OBJECT ORIENTED PROGRAMMING

OBJECTS

- Python supports many different kinds of data

`1234` `3.14159` `"Hello"` `[1, 5, 7, 11, 13]`

`{"CA": "California", "MA": "Massachusetts"}`

- each is an instance of an **object**, and every object has:
  - a **type**
  - an internal **data representation** (primitive or composite)
  - a set of procedures for **interaction** with the object
- each **instance** is a particular type of object
  - `1234` is an instance of an `int`
  - `a = "hello"`
    `a` is an instance of a string

OBJECT ORIENTED PROGRAMMING (OOP)

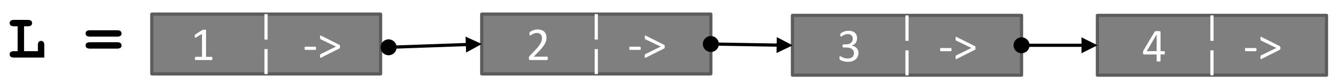
- everything in Python is an **object** and has a **type**
- objects are a **data abstraction** that capture:
  - internal **representation** through data attributes
  - **interface** for interacting with object through methods (procedures), defines behaviors but hides implementation
- can **create new instances** of objects
- can **destroy objects**
  - explicitly using `del` or just "forget" about them
  - Python system will reclaim destroyed or inaccessible objects – called "garbage collection"

STANDARD DATA OBJECTS

- some object types built in to Python
  - lists – [1, 2, 3, 4]
  - tuples – (1, 2, 3, 4)
  - strings – ‘abcd’
- want to explore ability to create our own data object types

EXAMPLE: [1,2,3,4]

- `[1,2,3,4]` is of type `list`
- how are lists **represented internally**? linked list of cells



follow pointer to the next index

- how to **manipulate** lists?
  - `L[i], L[i:j], L[i,j,k], +`
  - `len(), min(), max(), del(L[i])`
  - `L.append(),L.extend(),L.count(),L.index(),`
    `L.insert(),L.pop(),L.remove(),L.reverse(), L.sort()`
- internal representation should be **private**
- correct behavior may be compromised if you manipulate internal representation directly – **use defined interfaces**

CREATING AND USING YOUR OWN OBJECTS WITH CLASSES

- make a distinction between **creating a class** and **using an instance** of the class
- **creating** the class involves
  - defining the class name
  - defining class attributes
  - for example, someone wrote code to implement a list class
- **using** the class involves
  - creating new instances of objects
  - doing operations on the instances
  - for example, `L=[1,2]` and `len(L)`

ADVANTAGES OF OOP

- **bundle data into packages** together with procedures that work on them through well-defined interfaces
- **divide-and-conquer** development
  - implement and test behavior of each class separately
  - increased modularity reduces complexity
- classes make it easy to **reuse** code
  - many Python modules define new classes
  - each class has a separate environment (no collision on function names)
  - inheritance allows subclasses to redefine or extend a selected subset of a superclass' behavior

DEFINE YOUR OWN TYPES

- use the `class` keyword to define a new type

class name

class parent

```
class Coordinate(object):
    <define attributes here>
```

class definition

- similar to `def`, indent code to indicate which statements are part of the **class definition**
- the word `object` means that `Coordinate` is a Python object and **inherits** all its attributes (coming soon)
  - `Coordinate` is a subclass of `object`
  - `object` is a superclass of `Coordinate`

WHAT ARE ATTRIBUTES?

- data and procedures that "**belong**" to the class
- **data** attributes
  - think of data as other objects that make up the class
  - for example, a coordinate is made up of two numbers
- procedural attributes (**methods**)
  - think of methods as functions that only work with this class
  - for example you can define a distance between two coordinate objects but there is no meaning to a distance between two list objects

DEFINING HOW TO CREATE AN INSTANCE OF A CLASS

- first have to define **how to create an instance** of object
- use a **special method called `__init__`** to initialize some data attributes

