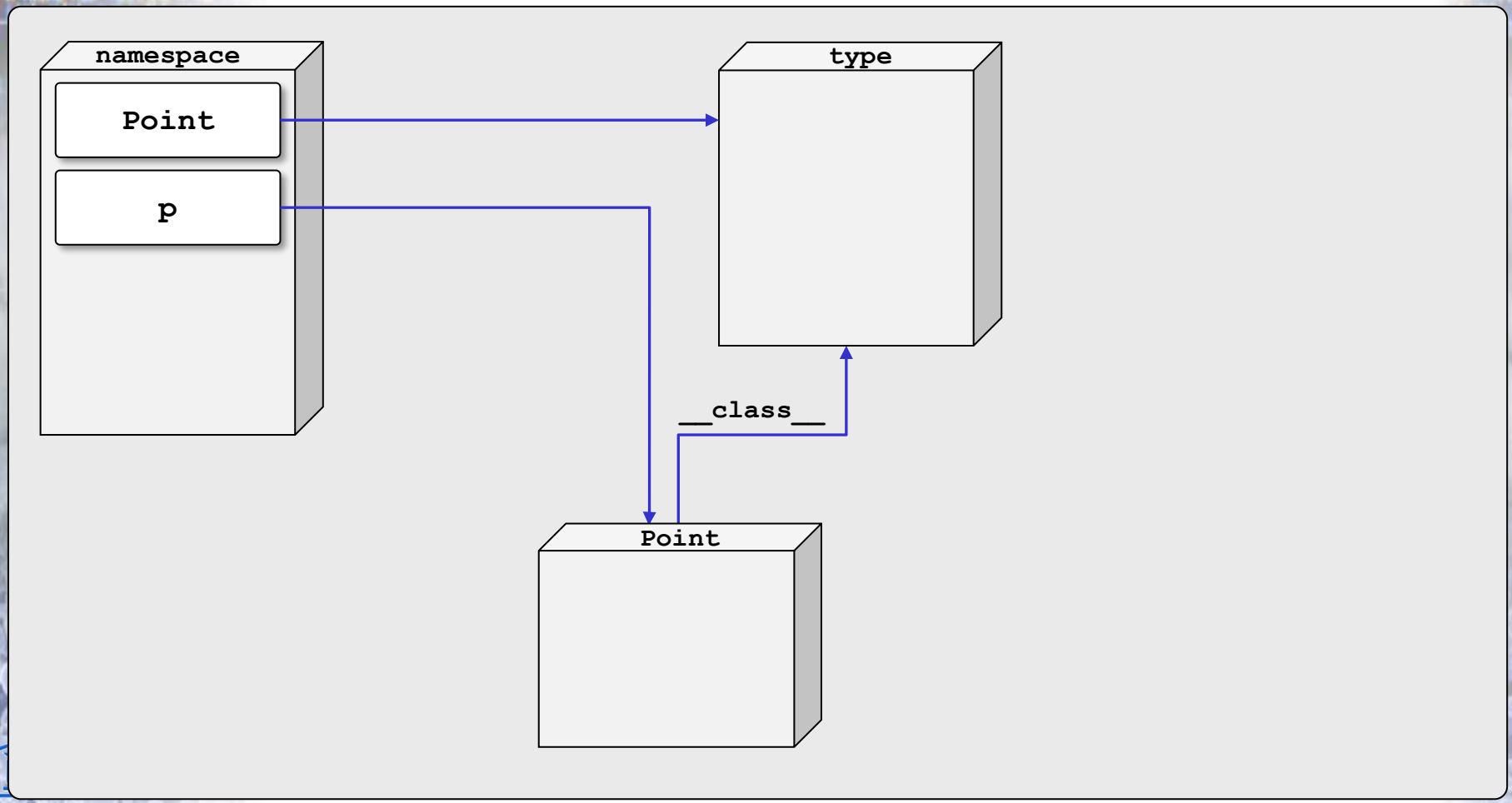
Properties



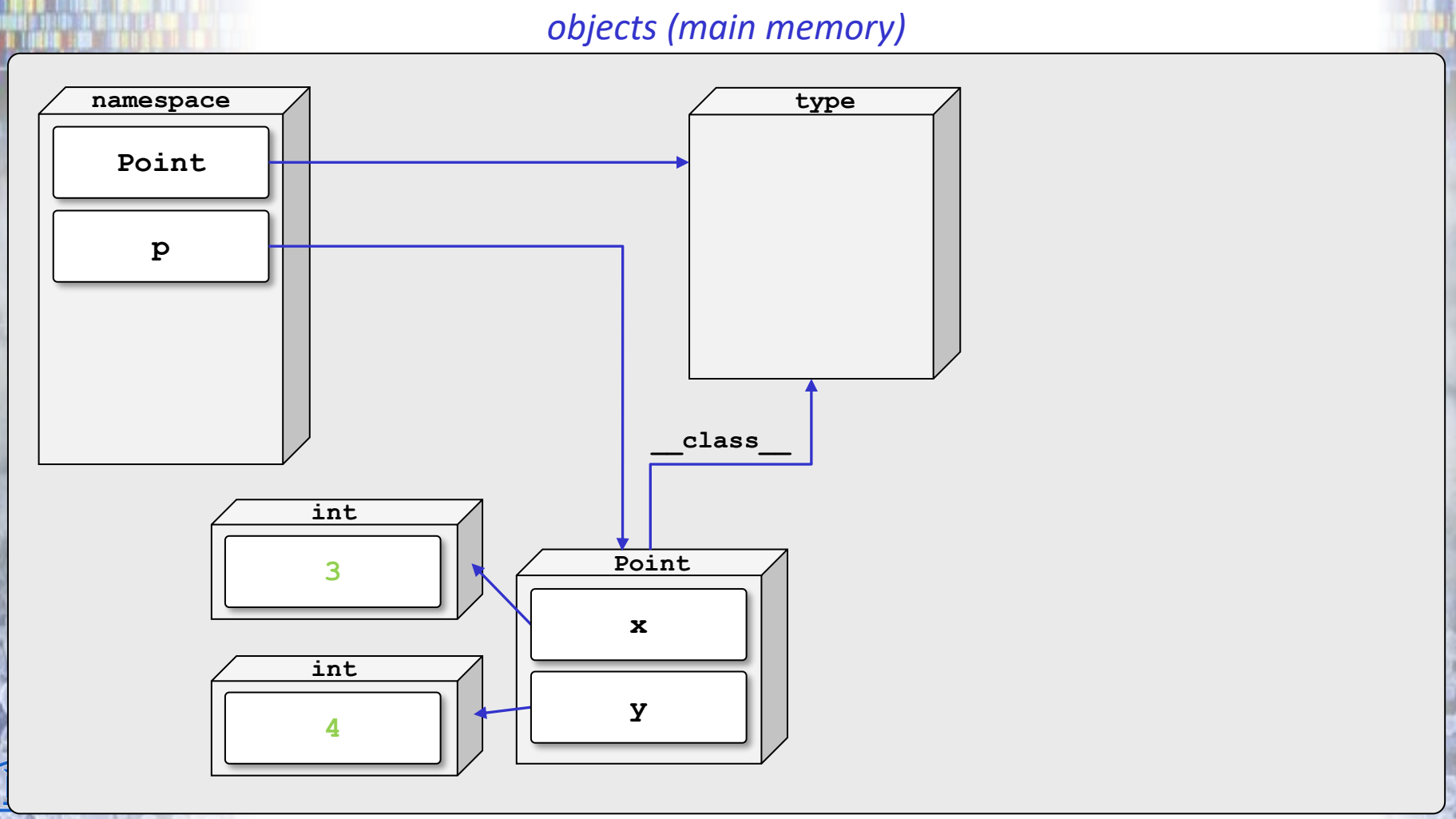

```
>>> class Point: pass
```

Properties




```
>>> p = Point()
```

Properties




```
>>> p.x, p.y = 3, 4
```

Properties


```
>>> class Point:
...     pass
...
>>> p = Point()
>>> p.x = 3
>>> p.y = 4
>>> p.y
4
>>> x = p.x
```

