Python OOP

Major concepts

- Classes and instances
- Methods and message passing
- Inheritance
- Polymorphism

Terminology

- Class:
  - specifies the common behavior of entities.
  - a blueprint that defines properties and behavior of an object.

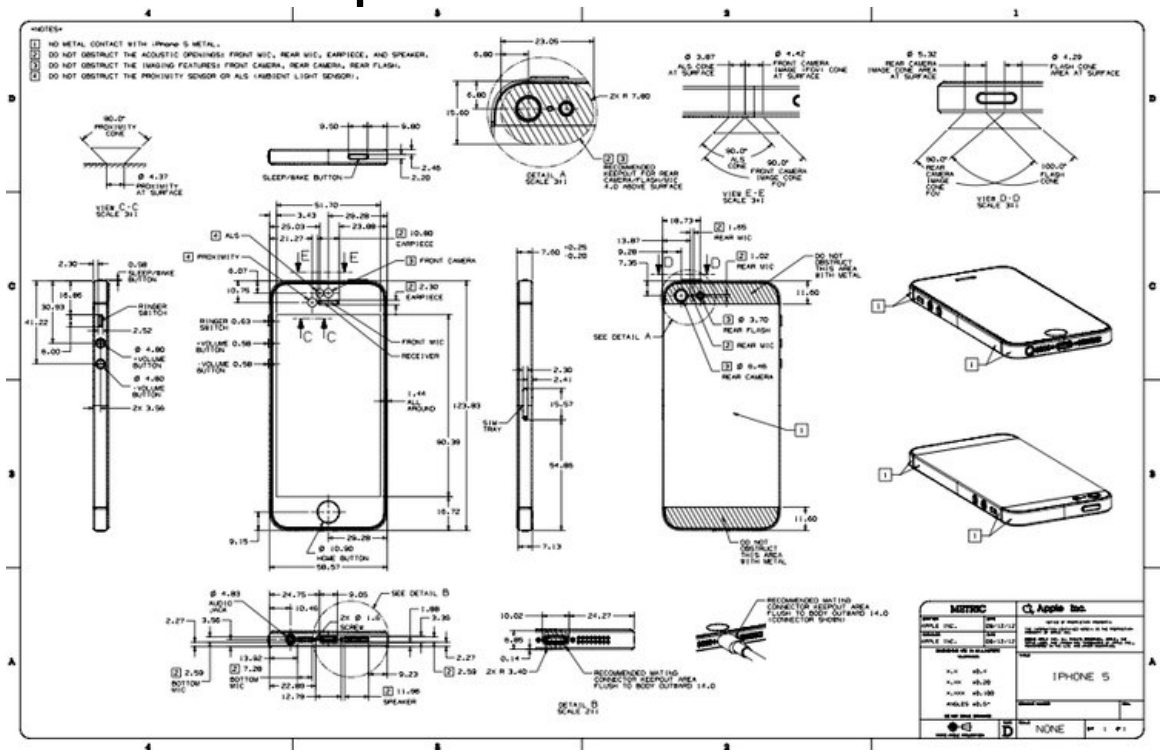
Terminology

- Instance:
  - A particular object or entity of a given class.
  - A concrete, usable object created from the blueprint.

Classes vs Instances

Class

- Blueprints



Instance

- Actual copies you use

One blueprint can produce a lot of copies of iPhone

One class can produce a lot of copies of instances

For example

- String is a class in Python

```
>>> s = 'abc'
>>> type(s)
<class 'str'>
```

- The variable s above, is an instance of the class String
- We can create a lot of other instances of the class String
- And each instance will store different values

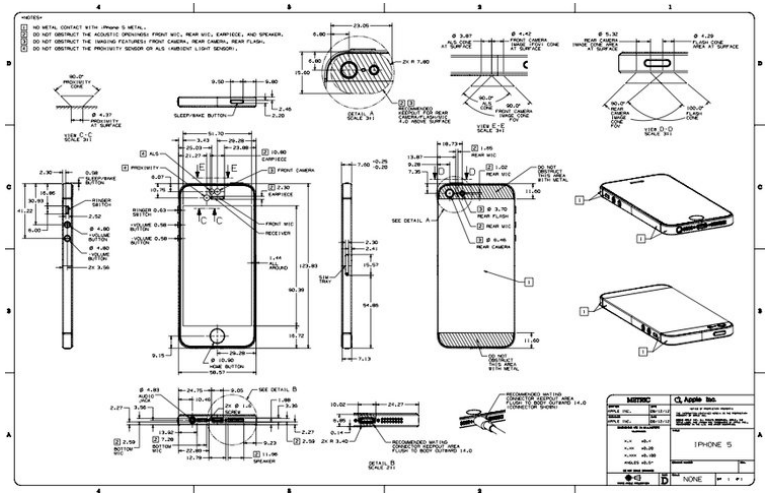
On Top of “Storage”

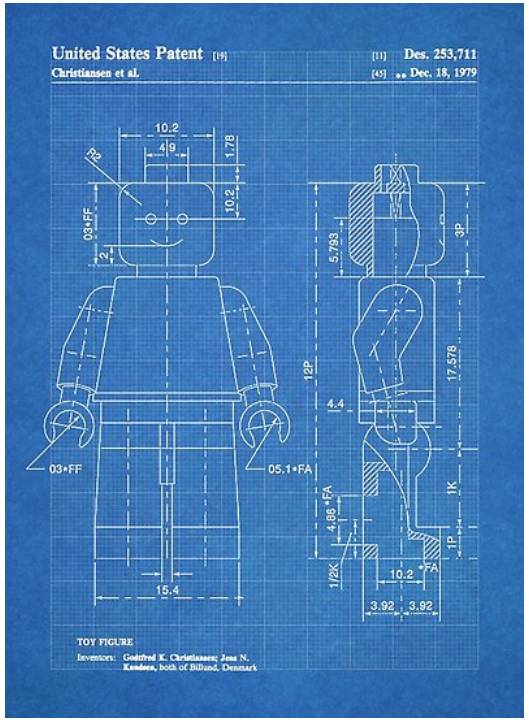
- An instance will store some information
- However, on top of that, there are some “methods”
- For example

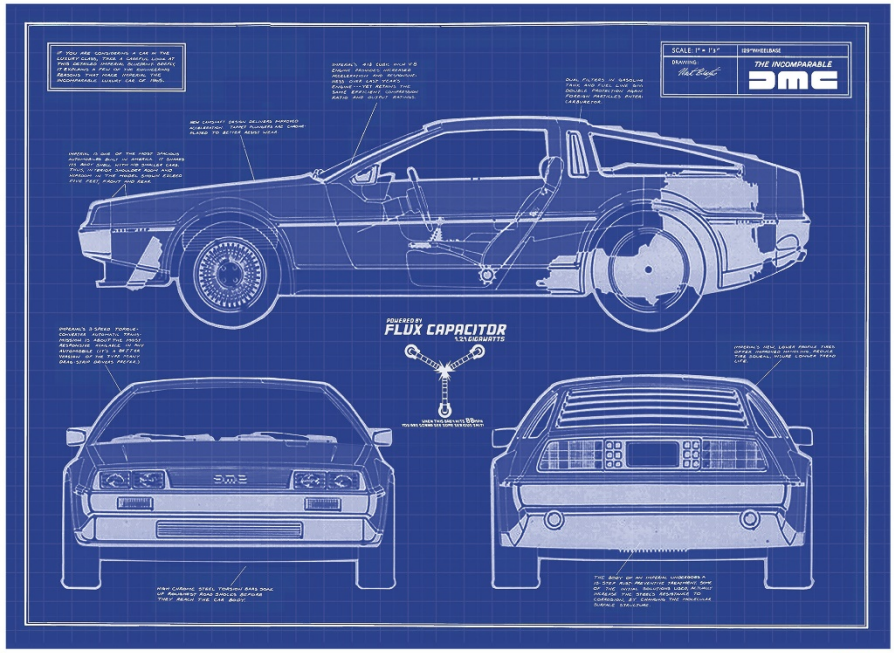
```
>>> s1 = '123'
>>> s.isalpha()
True
>>> s1.isalpha()
False
```

Designing our own class

- Python OOP means we can design our own class and methods!



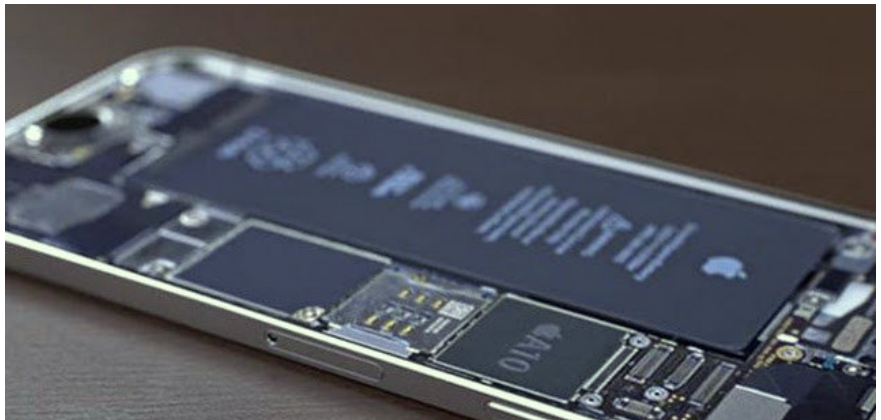


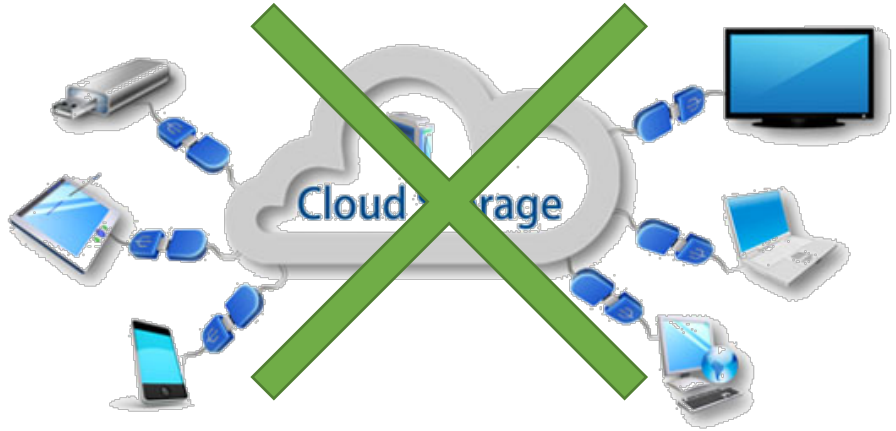


- Let's try to design a class called "BankAccount"

