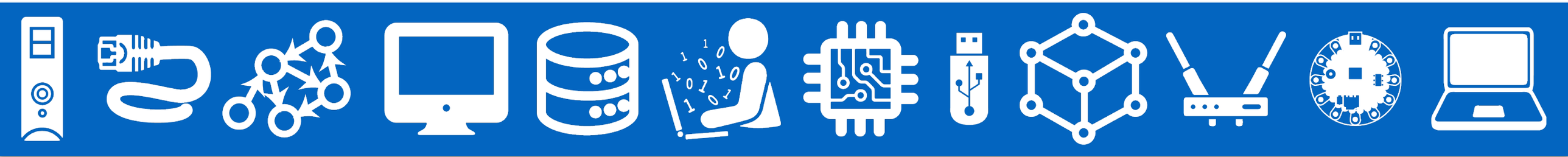
CS134:
Inheritance & sorted(..)



Announcements & Logistics

- **HW 8** due Monday (on Gradescope)
- **Lab 8** is a **partner lab : *autocomplete***
  - No prelab but do **read the handout** before arriving
  - Working with three classes, each in their own files
    - Good idea to use pencil/paper and map out the different attributes and methods
- Looking ahead: Lab 9 will be an implementation of the game **Boggle**
  - Brings together all OOP concepts, and we get to "build" a game

Do You Have Any Questions?

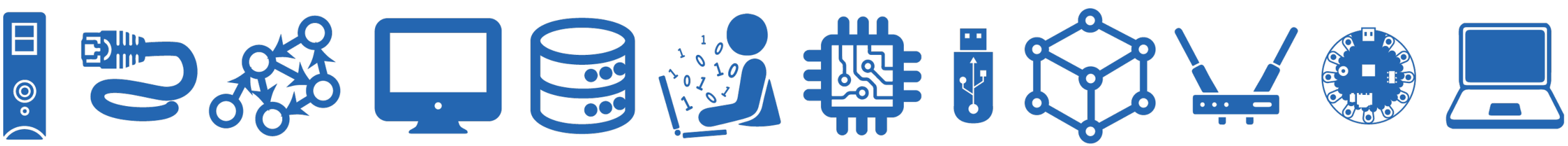
Last Time

- Built the Book **class** to represents book objects
- Learned about **private**, **protected**, **public** attributes and methods (indicate scope using underscores in Python)
- Explored **accessor** (getter) and **mutator** (setter) methods in Python
- Talked about `__init__` (aka constructor) and `__str__` methods

Today's Plan

- Design a Library class that stores a sorted shelf of Book objects
- Tools we need:
  - `sorted()` function in Python (with optional parameter `key`)
  - requires us to *pass a function* as a ***parameter***
  - first time using *optional* arguments in function/method calls
- We'll also review some useful string methods, including:
  - `s.split(), s.join(), s.format()`

Detour: Built-in `sorted()` function



sorted( )

- `sorted()` is a built-in Python function (not a method!) that takes a sequence (string, list, tuple) and returns a ***new sorted sequence as a list***
- By default, `sorted()` sorts the sequence in **ascending order** (for numbers) and alphabetical order for strings
- `sorted()` ***does not alter the sequence*** it is called on and always returns the type `list`

```
>>> nums = {42, -20, 13, 10, 0, 11, 18} # set of ints
>>> sorted(nums) # this returns a list!
[-20, 0, 10, 11, 13, 18, 42]
>>> letters = ['a', 'c', 'z', 'b', 'Z', ‘A']
>>> sorted(letters)
['A', 'Z', 'a', 'b', 'c', 'z']
```

Changing the Default Sorting Behavior

- To better understand the `sorted()` function, look at documentation

```
help(sorted)
```

```
Help on built-in function sorted in module builtins:

sorted(iterable, /, *, key=None, reverse=False)
    Return a new list containing all items from the iterable in ascending order.

    A custom key function can be supplied to customize the sort order, and the
    reverse flag can be set to request the result in descending order.
```

- An ***iterable*** is any object over which we can iterate (list, string, tuple, range)
- The optional parameter **key** specifies a function or method that determines how each element should be compared to other elements
- The optional boolean parameter **reverse** (which by default is set to **False**) allows us to sort in reverse order

Reverse Sorting Example

- Let's consider the optional `reverse` parameter to `sorted()`
- Sort sequences in reverse order by setting this parameter to be True

```
>>> nums = [42, -20, 13, 10, 0, 11, 18]
>>> sorted(nums, reverse=True)
[42, 18, 13, 11, 10, 0, -20]
```

Sorting with a **key** function

- Suppose we want to sort a data type based on our own criteria
- Example: A list of **course lists**, where the first item is the course name, second item is the enrollment capacity, and third item is the term (Fall/Spring).

```
courses = [['CS134',   90, 'Spring'], ['CS136',   60, 'Spring'],
           ['AFR206',  30, 'Spring'], ['ECON233', 30, 'Fall'],
           ['MUS112',  10, 'Fall'],   ['STAT200', 50, 'Spring'],
           ['PSYC201', 50, 'Fall'],   ['MATH110', 90, 'Spring']]
```

- Suppose we want to sort these courses by their **capacity** (second element)
- We can accomplish this by supplying the `sorted()` function with a `key` function that tells it how to compare the tuples to each other
- This same logic applies to sorting objects of any class that we define
    - We can sort them based on a specific attribute

Sorting with a **key** function

- **Defining a key function explicitly:**
  - We can define an explicit **key** function that, when given a tuple, returns the parameter we want to sort the tuples with respect to

```
def get_capacity(course):
    '''Takes a course tuple and returns capacity'''
    return course[1]
```

  - We can pass this function as a **key** when calling **sorted()**

```
# we can tell sorted() to sort by capacity instead
sorted(courses, key=get_capacity)
```

Sorting with a **key** function

- `sorted(seq, key=function)`
  - Interpret as `for el in seq`: use `function(el)` to determine where within sort order of `seq` that `el` belongs
  - For **each element in the sequence**, `sorted()` ***calls the key function on the element*** to figure out what "feature" of the data should be used for sorting

```
# we can tell sorted() to sort by capacity instead
sorted(courses, key=get_capacity)
```

  - For each `course` in `courses` (a list of lists), sort based on value returned by `capacity(course)`

Example: Sorting with key

```
courses = [['CS134',   90, 'Spring'], ['CS136',   60, 'Spring'],
           ['AFR206',  30, 'Spring'], ['ECON233', 30, 'Fall'],
           ['MUS112',  10, 'Fall'],   ['STAT200', 50, 'Spring'],
           ['PSYC201', 50, 'Fall'],   ['MATH110', 90, 'Spring']]
```

```
def get_capacity(course):
    '''Takes a course tuple and returns capacity'''
    return course[1]
```

```
# we can tell sorted() to sort by capacity instead
sorted(courses, key=get_capacity)
```

```
[['MUS112',  10, 'Fall'],
 ['AFR206',  30, 'Spring'],
 ['ECON233', 30, 'Fall'],
 ['STAT200', 50, 'Spring'],
 ['PSYC201', 50, 'Fall'],
 ['CS136',   60, 'Spring'],
 ['CS134',   90, 'Spring'],
 ['MATH110', 90, 'Spring']]
```

Sorting Objects using **key**

- Suppose we want to sort the Books in a list of Books using a specific data attribute (such as author's name)
- We can use the "getter" method for that attribute as our key argument
- Caveat: Key needs to be a **function** that can be applied to every object of the sequence, not a method that is called on an individual object
- Each method is a function that **belongs to a given class**
- The following are equivalent (left is method `get_author` called on Book `b`, right: function `Book.get_author` called on Book `b`):

```
b = Book("Dune", "Herbert, Frank", 1965)
```

`b1.get_author()` ⟷ `Book.get_author(b1)`

Sorting Objects using **key**

- The following sorts a list of Book objects by their author's name
- To use the "getter method" from the class Book as key, we need to use the functional variant `Book.get_author`
  - This function is called on every Book object and the result is used as the sorting criteria (author names)
- sorted() returns a new **list of Book objects** arranged in the alphabetical order of their author's name

```
sorted_books = sorted(list_of_books, key=Book.get_author)
```

Review: String Methods

Useful String Methods

Discover more str methods with `pydoc3 str` !

```
>>> s = "    CSCI 134 is great!\n \t"
>>> s.strip()
'CSCI 134 is great!'
```