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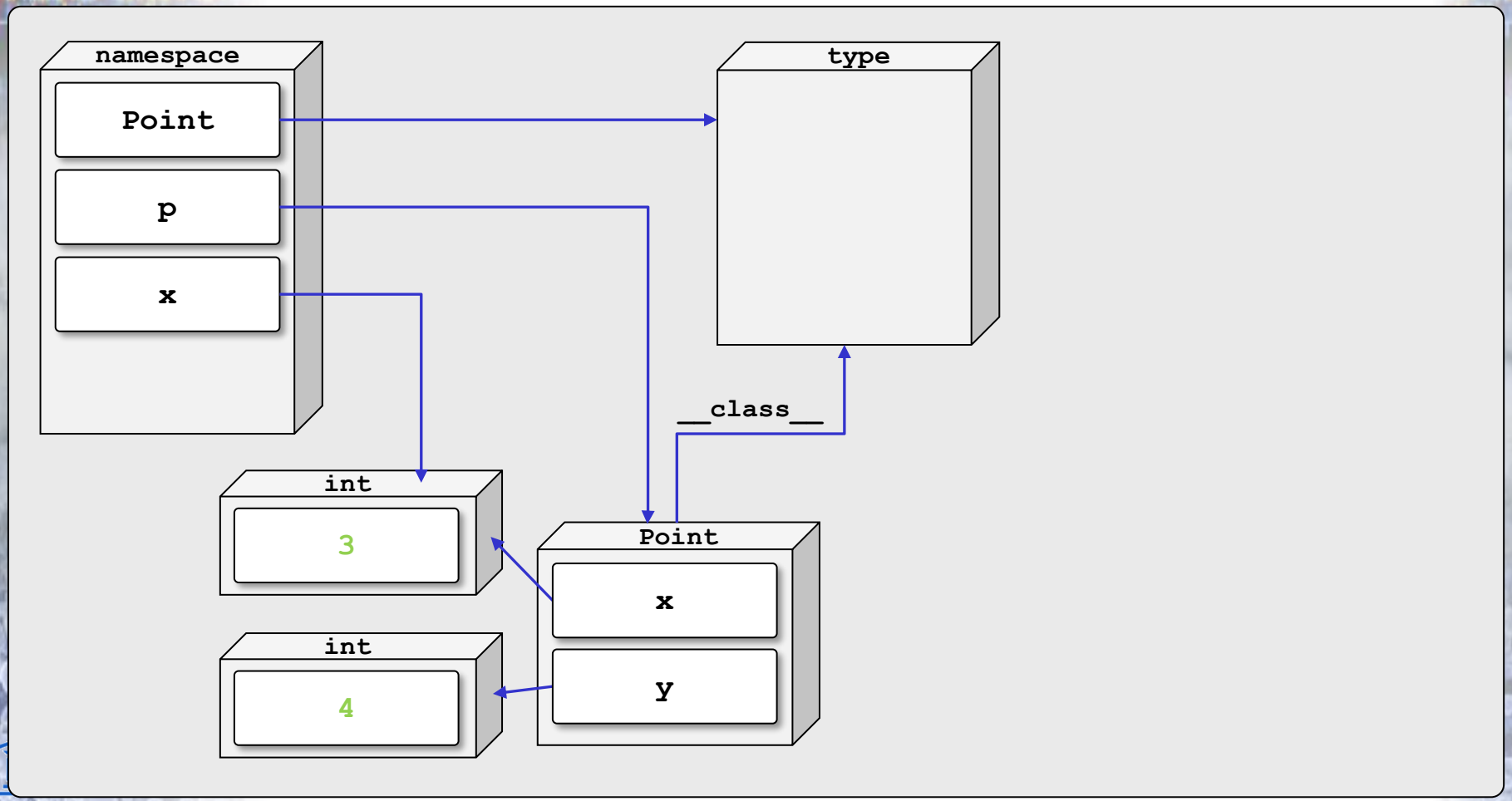
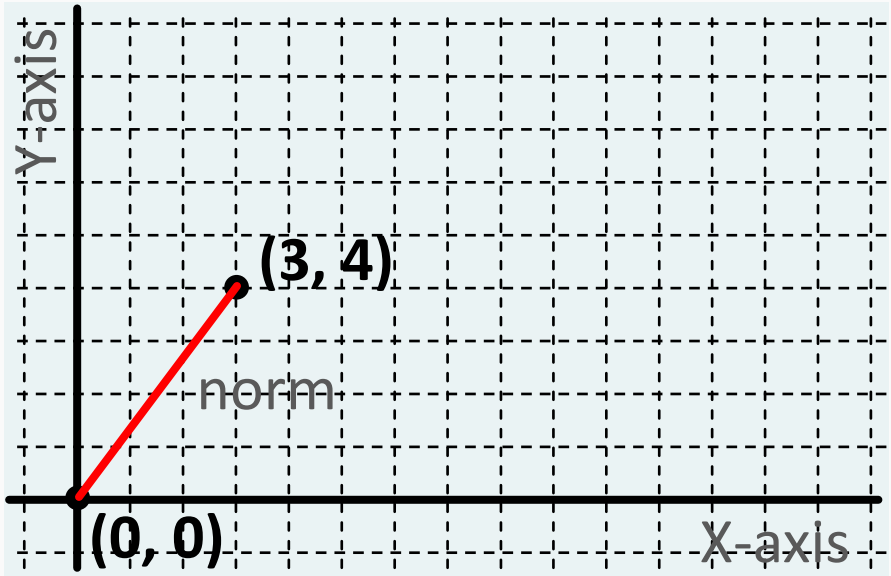
Properties




```
>>> x = p.x
```

Properties


```
>>> class Point:
...     pass
...
>>> p = Point()
>>> p.x = 3
>>> p.y = 4
>>> p.y
4
>>> x = p.x
>>> x
3
>>> print(f'({p.x:.2f}, {p.y:.2f})')
(3.00, 4.00)
>>> norm = (p.x ** 2 + p.y ** 2) ** 0.5
>>> norm
5.0
```



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Methods

- give a class methods by defining functions inside of it
  - object itself is always passed to the method as its first argument
    - universally called **`self`**
    - unlike **`this`** in C++ and Java, the name is just a convention
    - but everyone uses it, and you should too

```
>>> class Point:
...     def norm(self):
...         return (self.x**2 + self.y**2) ** 0.5
...
>>> p = Point()
```

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Methods

- give a class methods by defining functions inside of it
  - calling methods: **`object.method(arguments)`**
    - finds the class **`C`** that **`object`** is an instance of
    - then calls **`C.method(object, arguments)`**

```
>>> class Point:
...     def norm(self):
...         return (self.x**2 + self.y**2) ** 0.5
...
>>> p = Point()
>>> p.x, p.y = 3, 4
>>> p.norm()
5.0
>>> Point.norm(p)
5.0
```