Terminology

- Class:
  - specifies the common behavior of entities.
  - a blueprint that defines properties and behavior of an object.
  - Also specifies some common storages
    - Common as in, every instance has one own copy
    - Not every instance shares the same copy

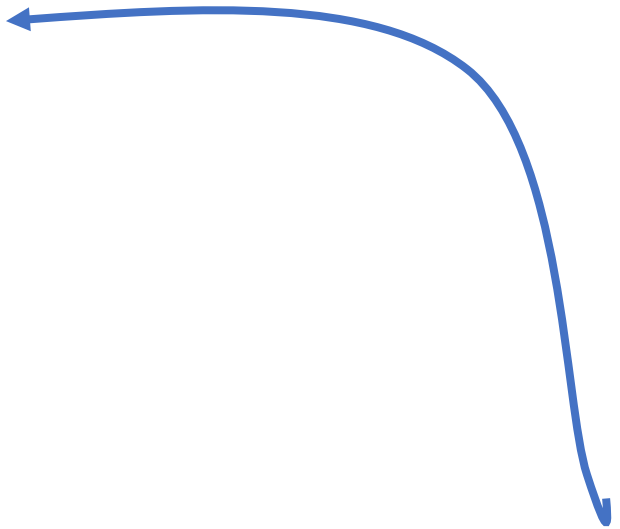




OOP Example

```
class BankAccount(object):
    def __init__(self, initial_balance):
        self.balance = initial_balance

    def withdraw(self, amount):
        if self.balance > amount:
            self.balance -= amount
            return self.balance
        else:
            return "Money not enough"
```

constructor



A storage for every instance/copy

OOP Example

```
def deposit(self, amount):
    self.balance += amount
    return self.balance
```

What is __init__ ?

- `def __init__(self, balance):`
  - called when the object is first initialized
  - `self` argument is a reference to the object calling the method.
  - It allows the method to reference properties and other methods of the class.
- Are there other special methods?
  - Yes! Special methods have __ in front and behind the name

Example: Bank Account

```
>>> my_account = BankAccount(100)
>>> my_account.withdraw(40)
60
>>> my_account.withdraw(200)
Money not enough
>>> my_account.deposit(20)
80
```

```
class BankAccount(object):
    def __init__(self, initial_balance):
        self.balance = initial_balance

    def withdraw(self, amount):
        if self.balance > amount:
            self.balance -= amount
            return self.balance
        else:
            return "Money not enough“

 def deposit(self, amount):
        self.balance += amount
        return self.balance
```

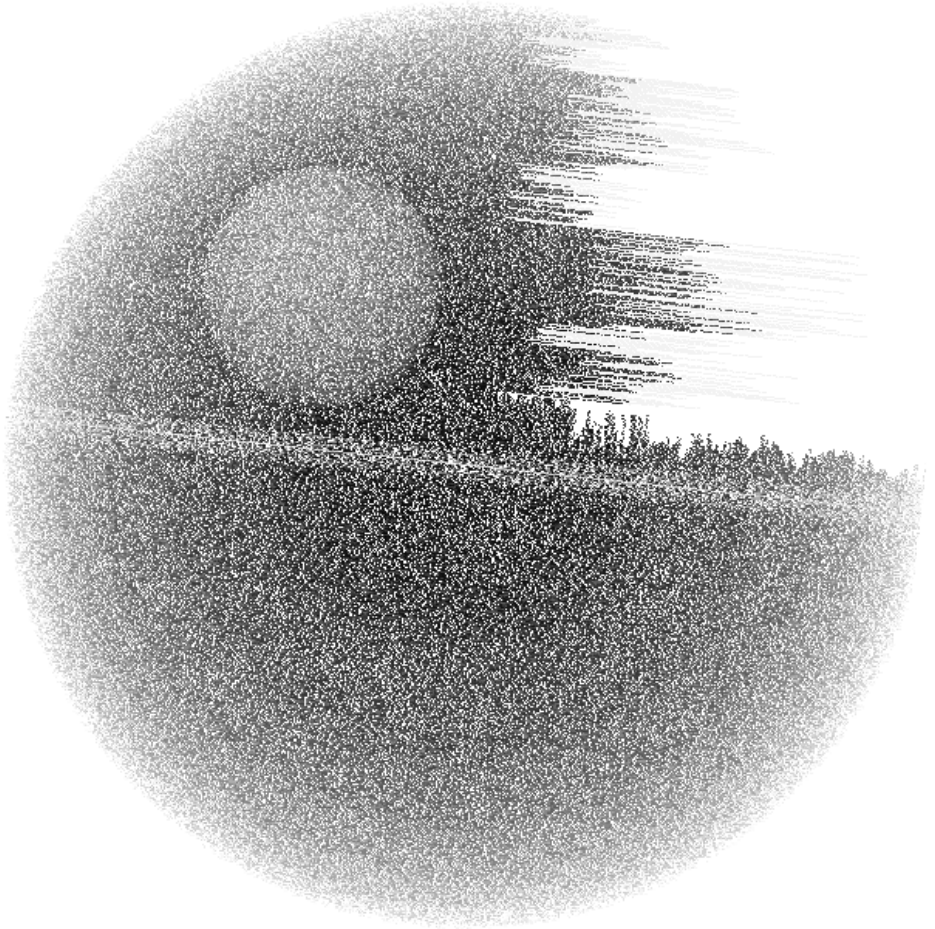
Is it a *really* a new thing?

- Recall your previous lectures…

```
lst = [1, 2, 3]
lst.append(4)
lst  →[1, 2, 3, 4]
```

- Conceptually, append is a method defined in the `List` class.
- Just like withdraw is a method defined in the `BankAccount` class

Suppose we want to build a “space wars” simulator



Using Classes & Instances to Design a System

- Start by thinking about what kinds of objects we want (what classes, their state information, and their interfaces)
  - ships
  - space stations
  - other objects

Using Classes & Instances to Design a System

- We can then extend to thinking about what particular instances of objects are useful
  - Enterprise
  - Millenium Falcon
  - Death Star

Defining the Ship Class

```
class Ship(object):
    def __init__(self, p, v, num_torps):
        self.position = p
        self.velocity = v
        self.num_torps = num_torps

    def move(self):
        self.position = …

    def fire_torps(self):
        if num_torps > 0:
            …
```

How to implement?

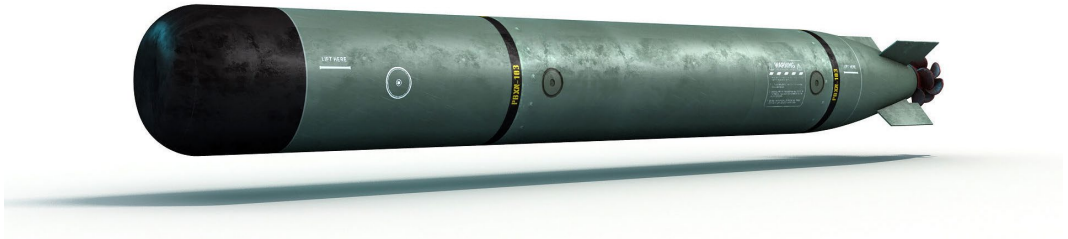
- Objects have:
  - State
  - Methods
- Starship example:
  - State: position, velocity, num_torps
  - Methods: move, attack