Remove whitespace from left/right sides of the `string s`

```
>>> lst = ['starry', 'starry', 'night']
>>> stars = '**'.join(lst)
>>> stars
'starry**starry**night'
```

Joins all elements from list of `str`, `lst`, using the leading `str '**'`

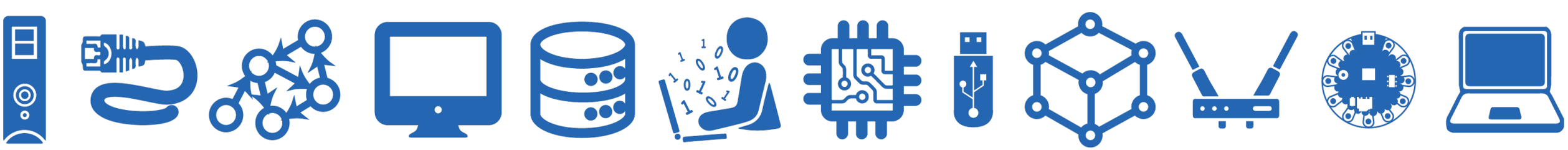
```
>>> stars.split('**')
['starry', 'starry', 'night']
```

Splits all elements from `str stars`, using the `str` argument `'**'`

```
>>> "I have {} {} & {} {}".format(2,'cats',1,'dog')
'I have 2 cats & 1 dog.'
```

Inserts arguments into the `{}` in the `str` instance object.

Another Class Example



Another Example: Name Class

- Names of people have certain attributes
    - Almost everyone has a **first and last name**
    - Some people have one (or more) **middle name(s)**
- We can create name objects by defining a class to represent these attributes
- Then we can define methods, e.g., getting initials of people's names, etc
- Let's practice some of the concepts using this class
    - **__str__**: how do we want the names to be printed?
    - **initials**: can we define a method that returns the initials of people's names?

Example: Name Class

```
class Name:
    """Class to represent a person's name."""

    def __init__(self, first, last, middle=''):
        self._f = first
        self._m = middle
        self._l = last


    def __str__(self):
        # if the person has a middle name
        if len(self._m) > 0:
            return self._f[0] + '. ' + self._m[0] + '. ' + self._l
        else:
            return self._f[0] + '. ' + self._l
```

Sets a default value, in case middle name isn't given!

```
>>> n1 = Name("John", “Schmidt", “Jacob Jingleheimer")
>>> n2 = Name("Paul", "Bunyan")
>>> print(n1)
J. J. Schmidt
>>> print(n2)
P. Bunyan
```

intials() method

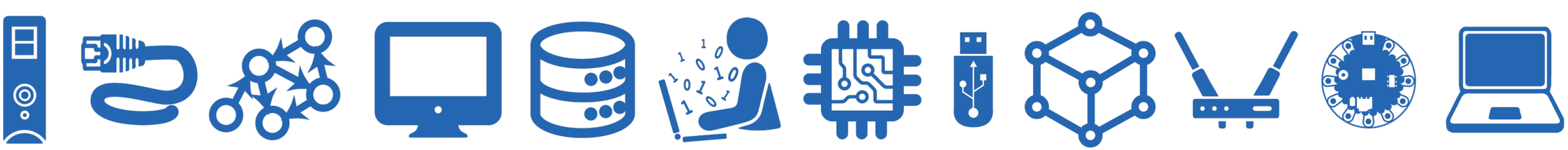
- Suppose we want to write a method that returns the person's initials as a string?
- How would we do that?

Example: Name Class

```
class Name:
    """Class to represent a person's name."""

    def __init__(self, first, last, middle=''):
        self._f = first
        self._m = middle
        self._l = last

    def initials(self):
        if len(self._m) > 0:
            return self._f[0] + '. ' + self._m[0] + '. ' + self._l[0] + '.'
        else:
            return self._f[0] + '. ' + self._l[0] + '.'

    def __str__(self):
        # if the person has a middle name
        if len(self._m) > 0:
            return self._f[0] + '. ' + self._m[0] + '. ' + self._l
        else:
            return self._f[0] + '. ' + self._l
```

```
>>> n1 = Name("John", “Schmidt", “Jacob Jingleheimer")
>>> n1.initials()
'J. J. S.'
>>> n2 = Name("Paul", "Bunyan")
>>> n2.initials()
'P. B.’
```

Inheritance

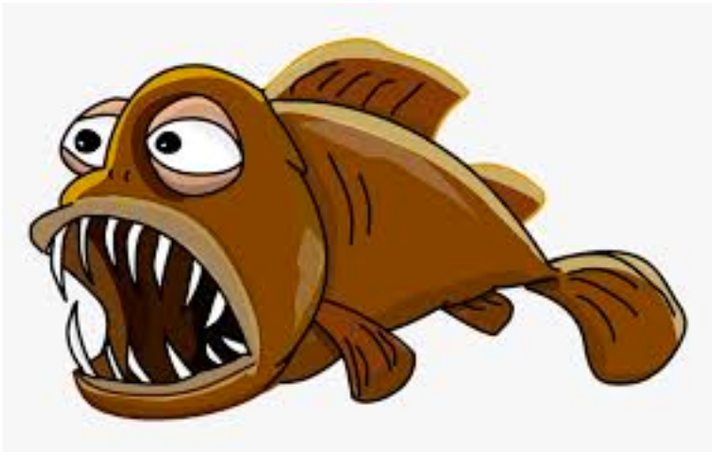


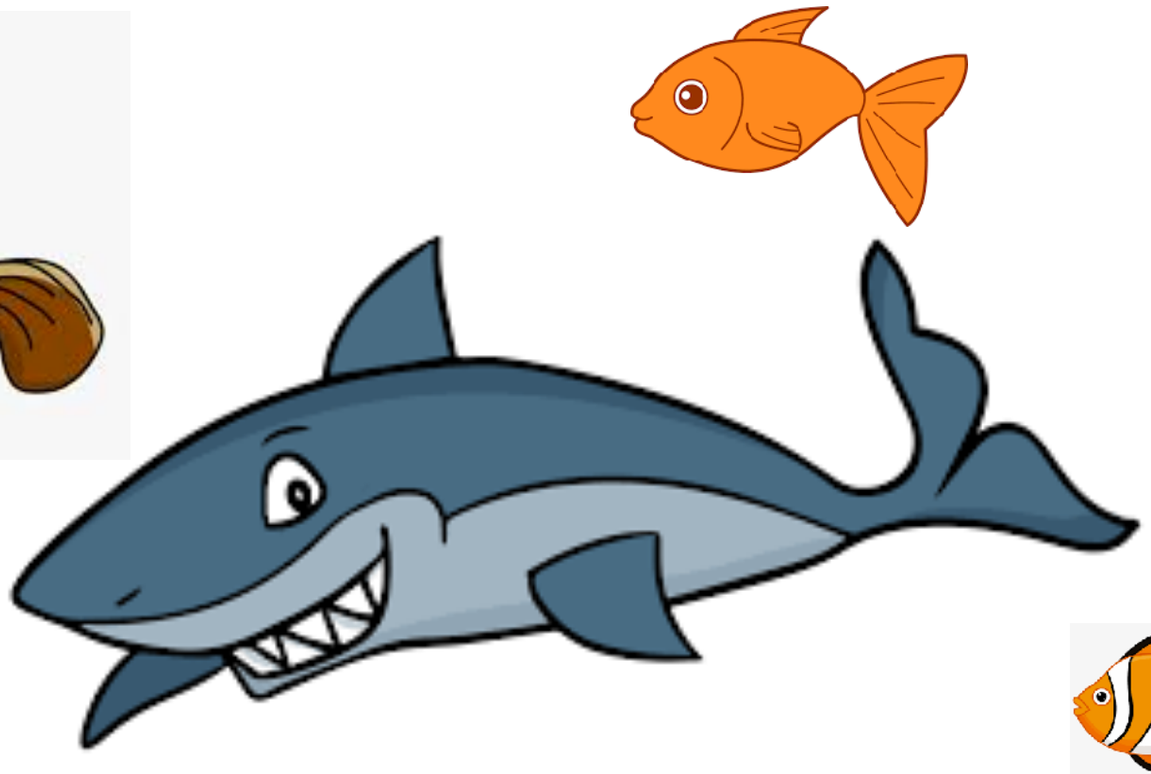
Introduction to Inheritance

- **Inheritance** is the capability of one class to derive or ***inherit*** the properties from another class
- The benefits of inheritance are:
  - Often represents real-world relationships well
  - Provides **reusability of code**, so we don't have to write the same code again and again
  - Allows us to add more features to a class without modifying it
- Inheritance is **transitive** in nature, which means that if class B inherits from class A, then all the subclasses of B would also automatically inherit from class A
- When a class inherits from another class, all methods and attributes are accessible to subclass, ***except private attributes*** (indicated with **__**)