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
```

what data initializes a `Coordinate` object

parameter to refer to an instance of the class

special method to create an instance is double __ underscore

two data attributes for every `Coordinate` object

when we invoke creation of an instance, this will bind the variables x and y within that instance to the supplied values

ACTUALLY CREATING AN INSTANCE OF A CLASS

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.x)
print(origin.x)
```

create a new object of type `Coordinate` and pass in 3 and 4 to the `__init__` method

note that argument for self is automatically supplied by Python!

use the dot to access an attribute of instance `c`

- data attributes of an instance are called **instance variables**
- don't provide argument for `self`, Python does this automatically

ACTUALLY CREATING AN INSTANCE OF A CLASS

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.x)
print(origin.x)
```

- think of `c` as pointing to a frame (like we saw with function calls)
  - within the scope of that frame we bound values to data attribute variables
  - `c.x` is interpreted as getting the value of `c` (a frame) and then looking up the value associate with `x` within that frame (thus the specific value for this instance)

WHAT IS A METHOD?

- procedural attribute, like a **function that works only with this class**
- Python always passes the actual object as the first argument, convention is to use **`self`** as the name of the first argument of all methods
- the **"." operator** is used to access any attribute
  - a data attribute of an object
  - a method of an object

DEFINE A METHOD FOR THE `Coordinate` CLASS

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
```

use it to refer to any instance

another parameter to method

dot notation to access data

- other than `self` and dot notation, methods behave just like functions (take params, do operations, return value)

HOW TO USE A METHOD FROM THE `Coordinate` CLASS

```
def distance(self, other)
```

- conventional way

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.distance(origin))
```

object on which to call method

name of method

parameters not including `self` (`self` is implied to be `c`)

- equivalent to

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(Coordinate.distance(c, origin))
```

name of class

name of method

parameters, including an object on which to call the method, representing `self`

HOW TO USE A METHOD FROM THE `Coordinate` CLASS

```
def distance(self, other)
```

- conventional way

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.distance(origin))
```

- equivalent to

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(Coordinate.distance(c, origin))
```

- think of `Coordinate` as pointing to a frame
  - within the scope of that frame we created methods
  - `Coordinate.distance` gets the value of `Coordinate` (a frame), then looks up the value associated with `distance` (a procedure), then invokes it (which requires two arguments)
  - `c.distance` inherits the `distance` from the class definition, an automatically uses c as the first argument

PRINT REPRESENTATION OF AN OBJECT

```
In  [1]: c = Coordinate(3,4)
In  [2]: print(c)

<__main__.Coordinate object at 0x7fa918510488>
```

- **uninformative** print representation by default
- define a **`__str__` method** for a class
- Python calls the `__str__` method when used with `print` on your class object
- you choose what it does! Say that when we print a `Coordinate` object, want to show

```
In  [3]: print(c)
<3,4>
```

DEFINING YOUR OWN PRINT METHOD

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
    def __str__(self):
        return "<" + str(self.x) + "," + str(self.y) + ">"
```

name of special method

must return a string

WRAPPING YOUR HEAD AROUND TYPES AND CLASSES

- can ask for the type of an object instance

```
In  [4]: c = Coordinate(3,4)
In  [5]: print(c)
<3,4>
In  [6]: print(type(c))
<class __main__.Coordinate>
```

- this makes sense since

```
In  [7]: print(Coordinate, type(Coordinate))
<class __main__.Coordinate> <type 'type'>
```

- use `isinstance()` to check if an object is a `Coordinate`

```
In  [8]: print(isinstance(c, Coordinate))
True
```

SPECIAL OPERATORS

- +, -, ==, <, >, len(), print, and many others

https://docs.python.org/3/reference/datamodel.html#basic-customization

- like `print`, can override these to work with your class
- define them with double underscores before/after

```
__add__(self, other)    →    self + other
__sub__(self, other)    →    self - other
__eq__(self, other)     →    self == other
__lt__(self, other)     →    self < other
__len__(self)           →    len(self)
__str__(self)           →    print(self)
```

... and others

EXAMPLE: FRACTIONS

- create a **new type** to represent a number as a fraction
- **internal representation** is two integers
  - numerator
  - denominator
- **interface** a.k.a. **methods** a.k.a **how to interact** with `Fraction` objects
  - print representation
  - add, subtract
  - convert to a float

INITIAL FRACTION CLASS