Instances of Objects

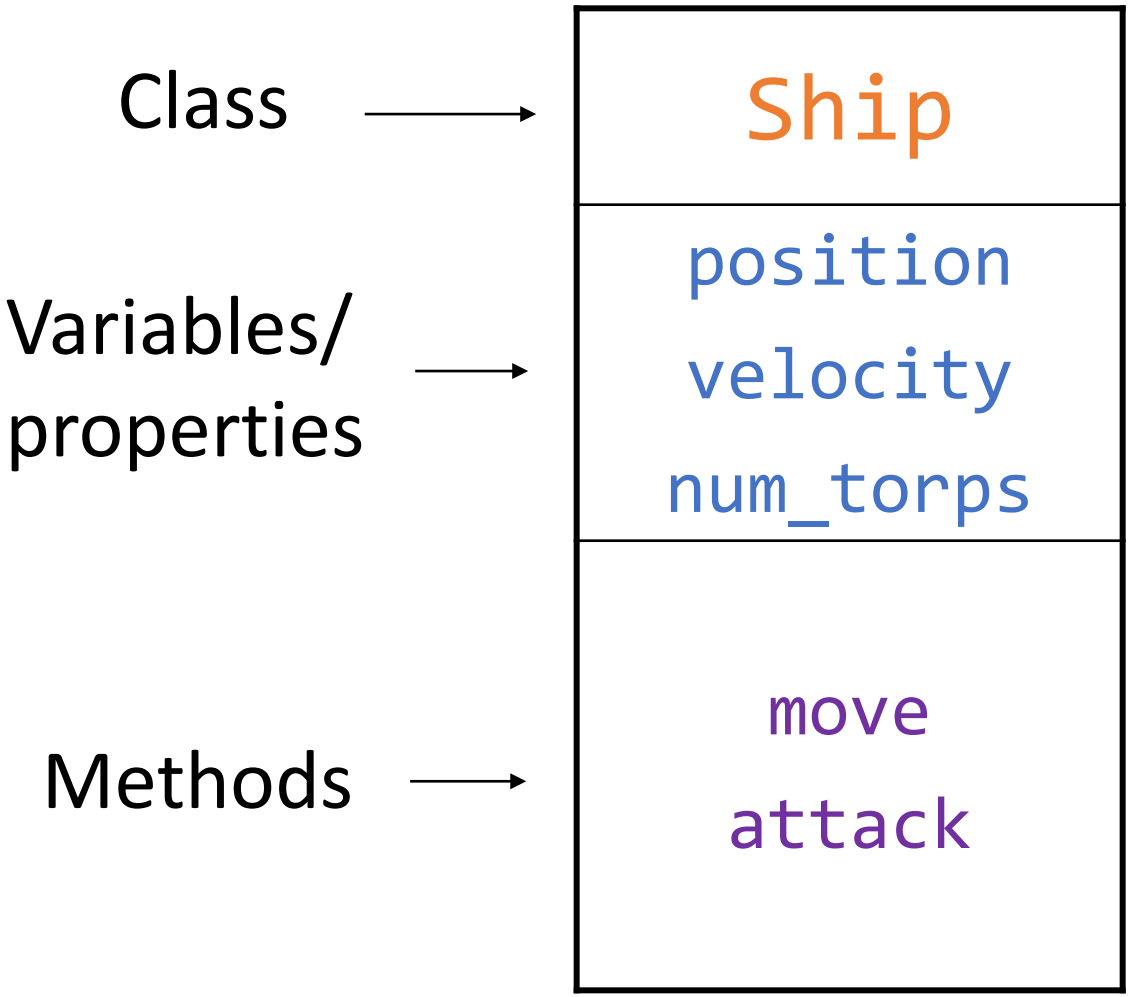
```
>>> enterprise = Ship((10,10), (5,0), 3)
>>> falcon = Ship((-10,10), (10,0), 8)
>>> print(enterprise)
<__main__.Ship object at 0x109b2fd90>

>>> print(falcon)
<__main__.Ship object at 0x109b2ff10>
```

Torpedo

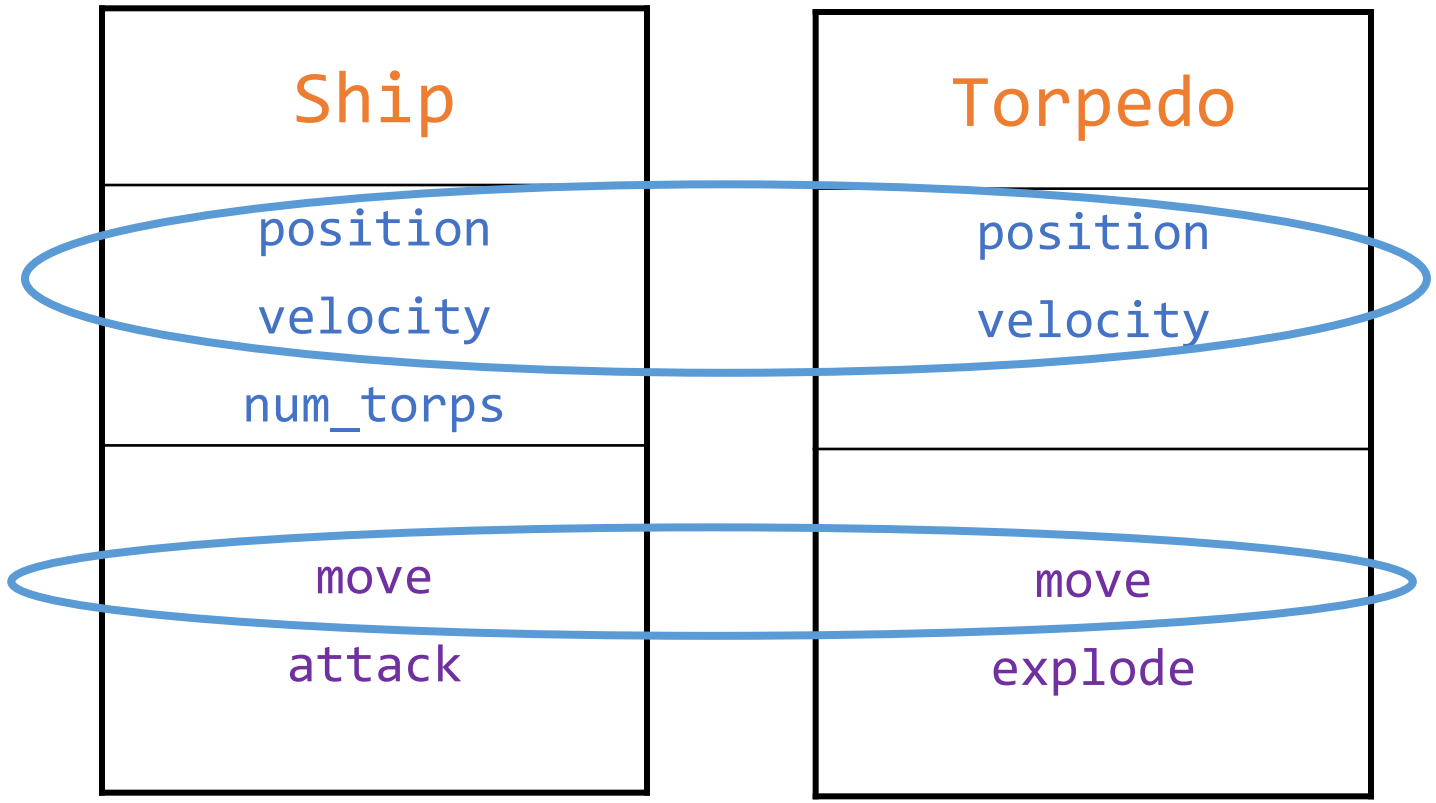
```
class Torpedo(object):
    def __init__(self, p, v):
        self.position = p
        self.velocity = v

    def move(self):
        self.position = ...

    def explode(self):
        print("torpedo goes off!")
        # remove torpedo from the world
```



A Tale of Two Objects

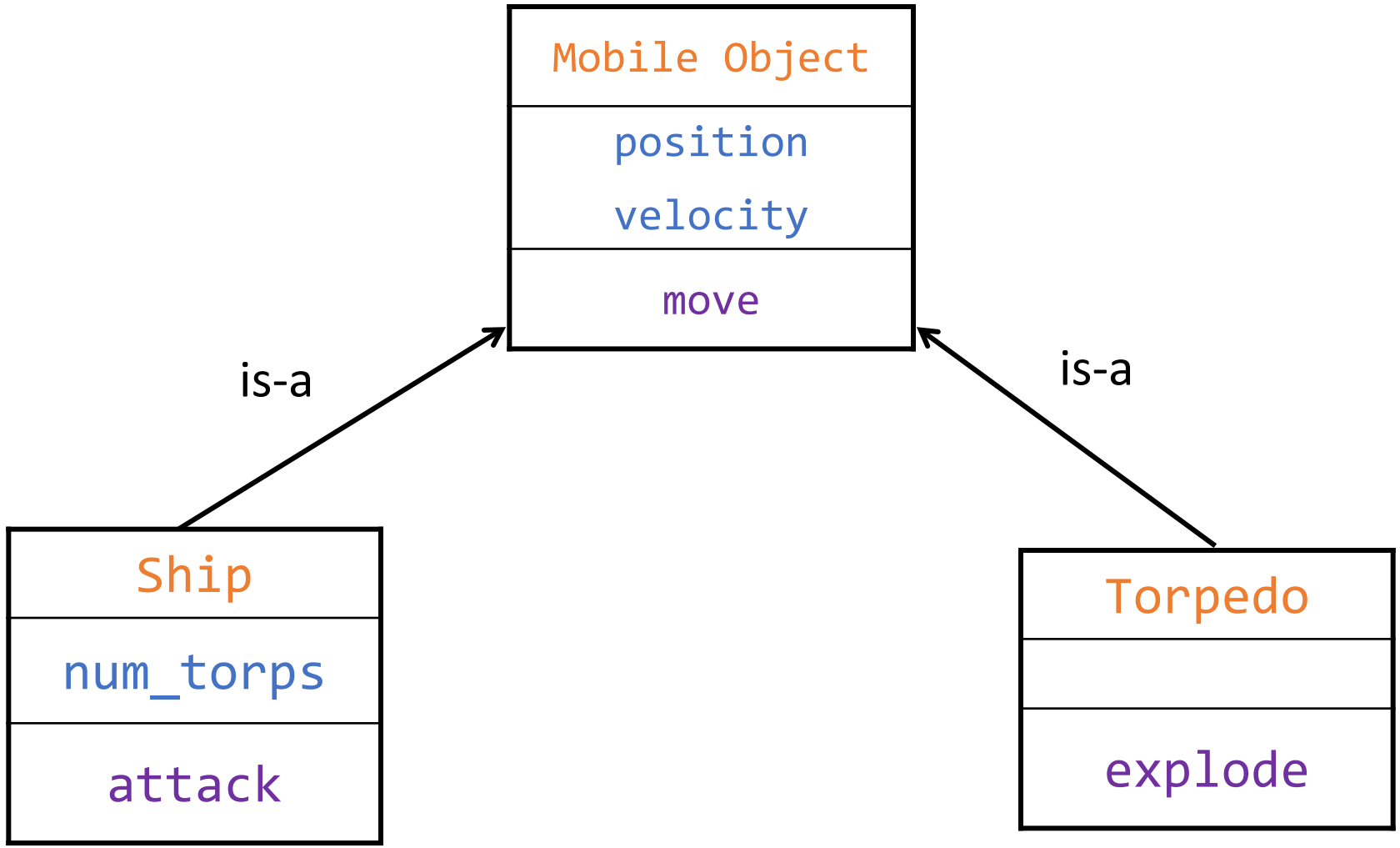


A Tale of Two Objects



What do you notice about the two objects?