Inheritance Example

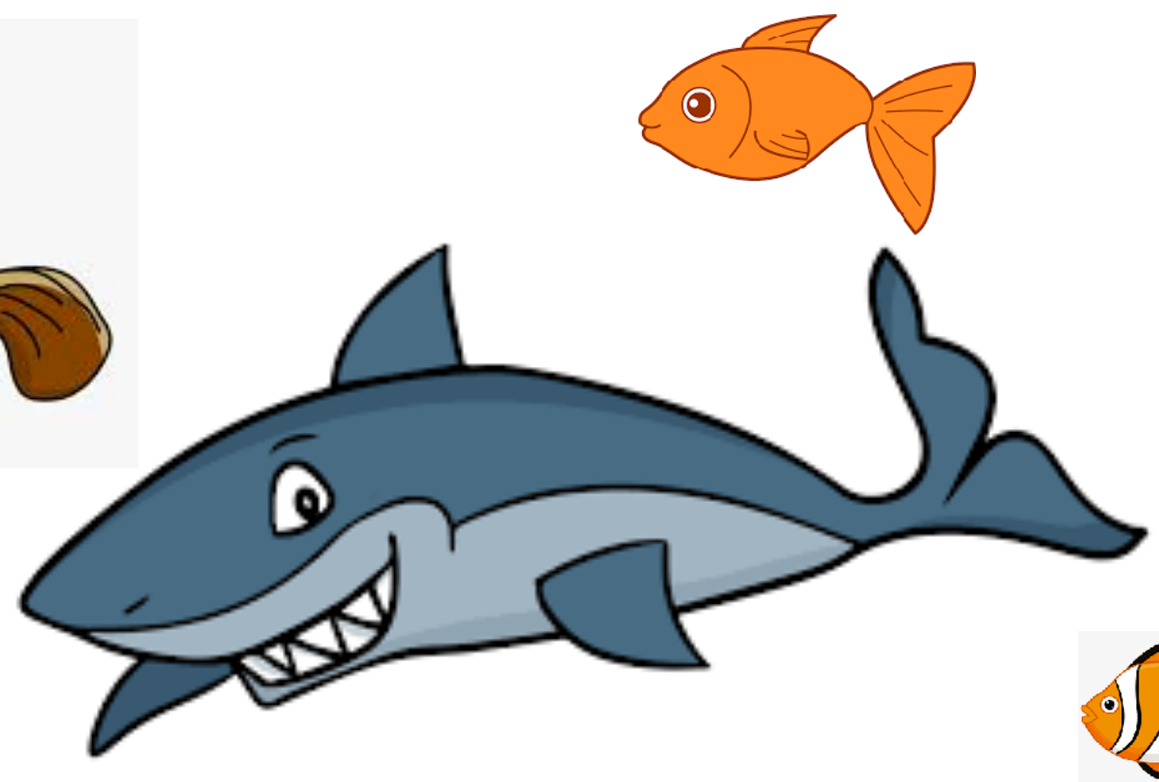
- Suppose we have a base (or parent) class `Fish`
- `Fish` defines several methods that are common to all fish:
  - `eat()`, `swim()`
- `Fish` also defines several attributes with default values:
  - `_length`, `_weight`, `_lifespan`





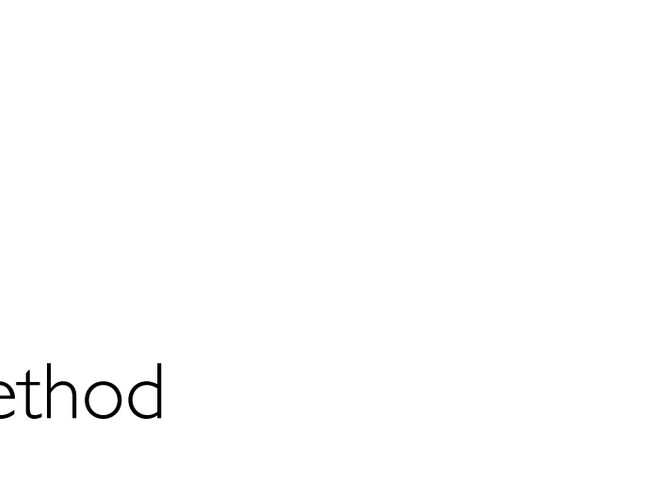
Inheritance Example

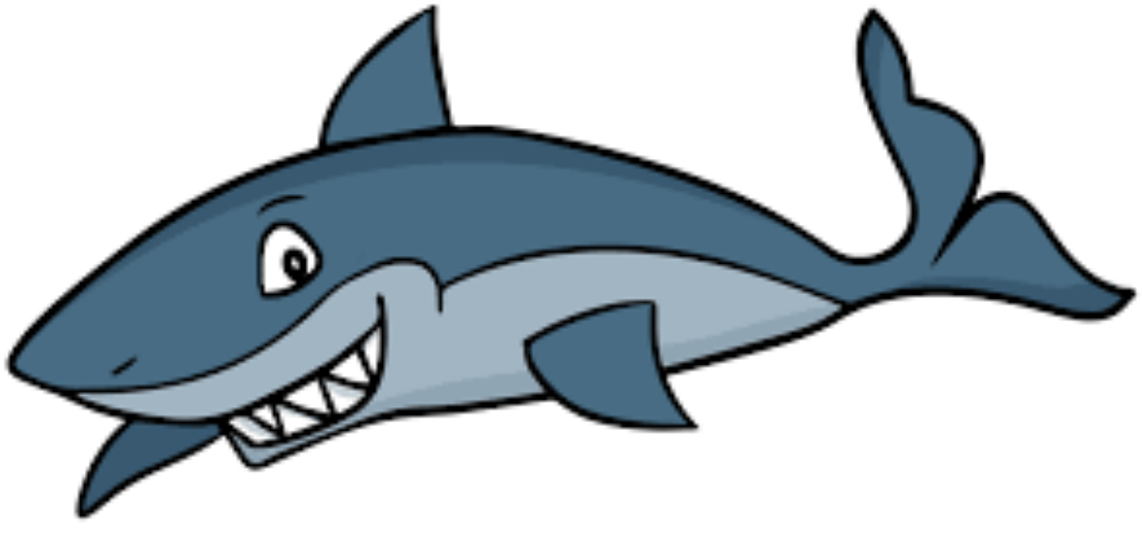
- All fish have some features in common
  - But not all fish are the same!
- Each `Fish` instance will specify different values for attributes (`_length`, `_weight`, `_lifespan`)
- Some fish may still need extra functionality!