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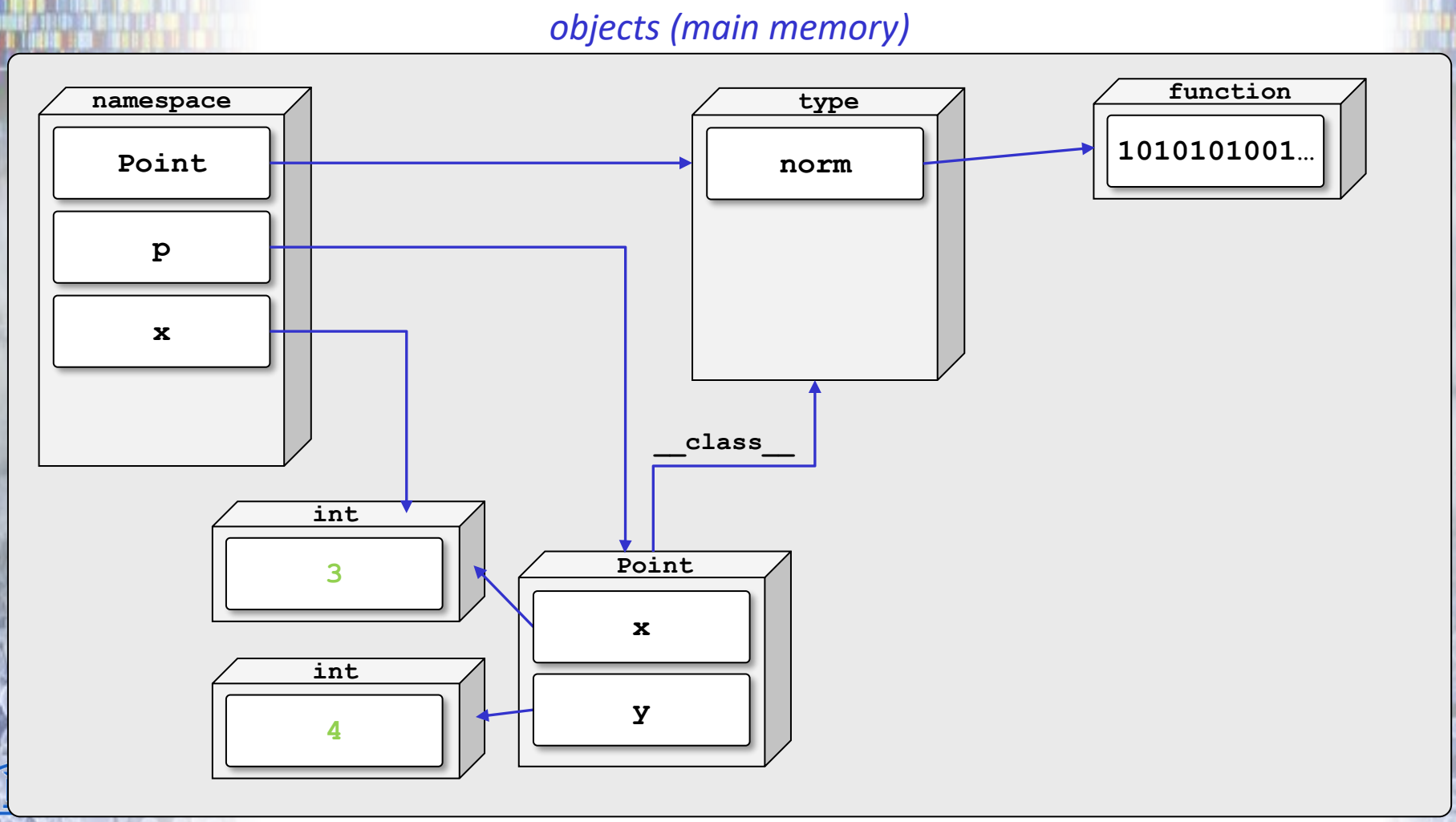
Methods



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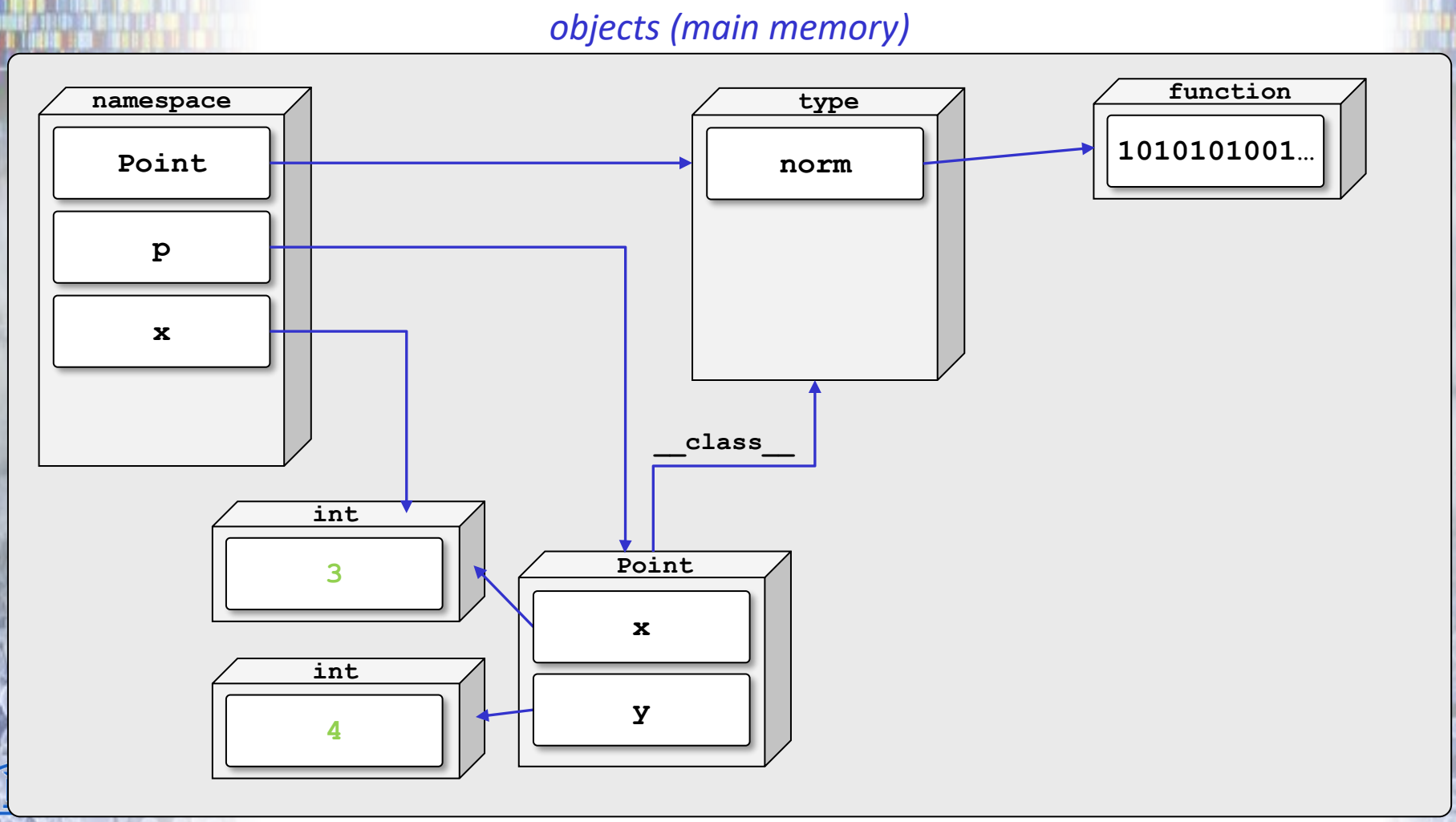
```
>>> p.norm()
```