Inheritance

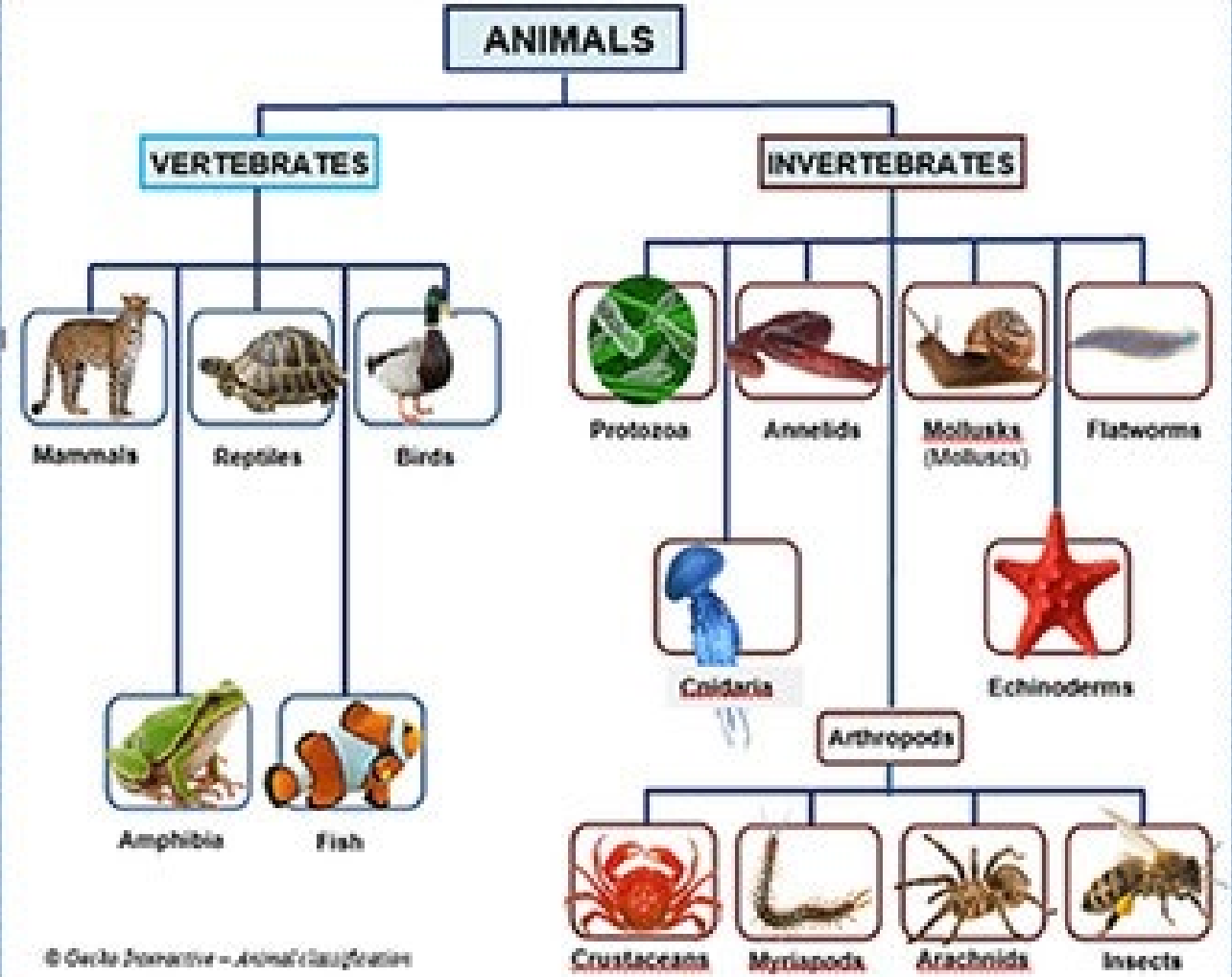


Inheritance

Exploit commonality to share structure and behaviour

Animal classification

Animals are classified by placing them into groups that have similar characteristics.

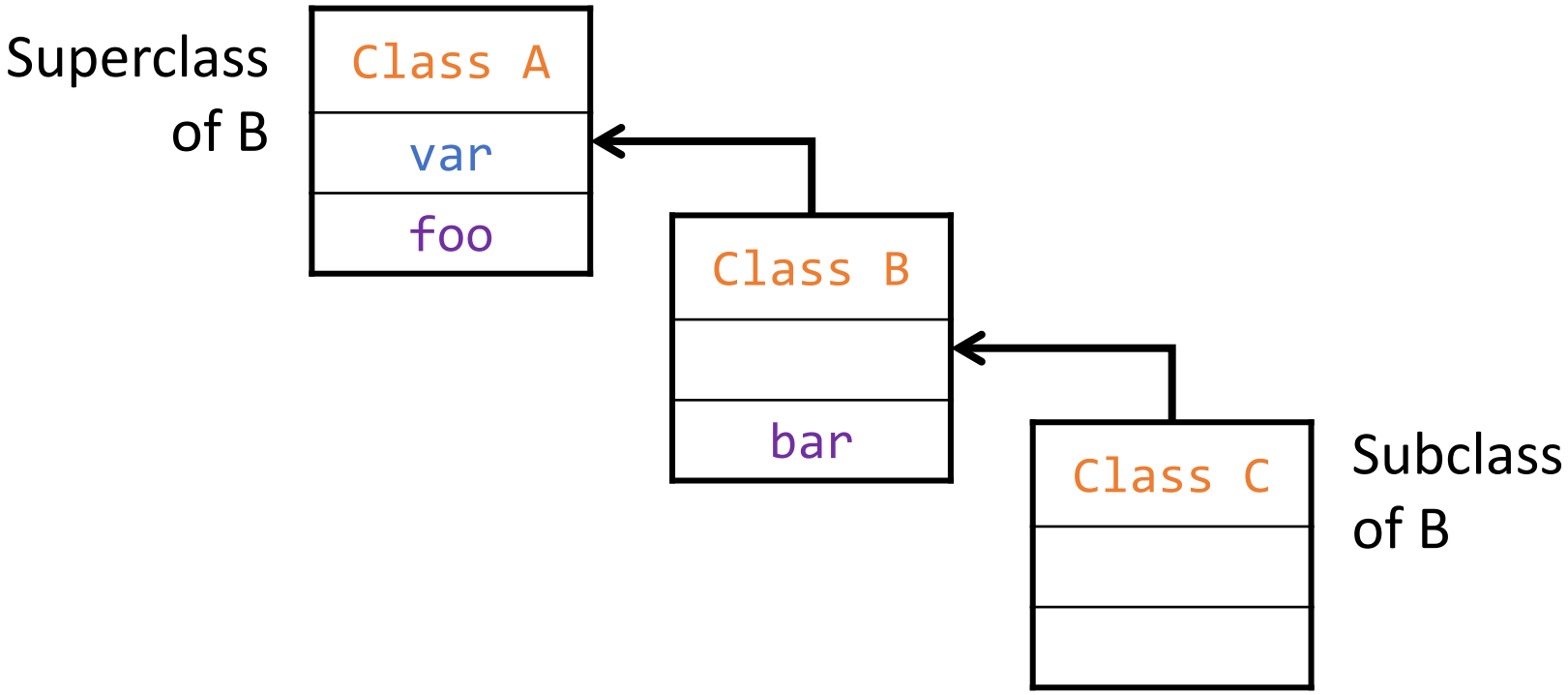


Inheritance

- Objects that exhibit similar functionality should “inherit” from the same base object, called the superclass.
- An object that inherits from another is called the subclass.

Inheritance

- Superclass vs Subclass
  - Subclass specializes the superclass by extending state/behavior