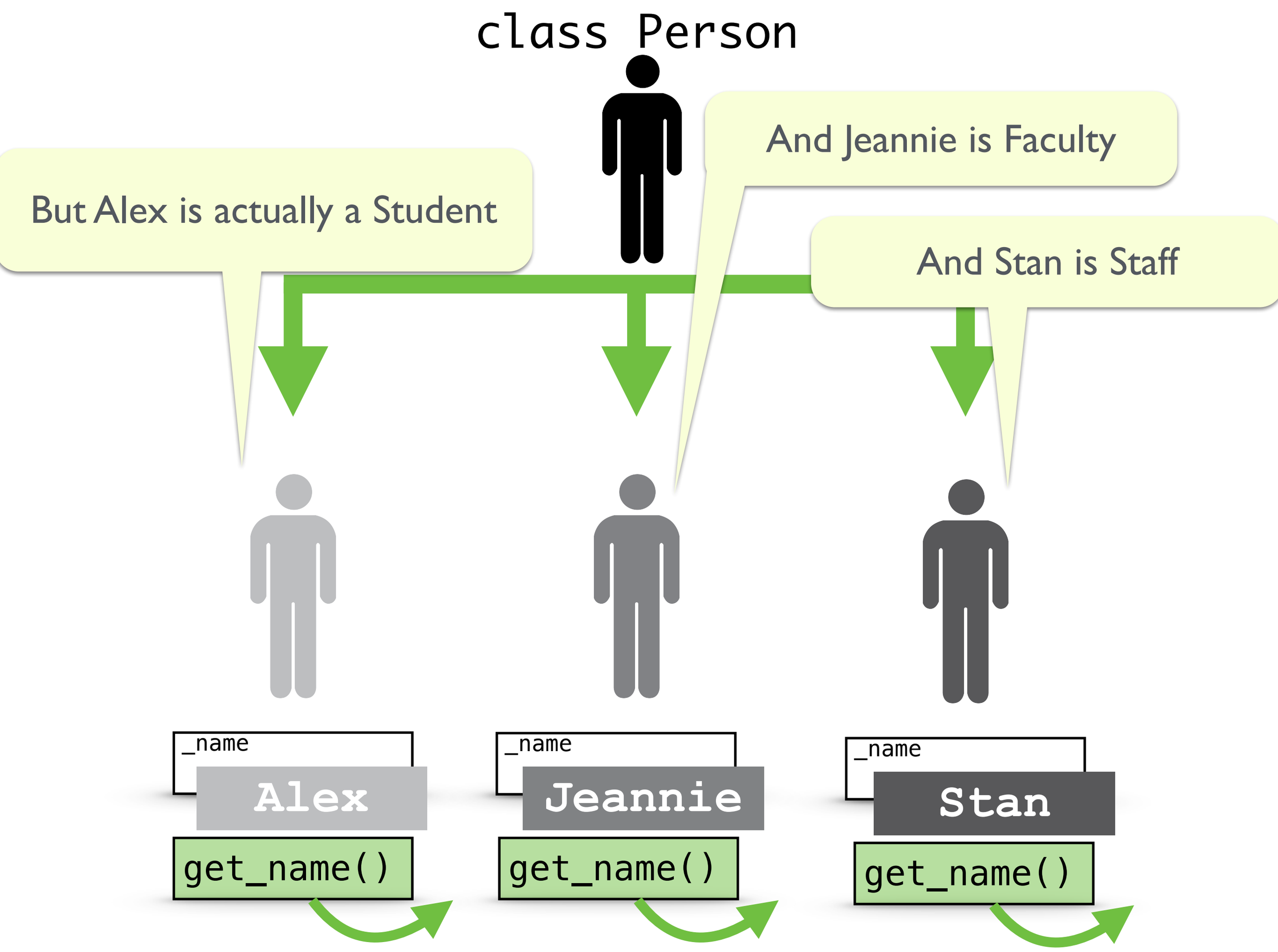


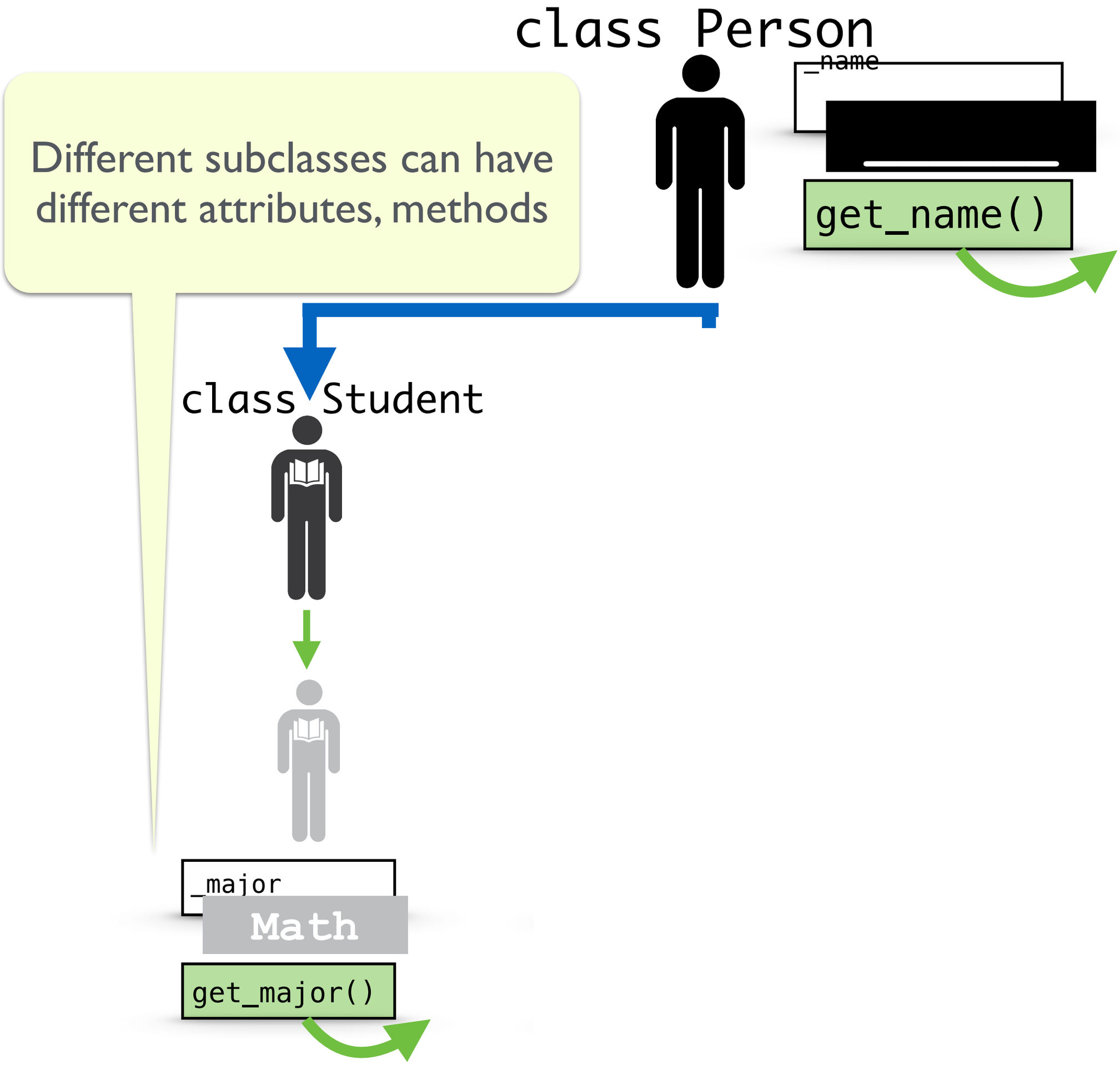
Inheritance Example

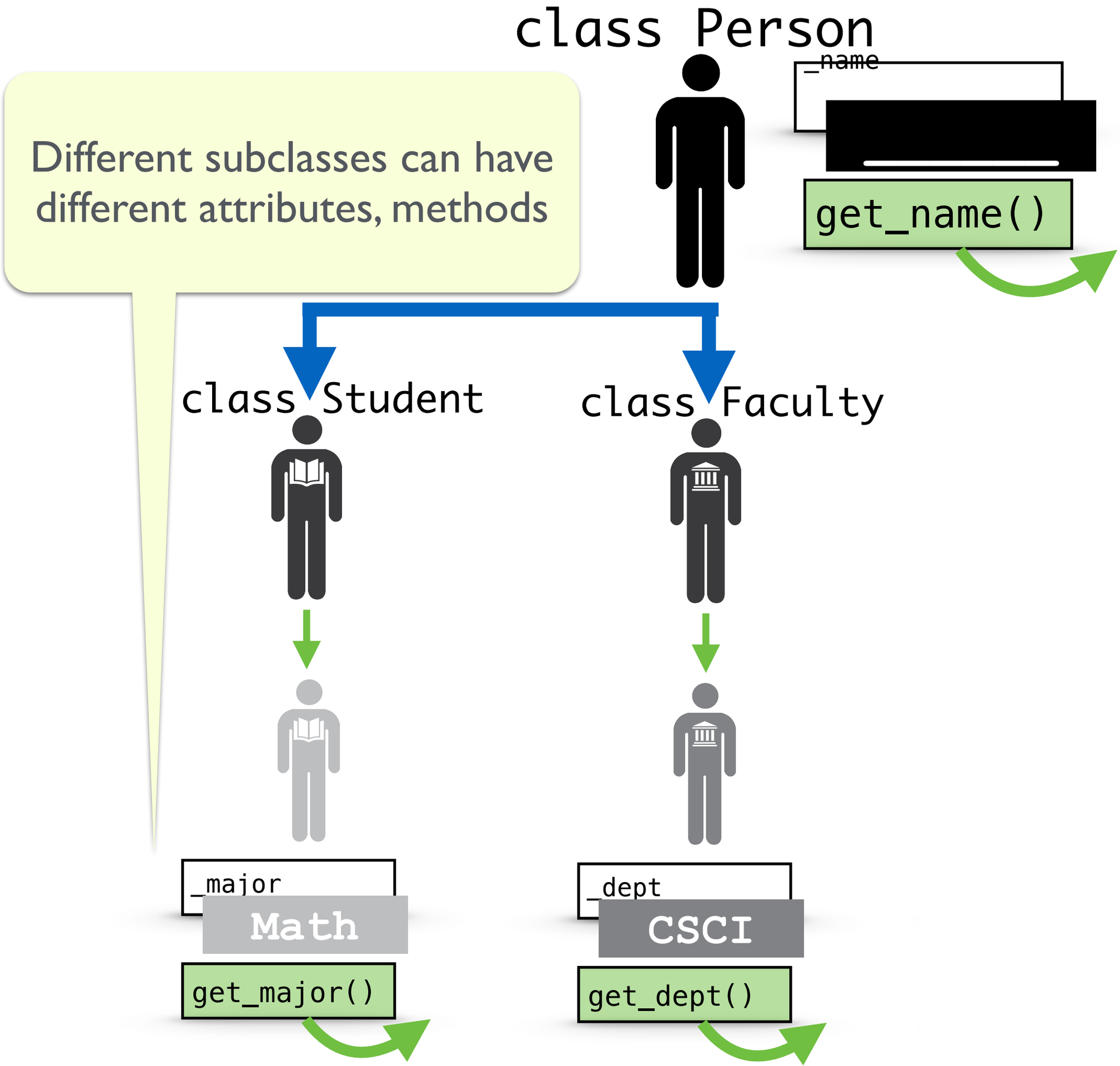
- For example, Sharks might need an `attack()` method
- Pufferfish might need a `puff()` method
- We might even want to ***override*** an existing method with a different (more specialized) implementation
    - Inheritance allows for all of this!