```
class fraction(object):
    def __init__(self, numer, denom):
        self.numer = numer
        self.denom = denom
    def __str__(self):
        return str(self.numer) + ' / ' + str(self.denom)
```

INITIAL FRACTION CLASS

```
In  [9]: oneHalf = fraction(1,2)

In [10]: twoThirds = fraction(2,3)

In [11]: print(oneHalf)
1 / 2

In [12]: print(twoThirds)
2 / 3
```

ACCESSING DATA ATTRIBUTES

```
class fraction(object):
    def __init__(self, numer, denom):
        self.numer = numer
        self.denom = denom
    def __str__(self):
        return str(self.numer) + ' / ' + str(self.denom)
    def getNumer(self):
        return self.numer
    def getDenom(self):
        return self.denom
```

ACCESSING DATA ATTRIBUTES

```
In  [9]: oneHalf = fraction(1,2)

In [10]: twoThirds = fraction(2,3)

In [13]: oneHalf.getNumer()
Out[13]: 1

In [14]: fraction.getDenom(twoThirds)
Out[14]: 3
```

this is a procedure, so must invoke by passing in arguments (zero in this case)

ADDING METHODS

```
class fraction(object):
    def __init__(self, numer, denom):
        self.numer = numer
        self.denom = denom
    def __str__(self):
        return str(self.numer) + ' / ' + str(self.denom)
    def getNumer(self):
        return self.numer
    def getDenom(self):
        return self.denom
    def __add__(self, other):
        numerNew = other.getDenon() * self.getNumer() \
                   + other.getNumER() * self.getDenom()
        denomNew = other.getDenom() * self.getDenom()
        return fraction(numerNew, denomNew)
    def __sub__(self, other):
        numerNew = other.getDenom() * self.getNumer() \
                   - other.getNumer() * self.getDenom()
        denomNew = other.getDenom() * self.getDenom()
        return fraction(numerNew, denomNew)
```

ADDING METHODS

```
In  [9]: oneHalf = fraction(1,2)

In [10]: twoThirds = fraction(2,3)

In [15]: new = oneHalf + twoThirds

In [16]: print(new)
7 / 6
```

ADDING MORE METHODS

```
class fraction(object):
    def __init__(self, numer, denom):
        self.numer = numer
        self.denom = denom
    def __str__(self):
        return str(self.numer) + ' / ' + str(self.denom)
    def getNumer(self):
        return self.numer
    def getDenom(self):
        return self.denom
    def __add__(self, other):
        numerNew = other.getDenon() * self.getNumer() \
                   + other.getNumER() * self.getDenom()
        denomNew = other.getDenom() * self.getDenom()
        return fraction(numerNew, denomNew)
    def __sub__(self, other):
        numerNew = other.getDenom() * self.getNumer()\
                   - other.getNumer() * self.getDenom()
        denomNew = other.getDenom() * self.getDenom()
        return fraction(numerNew, denomNew)
    def convert(self):
        return self.getNumer() / self.getDenom()
```

ADDING MORE METHODS

```
In  [9]: oneHalf = fraction(1,2)

In [10]: twoThirds = fraction(2,3)

In [17]: new = oneHalf + twoThirds

In [18]: new.convert()
Out[18]: 1.1666666666666667
```

EXAMPLE: A SET OF INTEGERS

- create a new type to represent a **collection of integers**
  - initially the set is empty
  - a particular integer appears only once in a set: **representational invariant** enforced by the code
- internal **data representation**
  - use a list to store the elements of a set
- **interface**

`insert(e)` – insert integer `e` into set if not there

`member(e)` – return `True` if integer `e` is in set, `False` else

`remove(e)` – remove integer `e` from set, error if not present

INTEGER SET CLASS