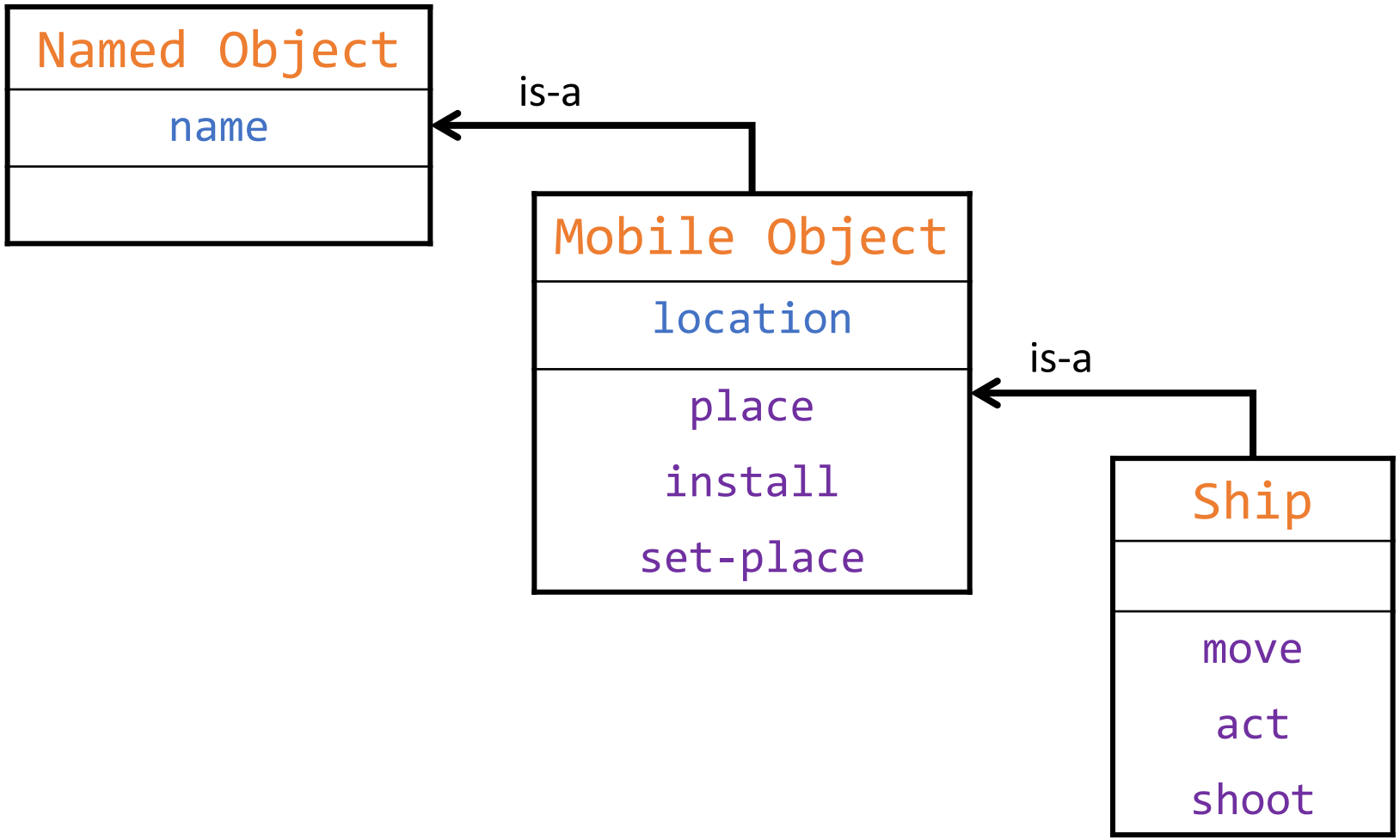
Inheritance

- Classes have an "is-a" relationship with their superclasses
  - Establishes a natural type hierarchy
  - When did we last see this??

Overview

- Class
  - Defines what is common to all instances of that class
    - Provides local state variables
    - Provides a message handler to implement methods
    - Specifies what superclasses and methods are inherited
  - Root class: All user defined classes should inherit from either root-object class or from some other superclass

Example: Star Trek Simulation



Example: Star Trek Simulation

The basic (root) object

```
class NamedObject(object):
    def __init__(self, name):
        self.name = name
```

A “self” variable?

- Every class definition has access to a `self` variable
- `self` is a reference to the entire instance

User View: Why a “self” variable?

- Why need this? How or when use self ?
  - When implementing a method, sometimes you “ask” a part of yourself to do something
  - However, sometimes we want to ask the whole instance to do something

- This mostly matters when we have subclass methods that shadow superclass methods, and we want to invoke one of those shadowing methods from inside the superclass

Example: Star Trek Simulation

```
class MobileObject(NamedObject):
    def __init__(self, name, location):
        self.name = name
        self.location = location

    def install(self):
        self.location.add_thing(self)
```

Did you notice repeated code?

```
class NamedObject(object):
    def __init__(self, name):
        self.name = name


class MobileObject(NamedObject):
    def __init__(self, name, location):
        self.name = name
        self.location = location
```

The ‘super()’ method

- What happens if a new directive states that all names must be in lowercase?

Did you notice repeated code?

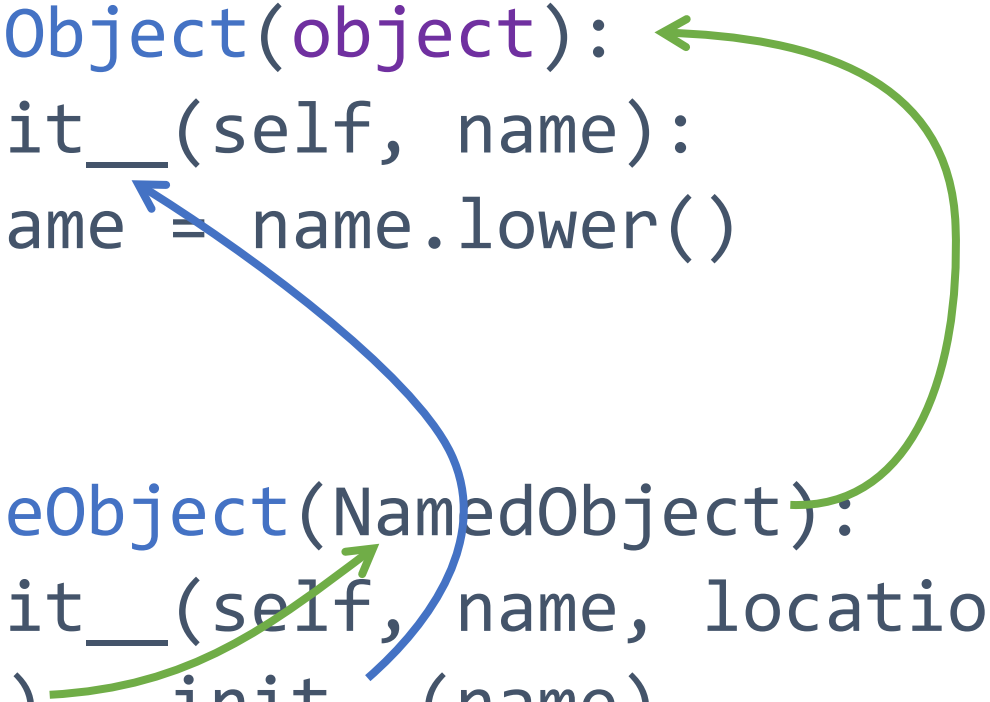
```
class NamedObject(object):
    def __init__(self, name):
        self.name = name.lower()


class MobileObject(NamedObject):
    def __init__(self, name, location):
        self.name = name.lower()
        self.location = location
```

The ‘super()’ method

- What happens if a new directive states that all names must be in lowercase?
- Do we have to manually change all the declarations in all the methods in the class hierarchy?
  - Doesn’t sound very reusable right?
- We need a way to access the next higher class in the class hierarchy – the `super()` method

The ‘super()’ method

```
class NamedObject(object):
    def __init__(self, name):
      self.name = name.lower()


class MobileObject(NamedObject):
    def __init__(self, name, location):
      super().__init__(name)
      self.location = location
```



isinstance vs type

```
class Vehicle:
    ...

class Truck(Vehicle):
    ...

isinstance(Vehicle(), Vehicle)  # returns True
type(Vehicle()) == Vehicle      # returns True
isinstance(Truck(), Vehicle)    # returns True
type(Truck()) == Vehicle        # returns False
type(Truck()) == Truck          # returns True
```

Another Example: A Speaker

```
class Speaker(object):
    def say(self, stuff):
        print(stuff)
```

What does the speaker do?

Example: A Speaker in action

```
>>> ah_beng = Speaker()
>>> ah_beng.say("Hello World")
Hello World


>>> ah_beng.dance()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'Speaker' object has no attribute
'dance'
```

More about Inheritance

- We can define an object type to be a more “specialized” kind of some other object type
- Example:
  - A lecturer is a kind of speaker
  - The lecturer also has a method called lecture
  - To lecture something, the lecturer says it and then says: “You should be taking notes”

More about Inheritance

- Observations:
  - A lecturer can do anything a speaker can (i.e. say things), and also lecture
  - Lecturer inherits the “say” method from speaker
  - Lecturer is a subclass of speaker
  - Speaker is a superclass of lecturer

Making a Lecturer

```
class Lecturer(Speaker):
  def lecture(self, stuff):
    self.say(stuff)
    self.say("You should be taking notes")
```

Python would go through up in the class hierarchy if a method definition is not found in the class

Example: A Lecturer in action

```
>>> seth = Lecturer()

>>> seth.lecture("Java is easy")
Java is easy
You should be taking notes

>>> seth.say("You have a quiz today")
You have a quiz today
```

Making an Arrogant Lecturer

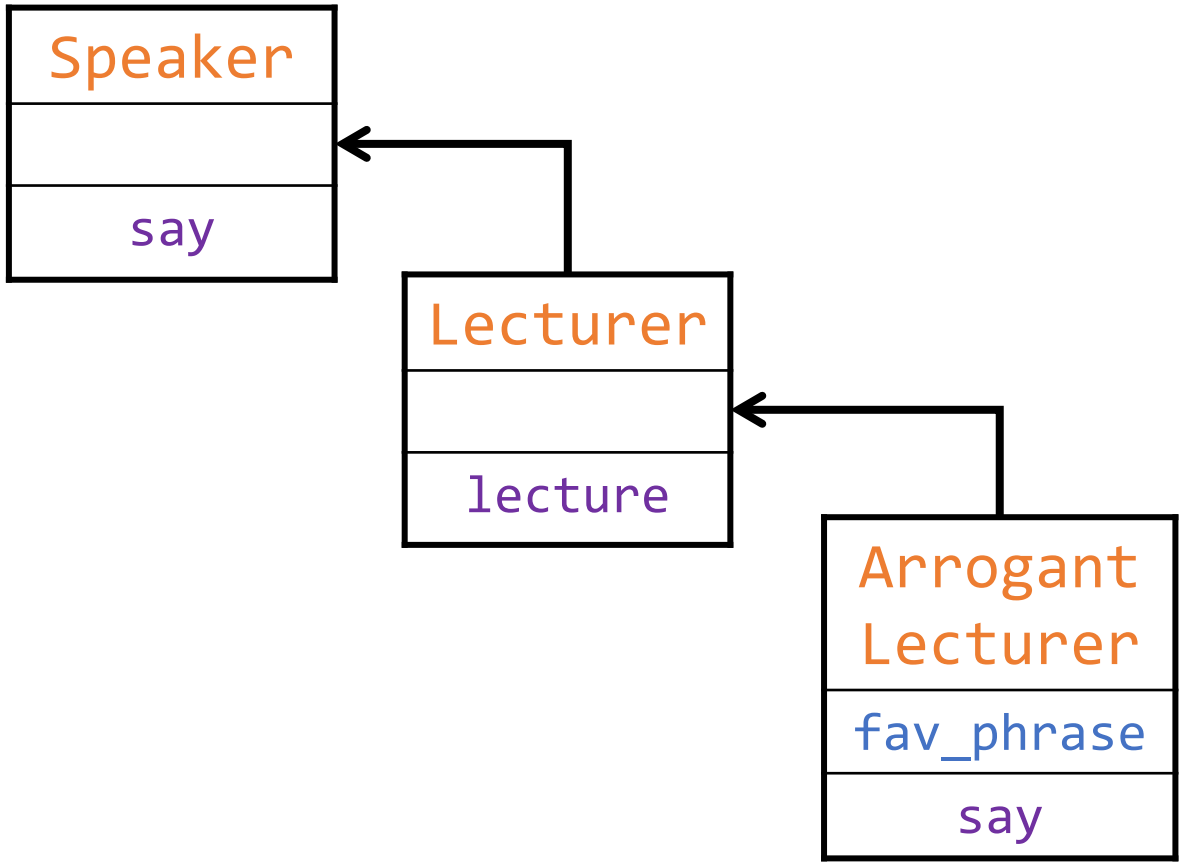
- Define an arrogant lecturer to be a kind of lecturer
- Whenever an arrogant lecturer says anything, she or he will say it as an ordinary lecturer would, but he will also add some favourite phrase of his/hers at the end.