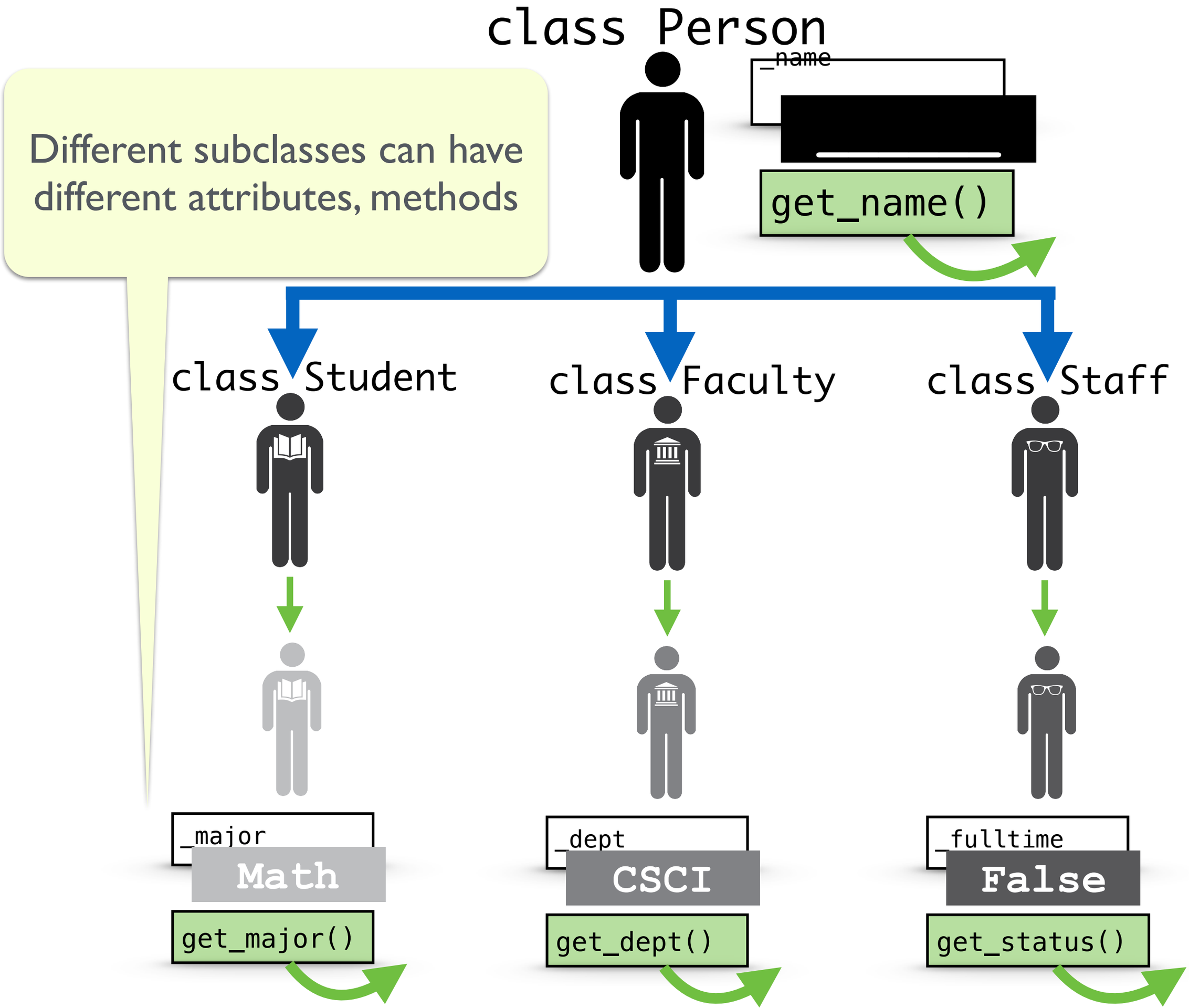


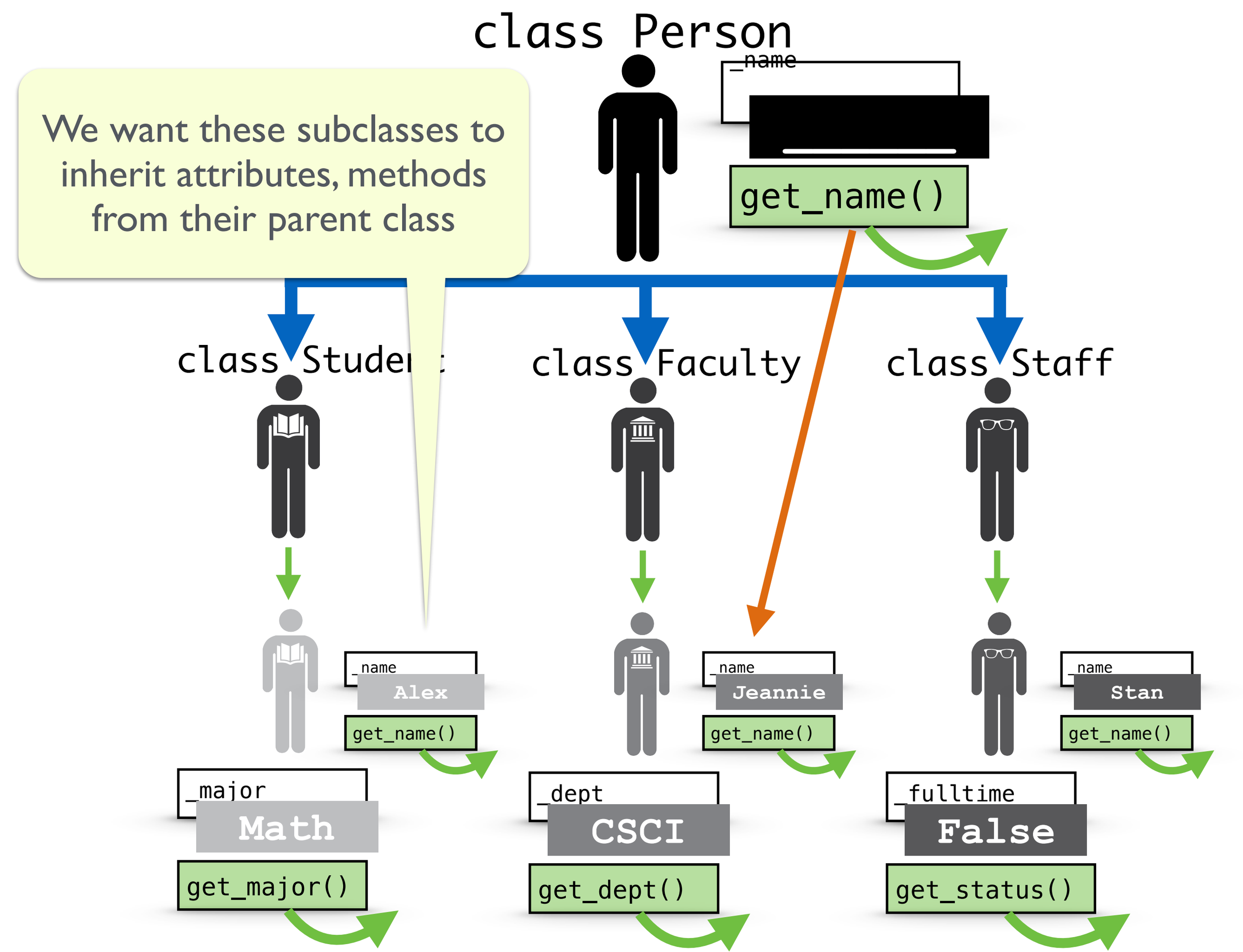



class Person
But Alex is actually a Student
And Jeannie is Faculty
And Stan is Staff
_name
Alex
get_name()
_name
Jeannie
get_name()
_name
Stan
get_name()

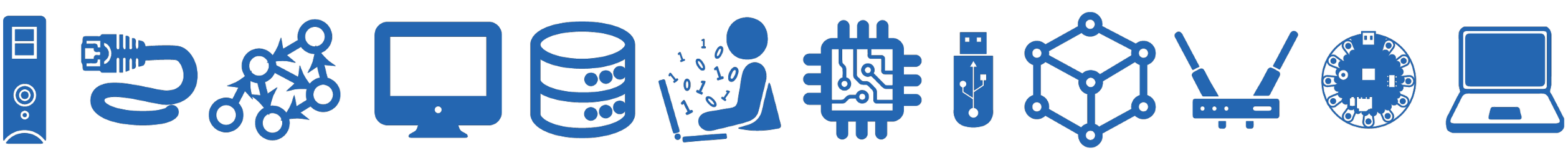

class Person
_name
get_name()
Different subclasses can have different attributes, methods
class Student
_major
Math
get_major()


class Person
_name
get_name()
Different subclasses can have different attributes, methods
class Student
class Faculty
_major
Math
get_major()
_dept
CSCI
get_dept()


class Person
_name
get_name()
Different subclasses can have different attributes, methods
class Student
class Faculty
class Staff
_major
Math
get_major()
_dept
CSCI
get_dept()
_fulltime
False
get_status()


class Person
_name
get_name()
We want these subclasses to inherit attributes, methods from their parent class
class Student
class Faculty
class Staff
_name
Alex
get_name()
_major
Math
get_major()
_name
Jeannie
get_name()
_dept
CSCI
get_dept()
_name