```
class intSet(object):
    def __init__(self):
        self.vals = []
    def insert(self, e):
        if not e in self.vals:
            self.vals.append(e)
    def member(self, e):
        return e in self.vals
    def remove(self, e):
        try:
            self.vals.remove(e)
        except:
            raise ValueError(str(e) + ' not found')
    def __str__(self):
        self.vals.sort()
        result = ''
        for e in self.vals:
            result = result + str(e) + ','
        return '{' + result[:-1] + '}'
```

using properties of lists; ensuring that element only appears once

using property that list is an iterable

can use exception to catch attempt to remove nonexistent element

USING INTEGER SETS

```
In [19]: s = intSet()

In [20]: print(s)
{}

In [21]: s.insert(3)
In [22]: s.insert(4)
In [23]: s.insert(3)
In [24]: print(s)
{3, 4}
```

USING INTEGER SETS

```
In [19]: s = intSet()
In [21]: s.insert(3)
In [22]: s.insert(4)
In [23]: s.insert(3)

In [25]: s.member(3)
True

In [26]: s.member(6)
False
```

USING INTEGER SETS

```
In [19]: s = intSet()
In [21]: s.insert(3)
In [22]: s.insert(4)
In [23]: s.insert(3)

In [27]: s.remove(3)
In [28]: s.insert(6)

In [29]: print(s)
{4,6}
```

USING INTEGER SETS

```
In [19]: s = intSet()
In [21]: s.insert(3)
In [22]: s.insert(4)
In [23]: s.insert(3)
In [27]: s.remove(3)
In [28]: s.insert(6)

In [30]: s.remove(3)
ValueError: 3 not found
```

THE POWER OF OOP

- **bundle together objects** that share
  - common attributes and
  - procedures that operate on those attributes
- use **abstraction** to make a distinction between how to implement an object vs how to use the object
- build **layers** of object abstractions that inherit behaviors from other classes of objects
- create our **own classes of objects** on top of Python's basic classes

IMPLEMENTING THE CLASS vs USING THE CLASS

- write code from two different perspectives
- all class examples we saw so far were numerical

implementing a new object type with a class

- **define** the class
- define **data attributes** (what IS the object)
- define **methods** (HOW to use the object)

using the new object type in code

- create **instances** of the object type
- do **operations** with them

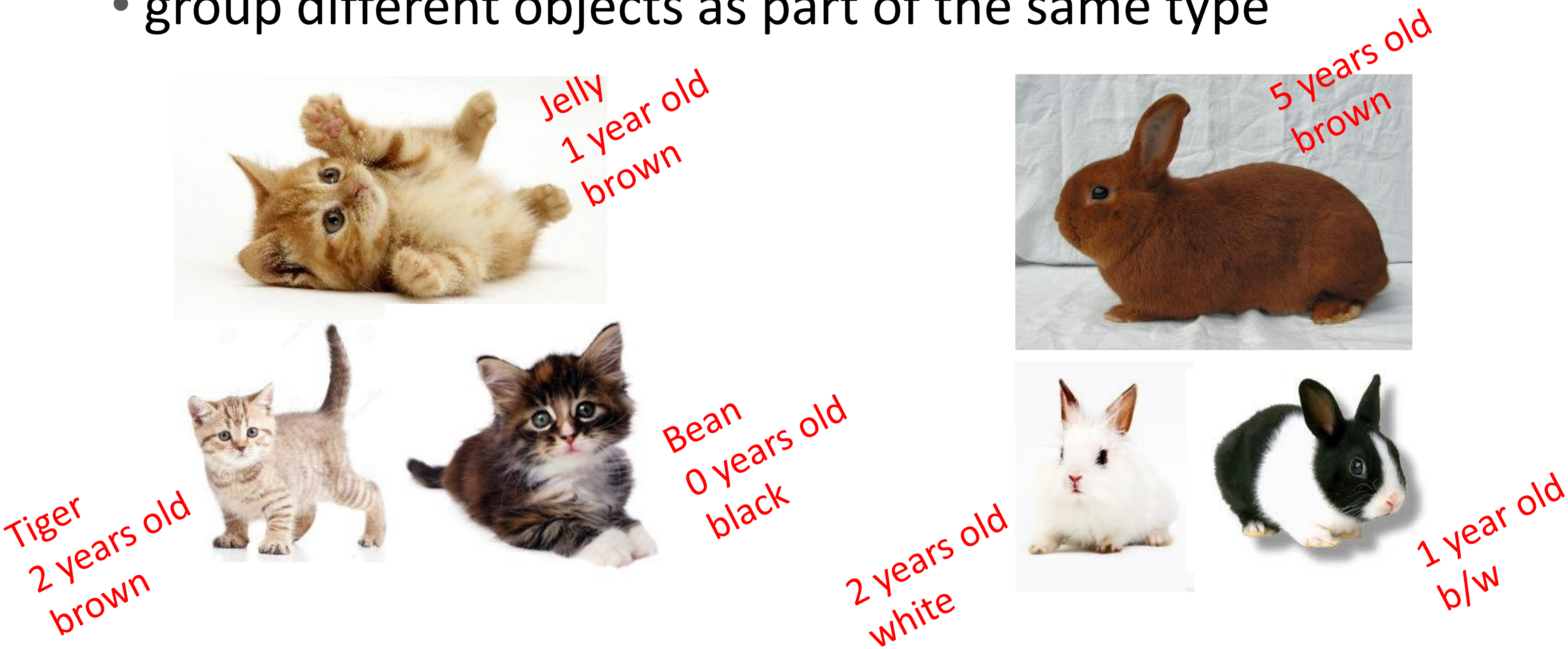
CLASS DEFINITION OF AN OBJECT TYPE vs INSTANCE OF A CLASS

- class is the **type**
  - a `Coordinate` type
  - `class Coordinate(object):`
- class is defined generically
  - use `self` to refer to any instance while defining the class
- class defines data and methods **common across all instances**

- instance is **one particular** object
  - `mycoo = Coordinate(1,2)`
- data values vary between instances
  - `c1 = Coordinate(1,2)`
  - `c2 = Coordinate(3,4)`
  - `C1` and `c2` have different data values because they are different objects
- instance has the **structure of the class**

WHY USE OOP AND CLASSES OF OBJECTS?

- mimic real life
- group different objects as part of the same type



WHY USE OOP AND CLASSES OF OBJECTS?

- mimic real life
- group different objects as part of the same type

GROUPS OF OBJECTS HAVE ATTRIBUTES

- **data attributes**
  - how can you represent your object with data?
  - **what it is**
  - <for a coordinate: x and y values>
  - <for an animal: age, name>
- **procedural attributes** (behavior/operations/methods)
  - what kinds of things can you do with the object?
  - **what it does**
  - <for a coordinate: find distance between two>
  - <for an animal: make a sound>

DEFINING A CLASS (Recap)

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None

myanimal = Animal(3)
```