Making an Arrogant Lecturer

```
class ArrogantLecturer(Lecturer):
  def __init__(self, fav_phrase):
    self.fav_phrase = fav_phrase

  def say(self, stuff):
    super().say(stuff + self.fav_phrase)
```

`super()` allows us to access methods in the superclass.

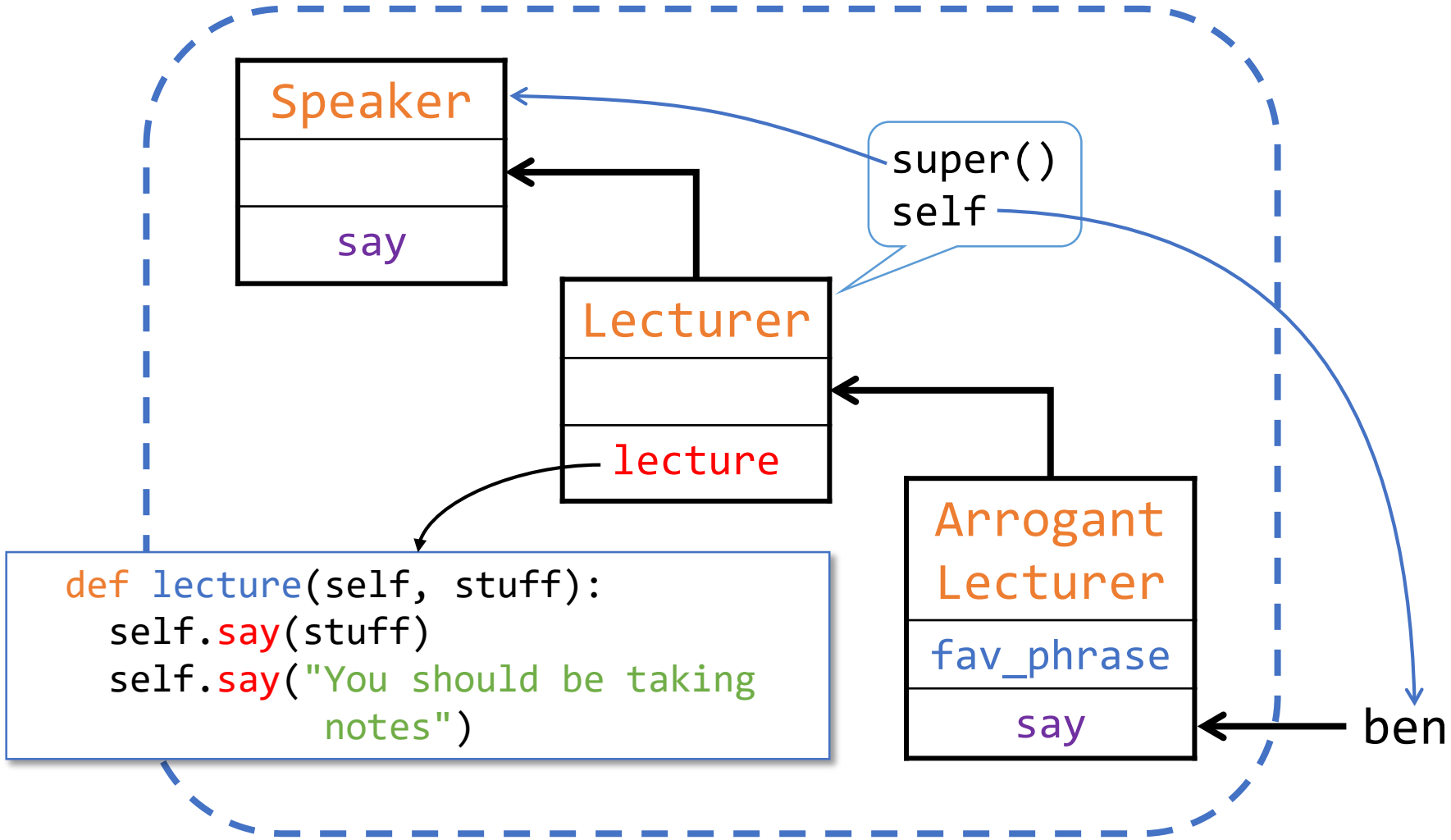
Object Hierarchy



Example: An Arrogant Lecturer in action

```
>>> ben = ArrogantLecturer(" ... How cool is that?")

>>> ben.say("We'll have a PE tomorrow")
We'll have a PE tomorrow ... How cool is that?

>>> ben.lecture("Python is cool")
Python is cool ... How cool is that?
You should be taking notes ... How cool is that?
```

Class Hierarchy



Polymorphism

Polymorphism

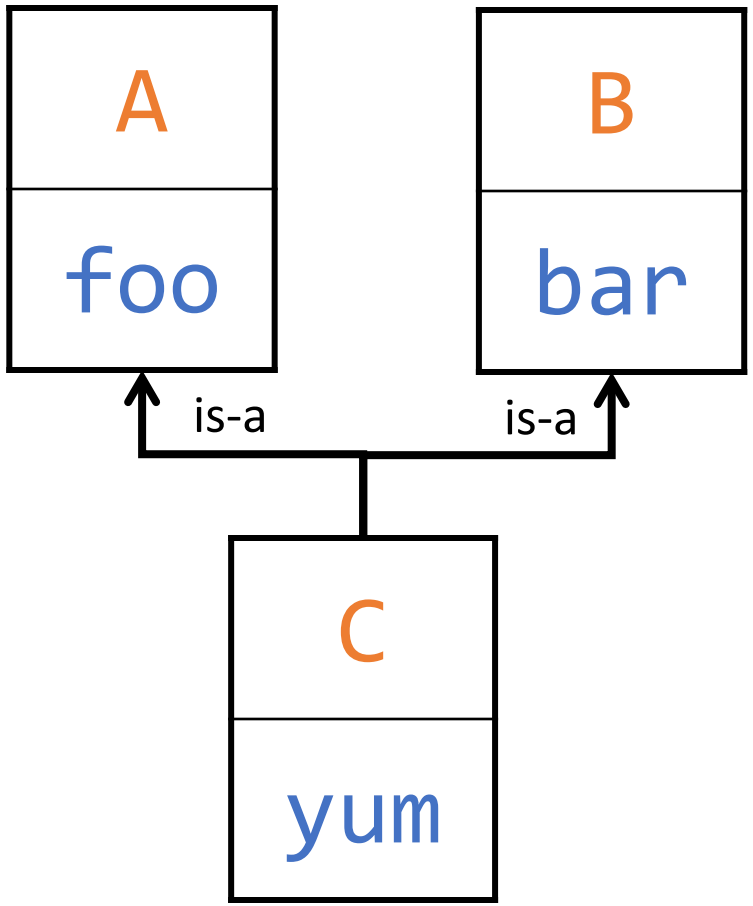
- Poly = many; Morphism = form
- Object-oriented programming provides a convenient means for handling polymorphic functions (overloading)
  - Functions that take different types of arguments
- The same message can be sent to different types of objects and handled by different methods that perform the proper actions based on the object class (overriding)
  - e.g. ask a speaker, lecturer, or arrogant-lecturer to “say” something

How would you implement overloading?

Polymorphism

- Benefits for programmer:
  - does not need to worry about the type of the object
  - can focus on the message

Multiple Inheritance



- A class can inherit from multiple classes
- C is subclass of both A and B
- A class inherits both its state and methods from superclasses
  - C has methods: `foo, bar, yum`
- Multiple inheritance has issues:
  - Not all languages support this
  - Resolution order issues

Multiple Inheritance

```
class Singer(object):
    def say(self, stuff):
        print("tra-la-la -- " + stuff)

    def sing(self):
        print("tra-la-la")
```

What does the singer do?

What is the singer a subclass of?

Singer Sings

```
>>> taylor_swift = Singer()
>>> taylor.say("I like the way you sound in the morning")
tra-la-la -- I like the way you sound in the morning

>>> taylor_swift.sing()
tra-la-la
```

Moonlighting.... shhhhh

Suppose Ben decides to moonlight as a singer....