Stan
get_name()
_fulltime
False
get_status()

Inheritance: Syntax

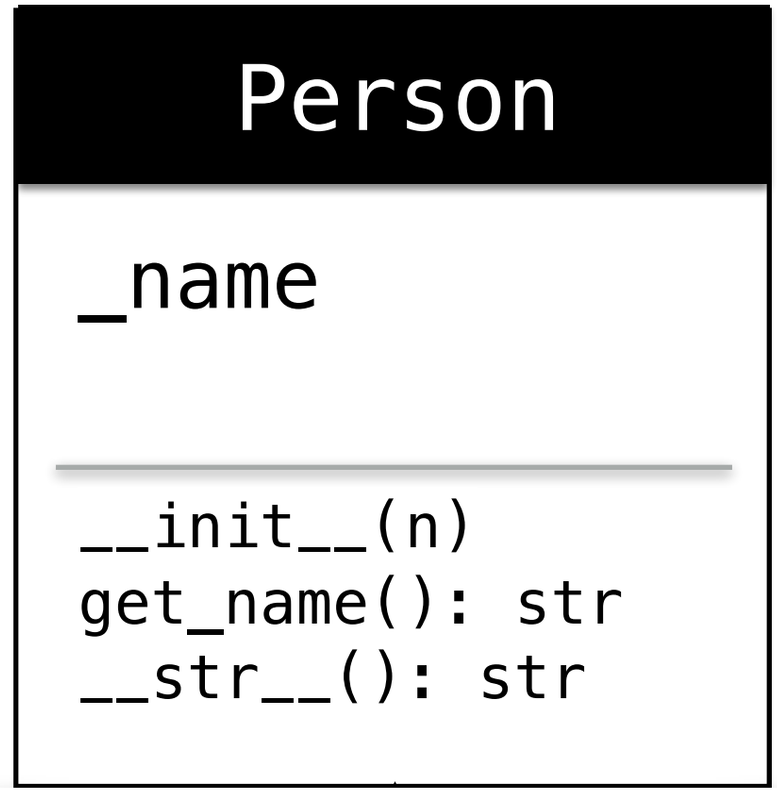


Inheritance

- When defining **super/parent** classes, think about the common features and methods that all subclasses will have
- In subclasses, inherit as much as possible from parent class, and add and/or override attributes and methods as necessary
- Consider an simple example:
  - **Person** class: defines common attributes for all people on campus
  - **Student** subclass: inherits from `Person` and adds additional attributes for student's ***major*** and ***year***
  - **Faculty** subclass: inherits from `Person` and adds additional attributes for ***department*** and ***office***
  - **Staff** subclass: inherits from `Person` and adds additional attributes for type/status of employee (***full-time, part-time***)

Person Class

```
class Person:

    def __init__(self, name):
        self._name = name

    def get_name(self):
        return self._name

    def __str__(self):
        return self._name
```