Methods




```
>>> Point.norm(p)
```

The initialisation method

- class **`Point`** intends to represent two-dimensional points
  - *all* point instances ought to have **`x`** and **`y`** attributes

```
>>> p2 = Point()
>>> p2.x
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: Point instance has no attribute 'x'
```

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The initialisation method

- class **`Point`** intends to represent two-dimensional points
  - *all* point instances ought to have **`x`** and **`y`** attributes
  - initialisation method **`__init__`** initialises **`Point`** objects
    - called automatically when the class is called (*instantiation*)
    - for that reason it is sometimes named the *constructor*
    - analogy: **`list()`** constructs a list, **`str()`** constructs a string

point1.py

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def norm(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5
```

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The initialisation method


```
>>> from point1 import Point
>>> p = Point(3, 4)
>>> p.x
3
>>> p.y
4
>>> p.norm()
5.0
>>> x = p.x
>>> q = Point(9, 2)
>>> q.x
9
>>> q.y
2
>>> q.norm()
9.219544572928871
```

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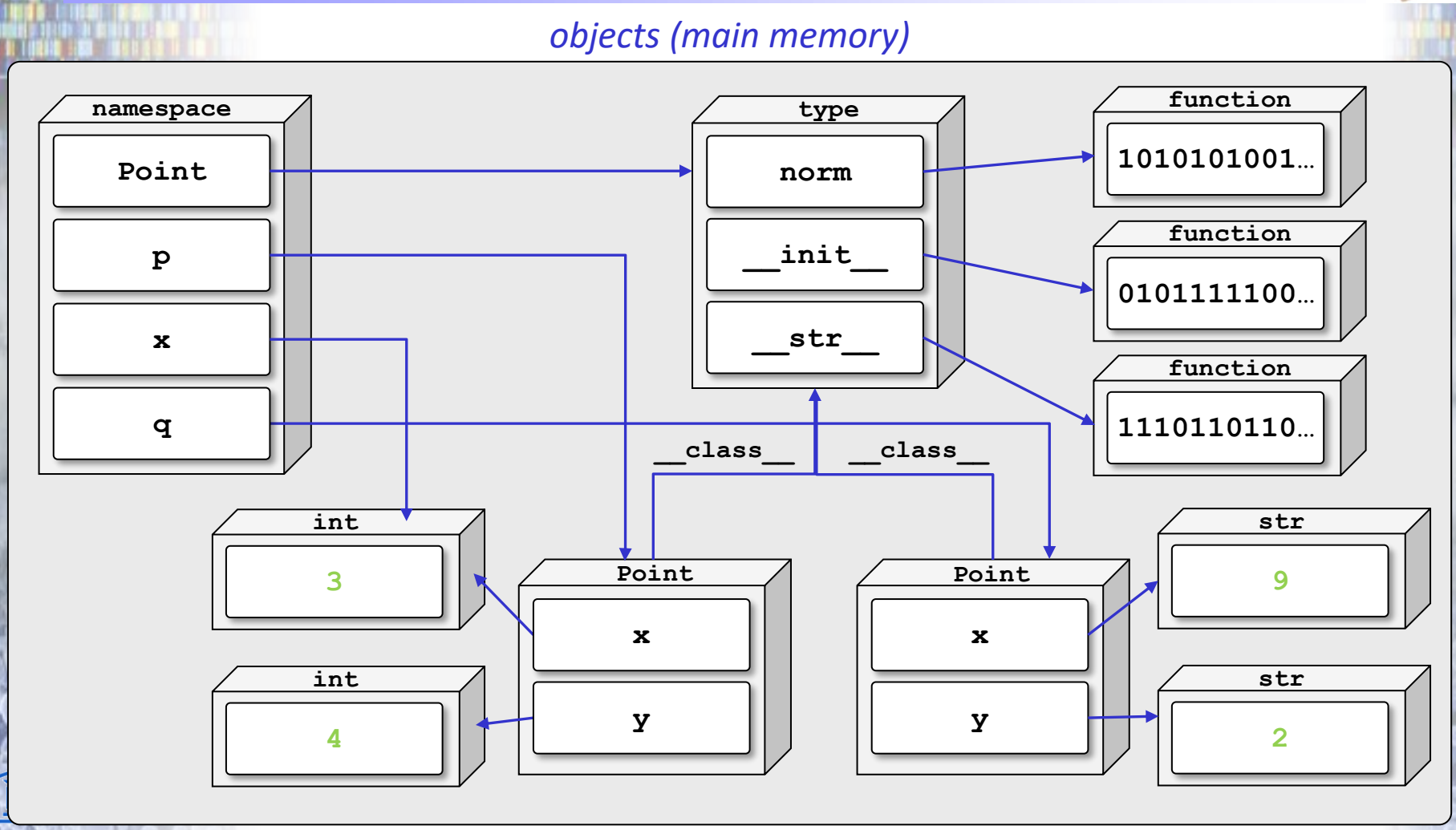
The initialisation method