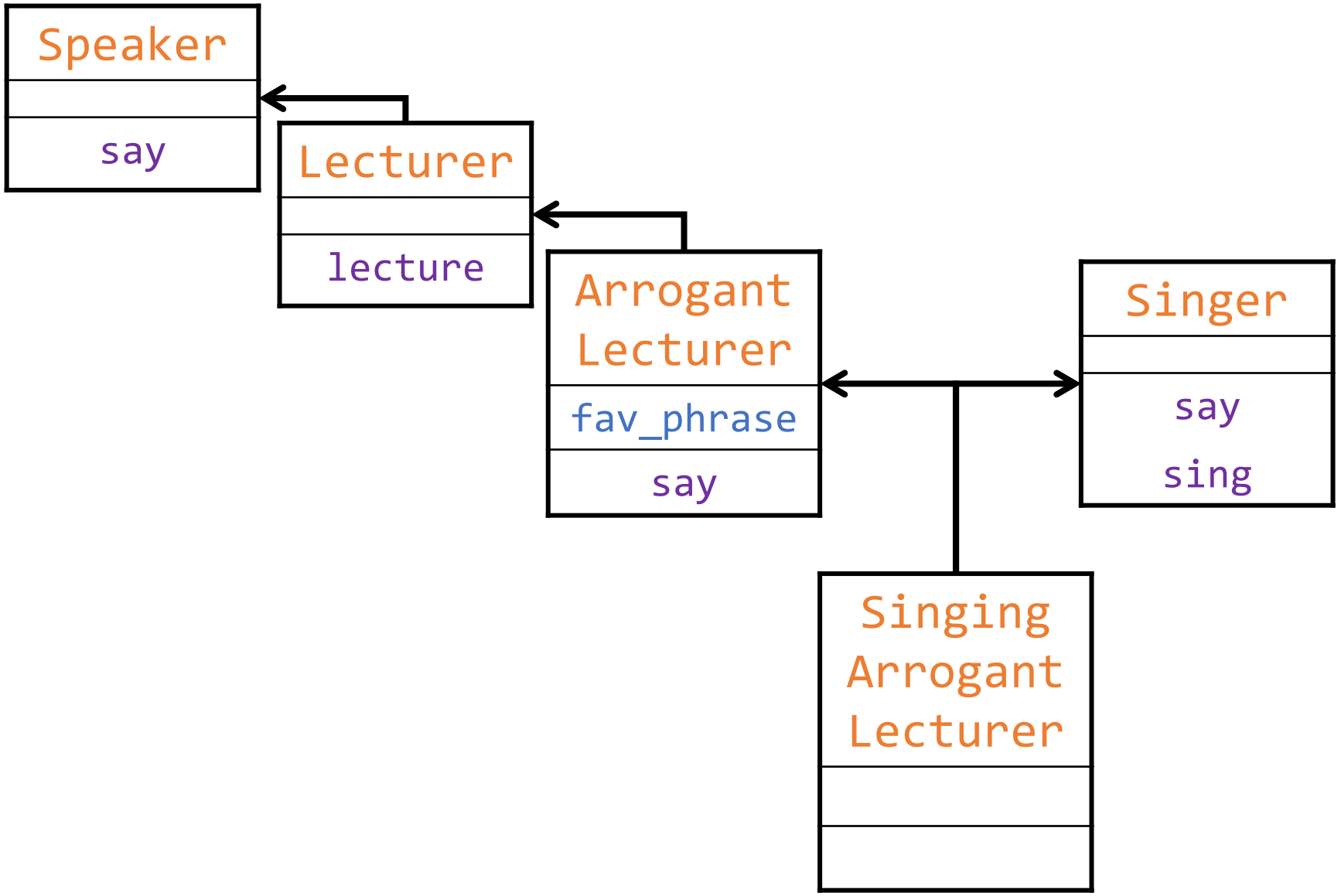
```
class SingingArrogantLecturer(ArrogantLecturer, Singer):
    def __init__(self, fav_phrase):
        super().__init__(fav_phrase)
```

Note the order of the super class!

Ben showing off his hidden talents

```
>>> ben = SingingArrogantLecturer(" ... How cool is that?")

>>> ben.say("We'll have a PE tomorrow")
We'll have a PE tomorrow ... How cool is that?
```

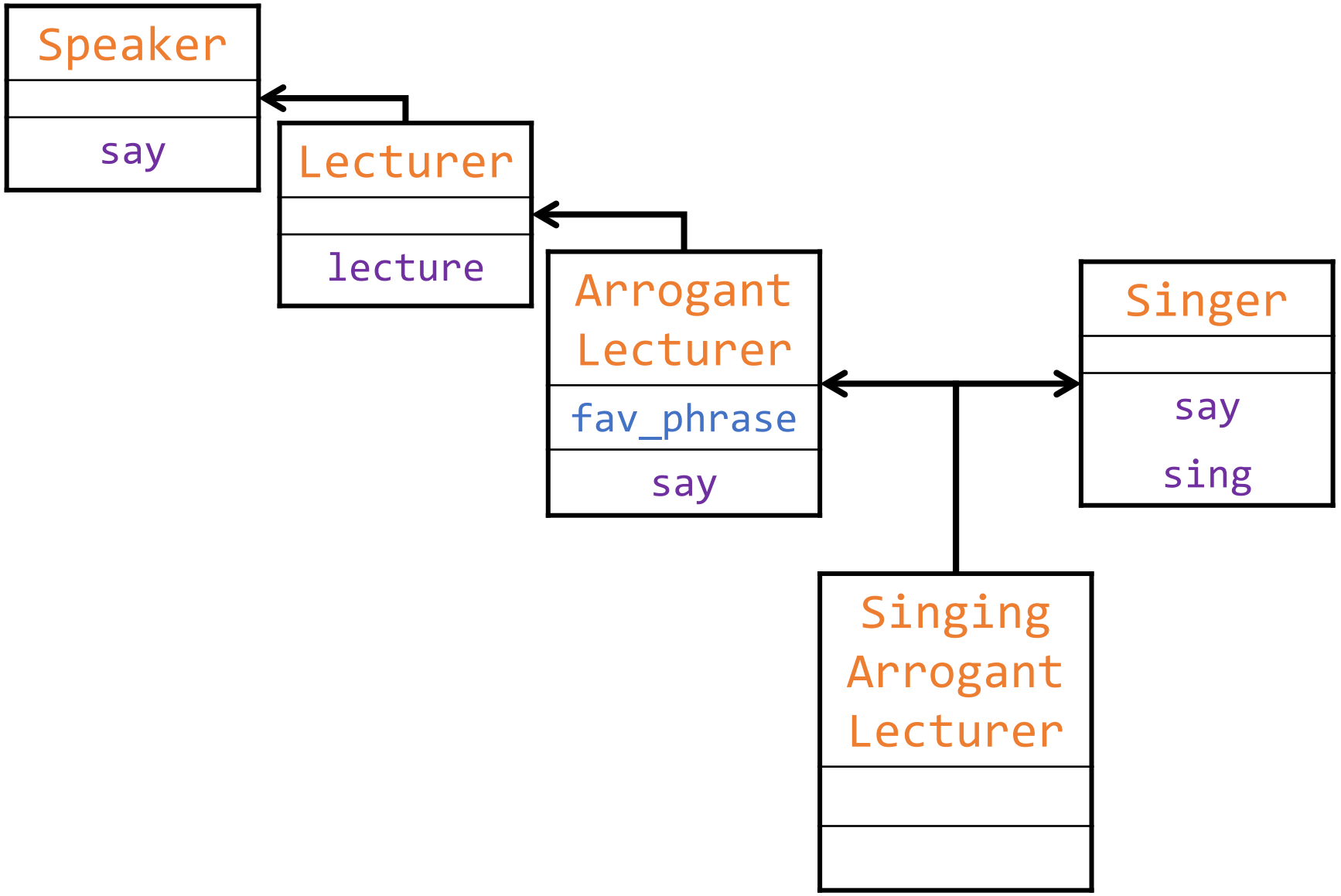
Object Hierarchy



Ben showing off his hidden talents

```
>>> ben.lecture("Python is cool")
Python is cool ... How cool is that?
You should be taking notes ... How cool is that?

>>> ben.sing()
tra-la-la
```

Object Hierarchy



Multiple Inheritance

- Complication arises when the same method is available in two distinct superclasses
- Ben is both a singer and a lecturer, but primarily a lecturer
- If his internal arrogant lecturer has a method with the name given by the message, then that method is returned
- If the singer has no method with that name, then the message is passed to the internal singer.