Person
_name
__init__(n)
get_name(): str
__str__(): str

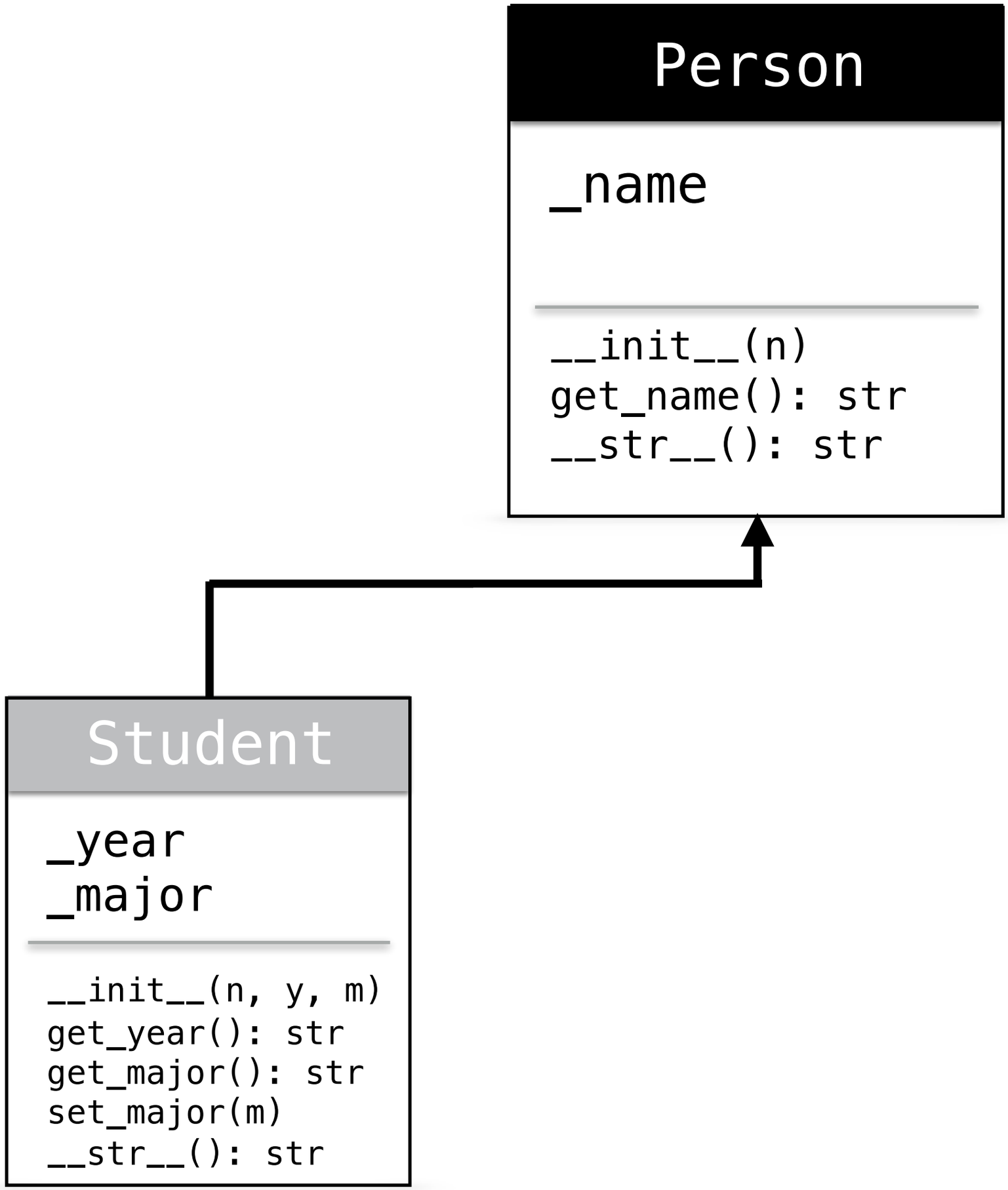
Student Class

Our Student class inherits from Person

Notice this does not include the inherited attribute _name since that is already provided in Person

```
class Student(Person):

    def __init__(self, name, year, major):
        # call __init__ of Person (the super class)
        super().__init__(name)
        self._year = year
        self._major = major

    def get_year(self):
        return self._year

    def get_major(self):
        return self._major

    def set_major(self, major):
        self._major = major

    def __str__(self):
        return self._name +', ' +self._major +', ' +str(self._year)
```

This calls the `__init__` method of Person


Person
_name
__init__(n)
get_name(): str
__str__(): str
Student
_year
_major
__init__(n, y, m)
get_year(): str
get_major(): str
set_major(m)
__str__(): str

Using the Student Class

```
>>> alex = Student("Alex", 2026, "Math")

>>> # inherited from Person
>>> alex.get_name()
'Alex'
>>> # defined in Student
>>> alex.get_major()
'Math'
>>> alex.set_major("CS")
>>> alex.get_major()
'CS'

>>> print(alex)
'Alex, CS, 2026'
```

This calls `__str__` of the Student class

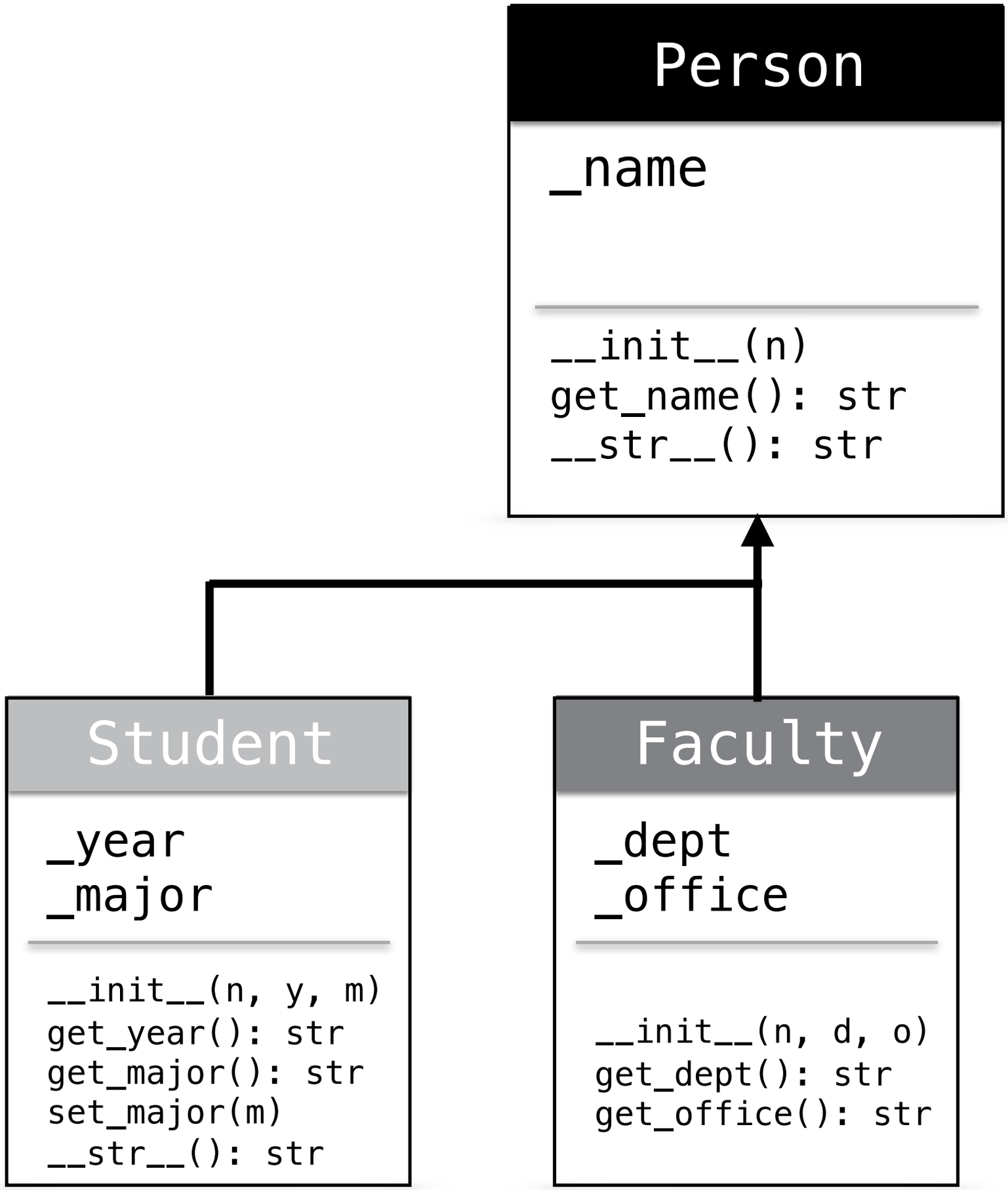
Faculty Class

Faculty inherits from Person

Does not include the inherited attribute _name from Person

```
class Faculty(Person):

    def __init__(self, name, dept, office):
        # call __init__ of Person (the super class)
        super().__init__(name)
        self._dept = dept
        self._office = office

    def get_dept(self):
        return self._dept

    def get_office(self):
        return self._office
```

Calls the `__init__` method of Person


Person
_name
__init__(n)
get_name(): str
__str__(): str
Student
_year
_major
__init__(n, y, m)
get_year(): str
get_major(): str
set_major(m)
__str__(): str
Faculty
_dept
_office
__init__(n, d, o)
get_dept(): str
get_office(): str

Using the Faculty Class

```
>>> iris = Faculty("Iris","CS","TCL 308")

>>> # inherited from Person
>>> iris.get_name()
'Iris'
>>> # defined in Faculty
>>> iris.get_dept()
'CS'
>>> print(iris)
iris
>>> iris.get_major()
AttributeError: 'Facu
attribute 'get_major'
```