```
>>> p, q = Point(3, 4), Point(9, 2)
```

Instances as parameters

- an object can be passed as an argument to a function in the usual way

```
>>> p, q = Point(3, 4), Point(9, 2)
>>> def display(p):
...     print(f'({p.x:.2f}, {p.y:.2f})')
>>> display(p)
(3.00, 4.00)
>>> def vectorsum(p1, p2):
...     return Point(p1.x + p2.x, p1.y + p2.y)
```

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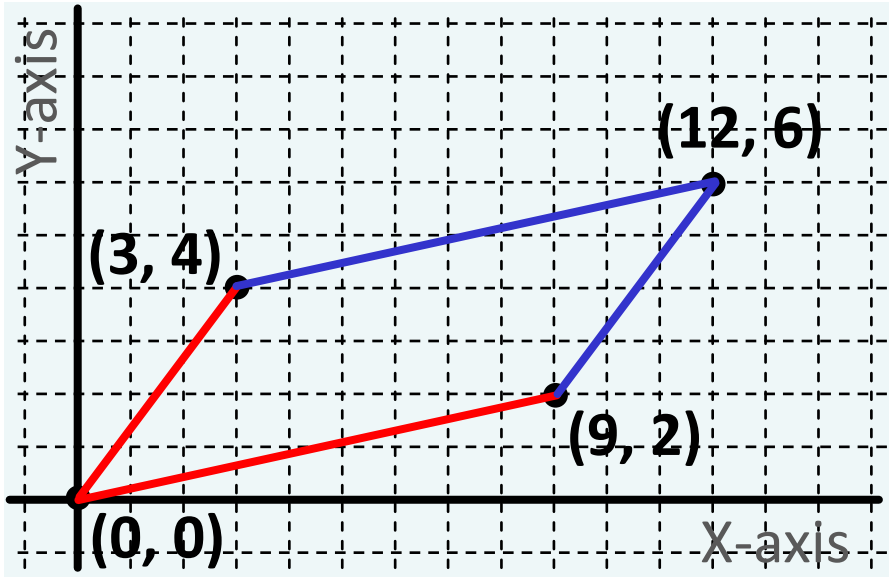
Instances as parameters




```
>>> def vectorsum(p1, p2):
...     return Point(p1.x + p2.x, p1.y + p2.y)
```

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Instances as parameters

- an object can be passed as an argument to a function in the usual way

```
>>> p, q = Point(3, 4), Point(9, 2)
>>> def display(p):
...     print(f'({p.x}, {p.y})')
>>> display(p)
(3.00, 4.00)
>>> def vectorsum(p1, p2):
...     return Point(p1.x + p2.x, p1.y + p2.y)
>>> r = vectorsum(p, q)
>>> isinstance(r, Point)
True
>>> display(r)
(12.00, 6.00)
```

Operator overloading

Operator overloading

- methods behave like functions, but
  - methods are defined inside class definitions
    - explicit relationship between class and method
  - syntax used to call methods differs from syntax use to call functions

point1.py

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def norm(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5
```

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Operator overloading


```
>>> from point2 import Point
>>> p, q = Point(3, 4), Point(9, 2)
>>> p.display()
'(3, 4)'
>>> r = p.vectorsum(q)
>>> r.display()
'(12, 6)'
```

point2.py

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def norm(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5

    def display(self):
        return f'({self.x:.2f}, {self.y:.2f})'

    def vectorsum(self, other):
        return Point(self.x + other.x, self.y + other.y)
```

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Operator overloading

- built-in functions and operators applied to object **o** are automatically forwarded to method calls on class **C**
  - **str(o) → C.__str__(o)**
    - returns string representation of object **o**
    - **str** function is called implicitly by **print** function
  - **repr(o) → C.__repr__(o)**
    - returns "internal" string representation of object **o**
  - **len(o) → C.__len__(o)**
  - **o + o2 → C.__add__(o, o2)**
  - **o * o2 → C.__mul__(o, o2)**