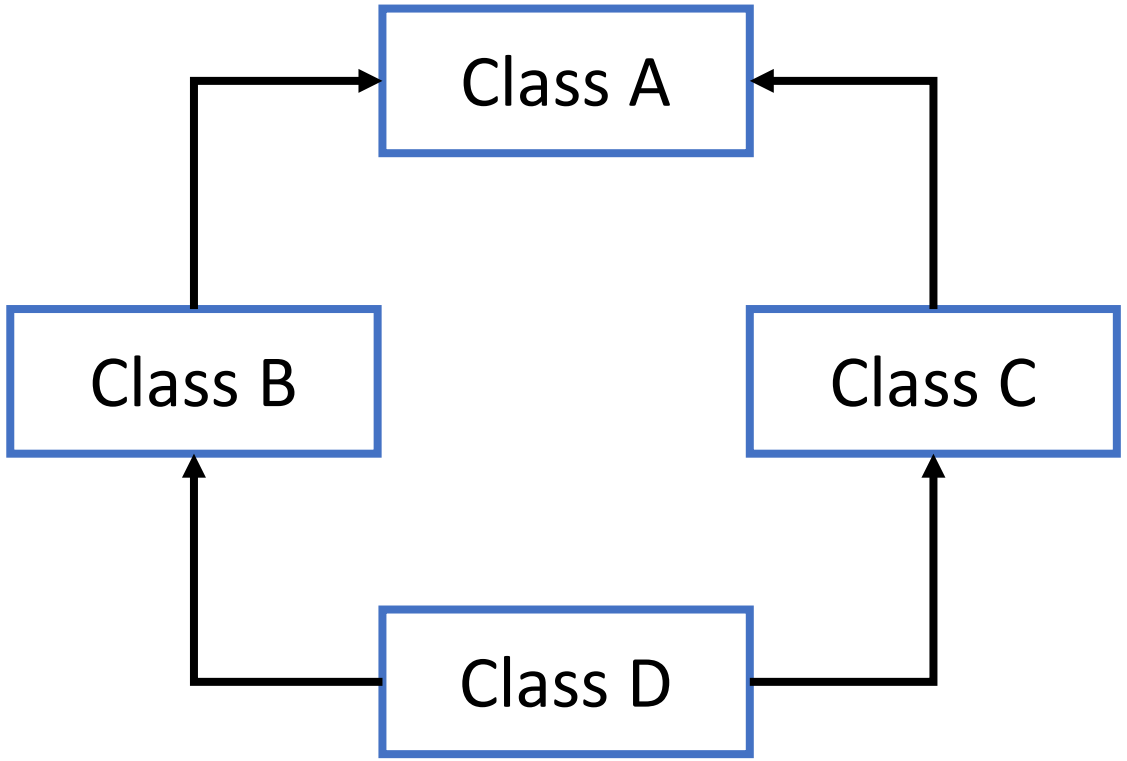
Diamond Inheritance

Suppose Singer inherits Speaker

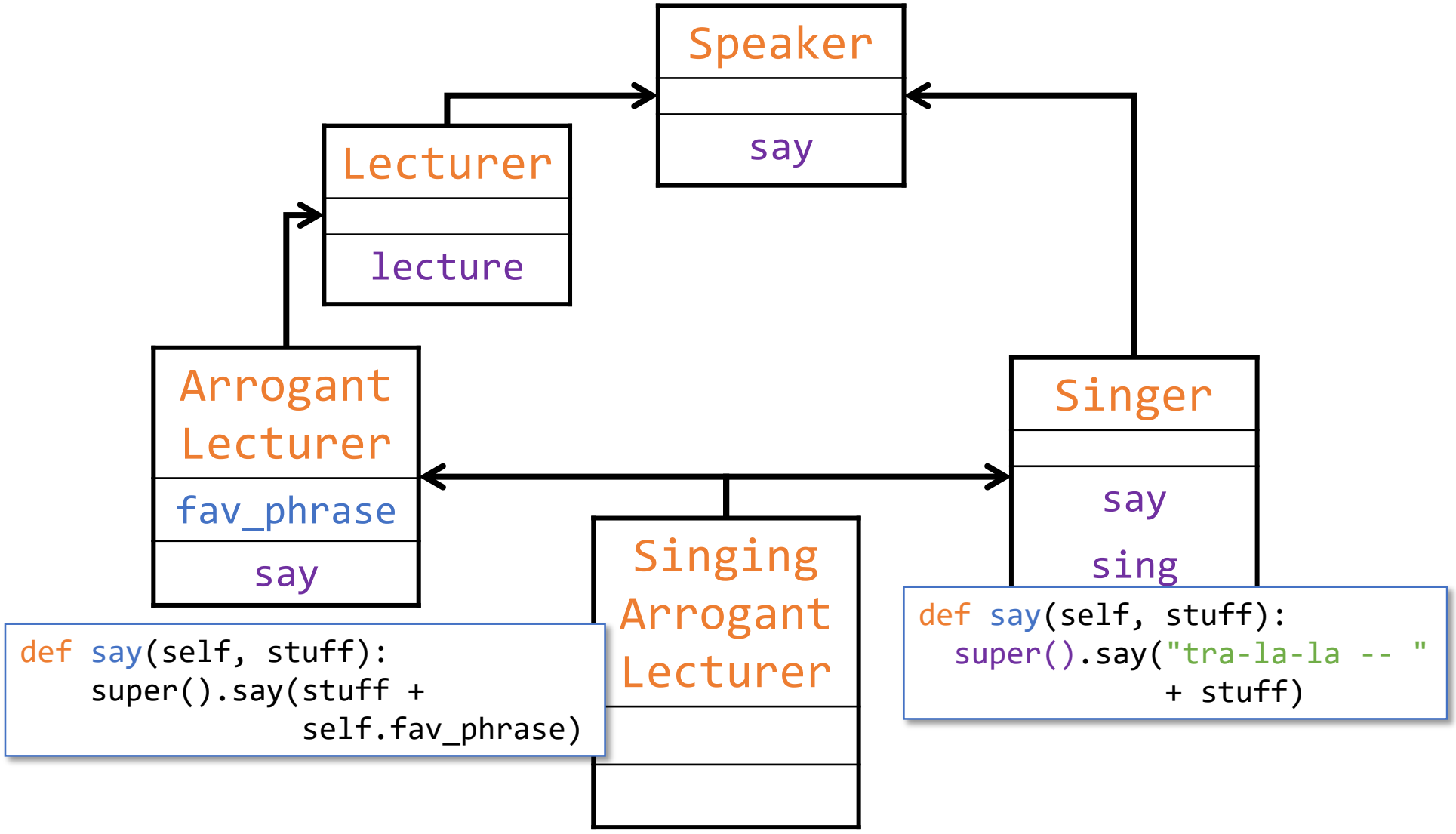
```
class Singer(Speaker):
    def say(self, stuff):
        super().say("tra-la-la -- " + stuff)

    def sing(self):
        print("tra-la-la")
```

Diamond Problem

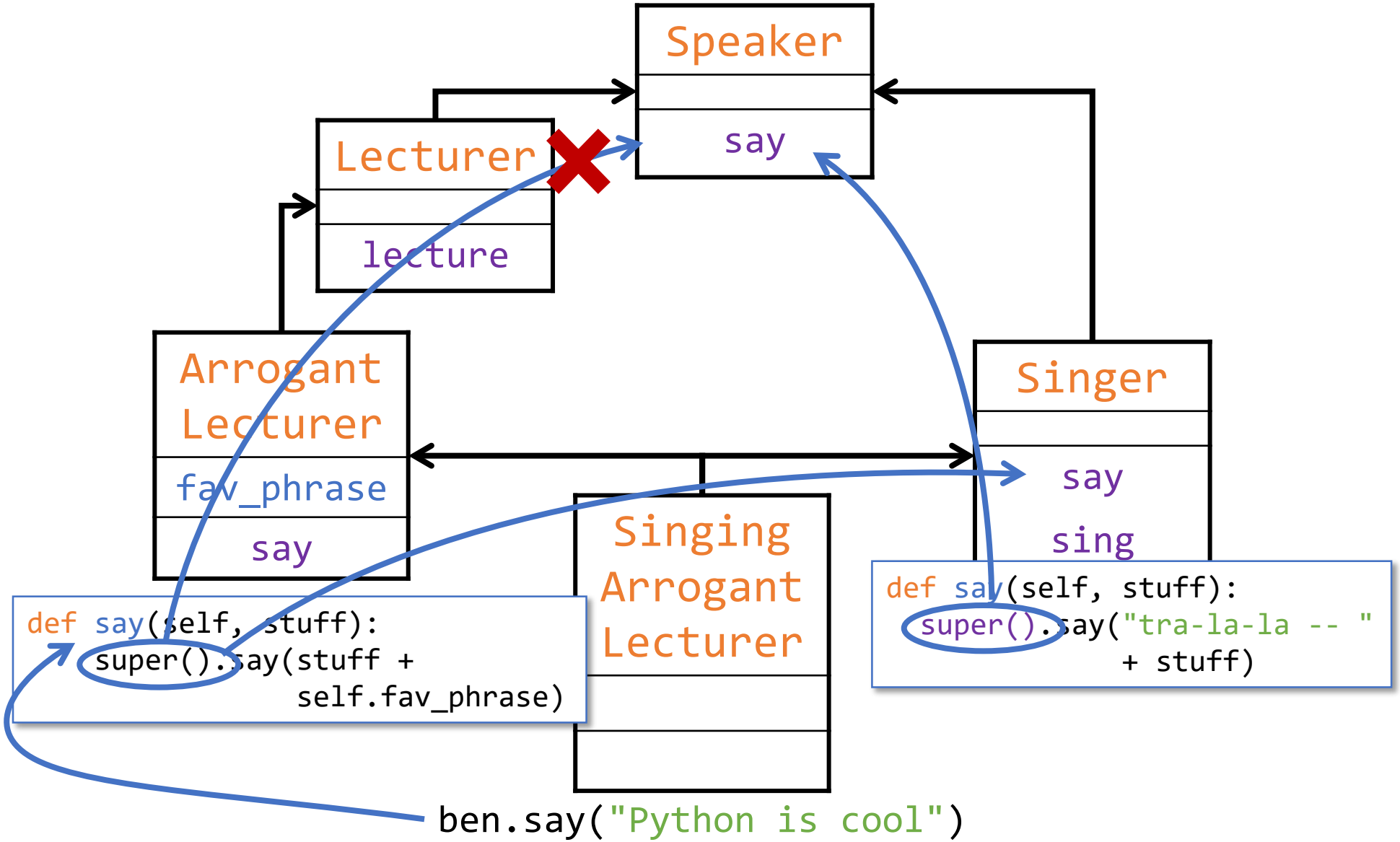
If all classes have same method.
Which class's method to call?



Diamond Hierarchy



Diamond Hierarchy



Benefits of OOP

- Simplification of complex, possibly hierarchical structures
- Easy reuse of code
- Easy code modifiability
- Intuitive methods
- Hiding of details through message passing and polymorphism

Costs of OOP

Overhead associated with the creation of classes, methods and instances

Major Programming Paradigms

- Imperative Programming
  - C, Pascal, Algol, Basic, Fortran
- Functional Programming
  - Scheme, ML, Haskell,
- Logic Programming
  - Prolog, CLP
- Object-oriented programming
  - Java, C++, Smalltalk

Python??

Which is the best paradigm?

- Certain tasks may be easier using a particular style
- Any style is general enough such that a problem written in one style could be rewritten in another style
- Choice of paradigm is context dependent and subjective

Summary

- Classes: capture common behavior
- Instances: unique identity with own local state
- Hierarchy of classes
  - Inheritance of state and behavior from superclass
  - Multiple inheritance: rules for finding methods
- Polymorphism : override methods with new functionality