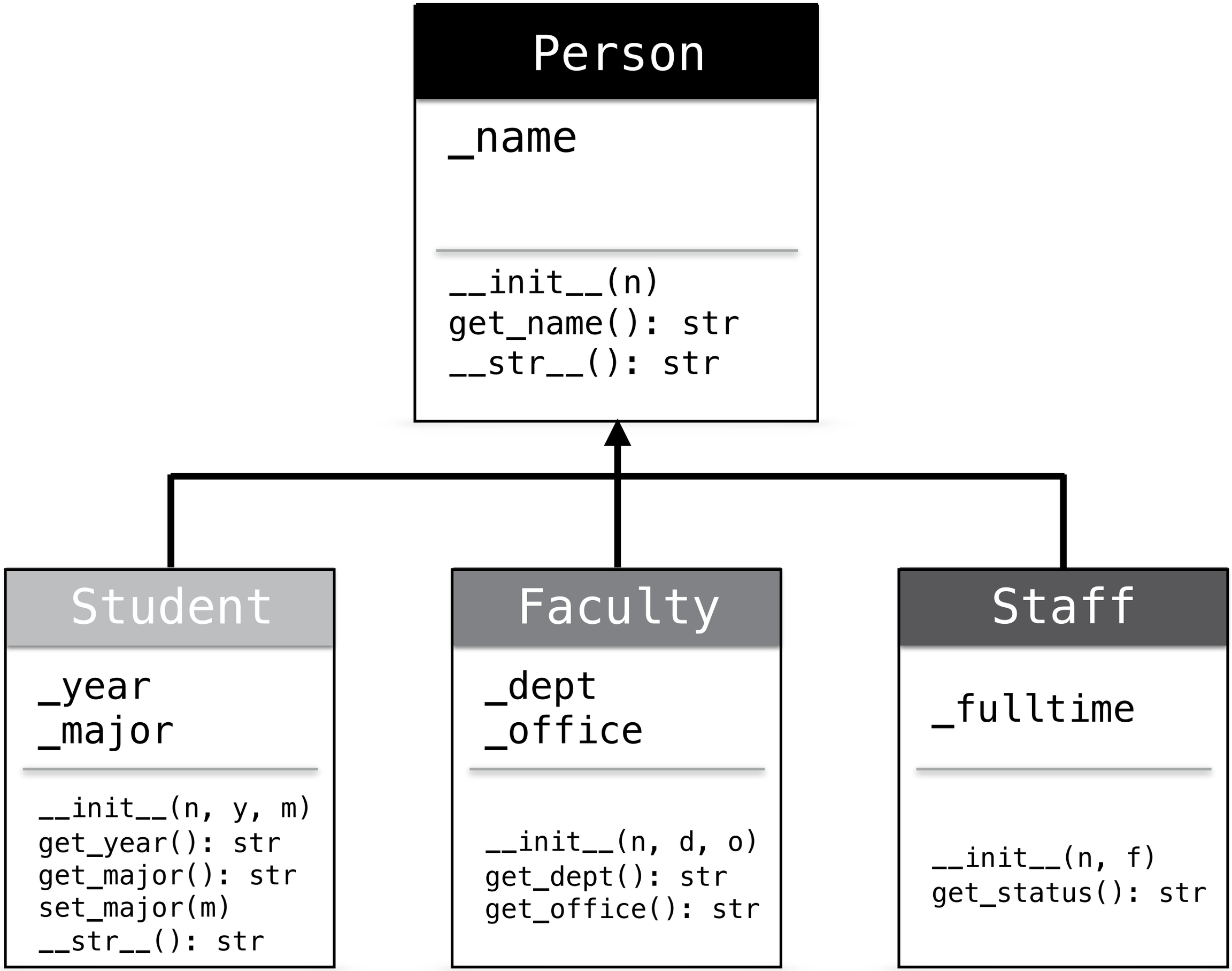
This calls `__str__` of the Person class

`get_major` is a method of Student, not Person, and it is not defined in Faculty. This will not work.

Staff Class

```
class Staff(Person):
    # fulltime is a Boolean

    def __init__(self, name, fulltime):
        # call __init__ of super class
        super().__init__(name)
        self._fulltime = fulltime

    def get_status(self):
        if self._fulltime:
            return "fulltime"
        return "parttime"
```

Notice that getter methods can do more than just return an attribute directly


Person
_name
__init__(n)
get_name(): str
__str__(): str
Student
_year
_major
__init__(n, y, m)
get_year(): str
get_major(): str
set_major(m)
__str__(): str
Faculty
_dept
_office
__init__(n, d, o)
get_dept(): str
get_office(): str
Staff
_fulltime
__init__(n, f)
get_status(): str

Using the Staff Class

```
>>> stan = Staff("Stan", False)

>>> print(stan)
Stan

>>> stan.get_status()
'parttime'
```

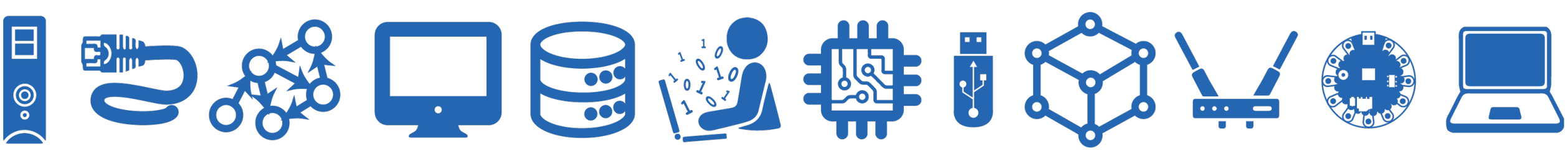
This calls __str__ of the Person class

Summary

- Inheritance is a very useful feature of OOP
- Supports code reusability
- One superclass can be used for any number of subclasses in a hierarchy
- Can change the parent class without changing the subclasses
- More next time!

The end!

Library Class



Last Time: Book Class

```python
class Book:
    """This class represents a book with attributes title, author, and year"""

    # attributes: _title, _author, _year
      def __init__(self, book_title, book_author, book_year):
        self._title = book_title
        self._author = book_author
        self._year = int(book_year)

    # accessor (getter) methods
    def get_title(self):
        return self._title

    def get_author(self):
        return self._author

    def get_year(self):
        return self._year

    # mutator (setter) methods
    def set_title(self, book_title):
        self._title = book_title

    def set_author(self, book_author):
        self._author = book_author

    def set_year(self, book_year):
        self._year = int(book_year)

     # methods for returning book properties
     def num_words_in_title(self):
         """Returns the number of words in title of book"""
         return len(self._title.split())

     def years_since_pub(self, current_year):
         """Returns the number of years since book was published"""
         return current_year - self._year

     def same_author_as(self, other_book):
         """Check if self and other_book have same author"""
         return self._author == other_book.get_author()
```

Library Class

- Let's build a Library class that stores a collection of Books
- Data attribute:
  - `_books` : collection of book objects
  - What built-in collection data type to use?
    - sorted, unsorted? mutable, immutable?
- What methods?
  - __init__, __str__
  - check out a book
  - return a book
- Invariant: shelves should remain in sorted order!

Library Class: Constructor

```
from book import Book

class Library:
    '''Represents a sorted shelf of Book objects'''

    def __init__(self, list_of_books=[]):
        self._books = [b for b in list_of_books]


if __name__ == "__main__":
    # creating book objects:
    b1 = Book('Pride and Prejudice', 'Jane Austen', 1813)
    b2 = Book('Emma', 'Jane Austen', 1815)
    b3 = Book("Parable of the Sower", "Octavia Butler", 1993)
    # creating library object
    lib = Library([b1, b2, b3])
```

Create a **new list** containing the list of Book objects passed when an object is created

Calls `__init__` on `lib` object (passed to `self`)

Library Class: __str__

```
from book import Book
class Library:
    '''Represents a sorted shelf of Book objects'''

    def __str__(self):
        list_of_strings = []
        for book in self._books:
            list_of_strings.append(str(book))
        return " | ".join(list_of_strings)

if __name__ == "__main__":
    # creating book objects:
    b1 = Book('Pride and Prejudice', 'Jane Austen', 1813)
    b2 = Book('Emma', 'Jane Austen', 1815)
    b3 = Book("Parable of the Sower", "Octavia Butler", 1993)
    # creating library object
    lib = Library([b1, b2, b3])
    print(lib)
```

Calls `str` special method on each Book object and accumulates them in a list

joins the string in `list_of_strings` together with the connector string `" | "` in between each

Calls `__str__` method on `lib` object

Library Class: Other Methods

```
from book import Book
class Library:
    '''Represents a sorted shelf of Book objects'''

    def checkout(self, title) :
        '''given title (str) of a book, checks if it
        is in the library, if it is remove it and return True,
        else return False'''
        for book in self._books:
            if book.get_title() == title:
                self._books.remove(book)
                return True
        return False
```

List method that deletes the given item from the list

Library Class: Other Methods

```
from book import Book
class Library:
    '''Represents a sorted shelf of Book objects'''

    def shelve(self, book) :
        # add the book back to the shelves
        self._books.append(book)

        # now the shelves might be out of order!
        # lets sort them by author name
        self._books = sorted(self._books, key=Book.get_author)
```

To understand this, we need to review `sorted()` function in Python