```
class C: pass
o = C()
```

Operator overloading


```
>>> from point3 import Point
>>> p, q = Point(3, 4), Point(9, 2)
>>> p
Point(3, 4)
>>> r = p + q
>>> print(r)
(12.00, 6.00)
```

point3.py

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y
    def norm(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5
    def __str__(self):
        return f'({self.x:.2f}, {self.y:.2f})'
    def __repr__(self):
        return f'Point({self.x}, {self.y})'
    def __add__(self, other):
        return Point(self.x + other.x, self.y + other.y)
```

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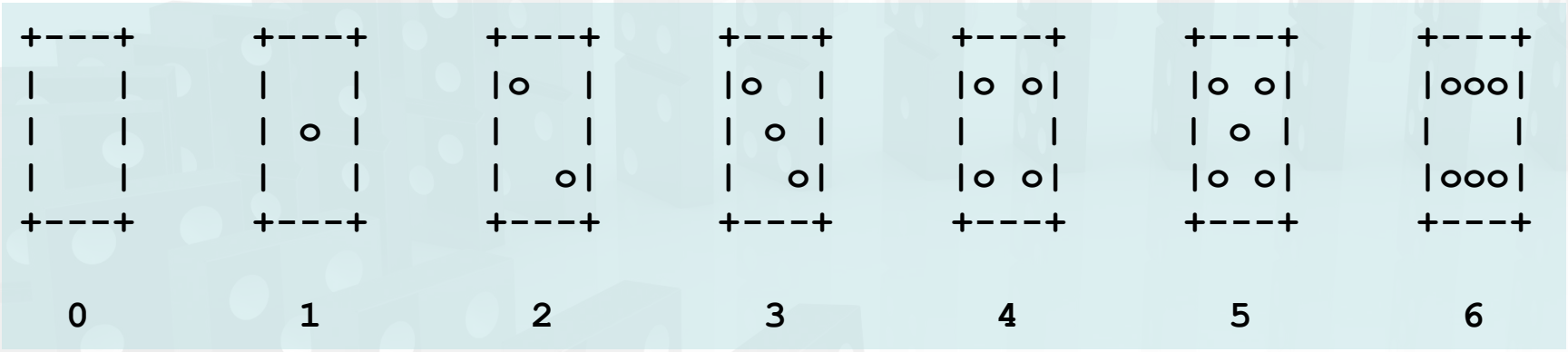
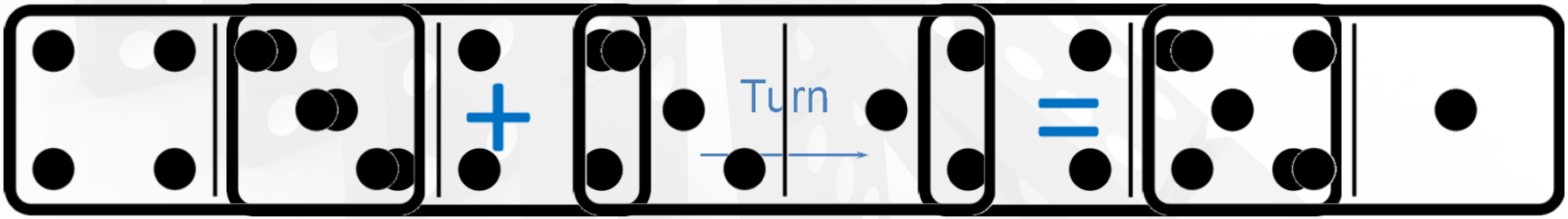
Domino tiles





Roman numerals

I = 1
II = 2
III = 3
IV = 4
V = 5
VI = 6
VII = 7
VIII = 8
IX = 9
X = 10

XL = 40
L = 50
LX = 60
LXX = 70
LXXX = 80
XC = 90
C = 100
D = 500
M = 1000

Classes: 'new style' vs 'old style'

- Python 2.x
  - differentiates between 'new style' and 'old style' classes
  - most differences are in advanced (technical) details

```
class Point:
    pass
```
old style

```
class Point(object):
    pass
```
new style

- Python 3.x
  - no difference between 'new style' and 'old style' classes

```
class Point:
    pass
```
new style

```
class Point(object):
    pass
```
new style

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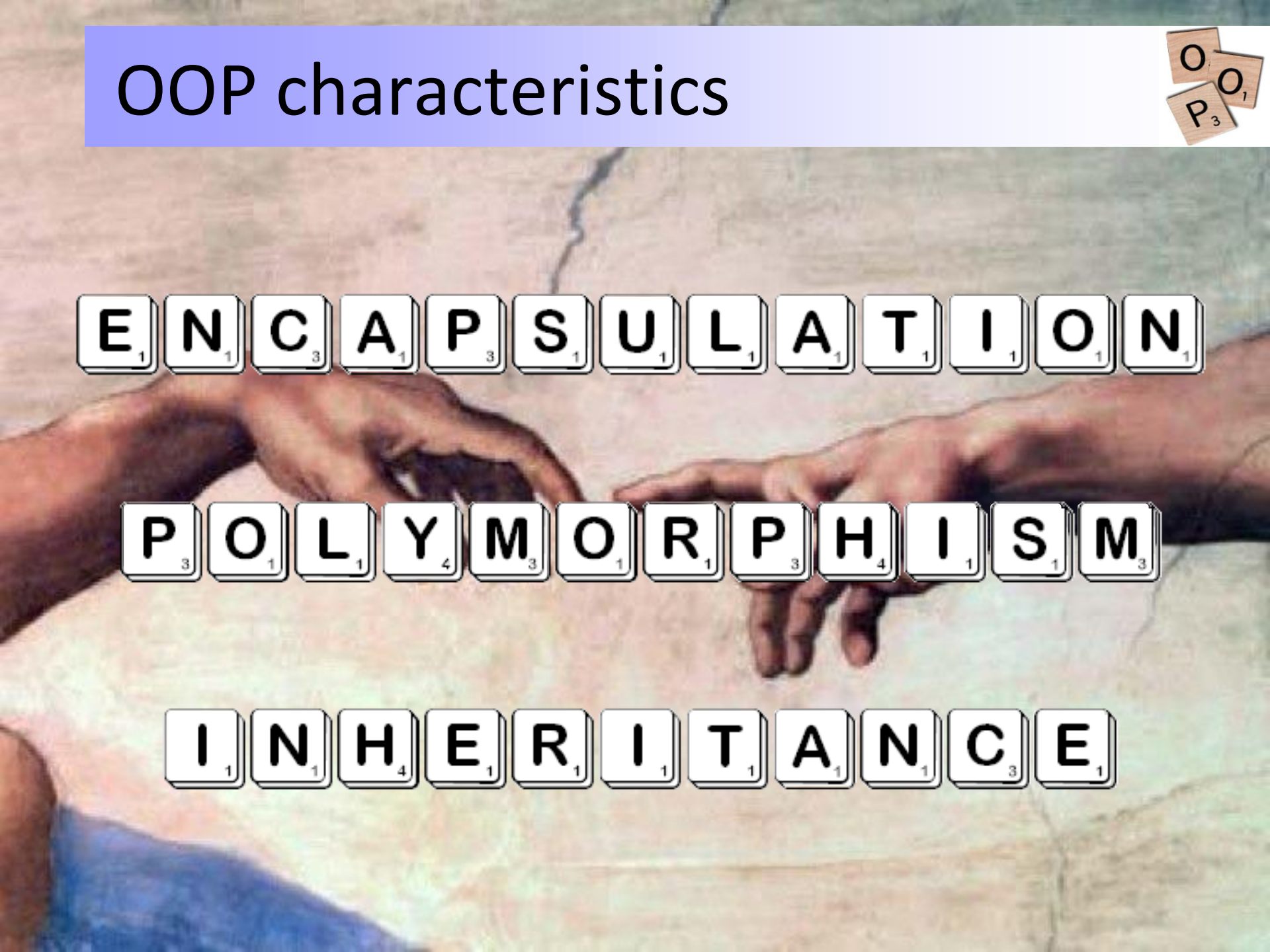
OOP characteristics



Homework (next lecture)

- course book
  - read chapter 12 (more on classes)
  - read chapter 13 (OOP development)
  - pay attention in particular to OOP terminology
- classroom exercises (series 10)
  - Roman numerals
  - Immune system

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Homework (hands-on sessions)

- mandatory exercises series 10 (OOP)
  - deadline: Tuesday, December 17, 2024
- second evaluation
  - Monday, December 16, 2024 (14:30-16:45)
  - Tuesday, December 17, 2024 (10:00-12:15)
  - register via Ufora groups

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Questions or remarks?

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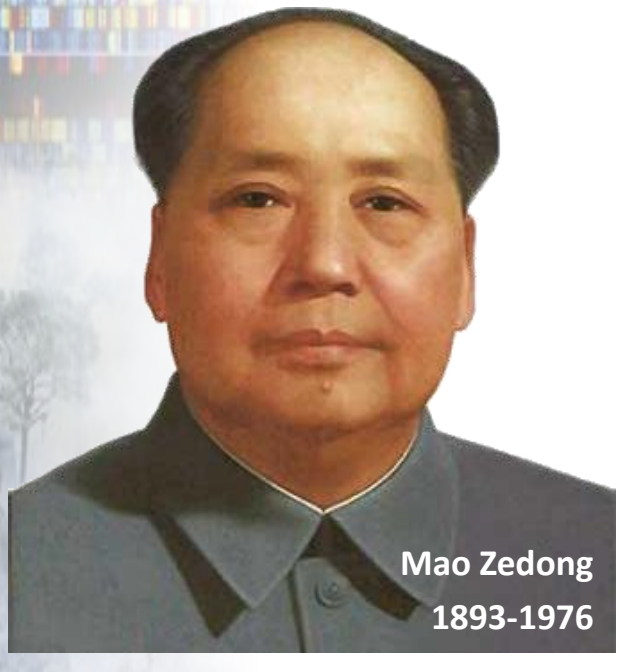
The sky is the limit …



"Classes struggle,
some classes triumph,
others are eliminated."

— Mao Zedong

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