class definition

name

class parent

variable to refer to an instance of the class

what data initializes an Animal type

special method to create an instance

name is a data attribute even though an instance is not initialized with it as a parameter

one instance

mapped to self.age in class def

GETTER AND SETTER METHODS

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def __str__(self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

getter

setter

- **getters and setters** should be used outside of class to access data attributes

AN INSTANCE and DOT NOTATION (Recap)

- instantiation creates an **instance of an object**

```
a = Animal(3)
```

- **dot notation** used to access attributes (data and methods) though it is better to use getters and setters to access data attributes

```
a.age
```

```
a.get_age()
```

access data attribute

access and **use** method; if just call `a.get_age`, get method but don't invoke

INFORMATION HIDING

- author of class definition may **change data attribute** variable names

replaced age data attribute by years

```
class Animal(object):
    def __init__(self, age):
        self.years = age
    def get_age(self):
        return self.years
```

- if you are **accessing data attributes** outside the class and class **definition changes**, may get errors
- outside of class, use getters and setters instead
  use `a.get_age()` NOT `a.age`
  - good style
  - easy to maintain code
  - prevents bugs

PYTHON NOT GREAT AT INFORMATION HIDING

- allows you to **access data** from outside class definition

```
print(a.age)
```

- allows you to **write to data** from outside class definition

```
a.age = 'infinite'
```

- allows you to **create data attributes** for an instance from outside class definition

```
a.size = "tiny"
```

- it's **not good style** to do any of these!

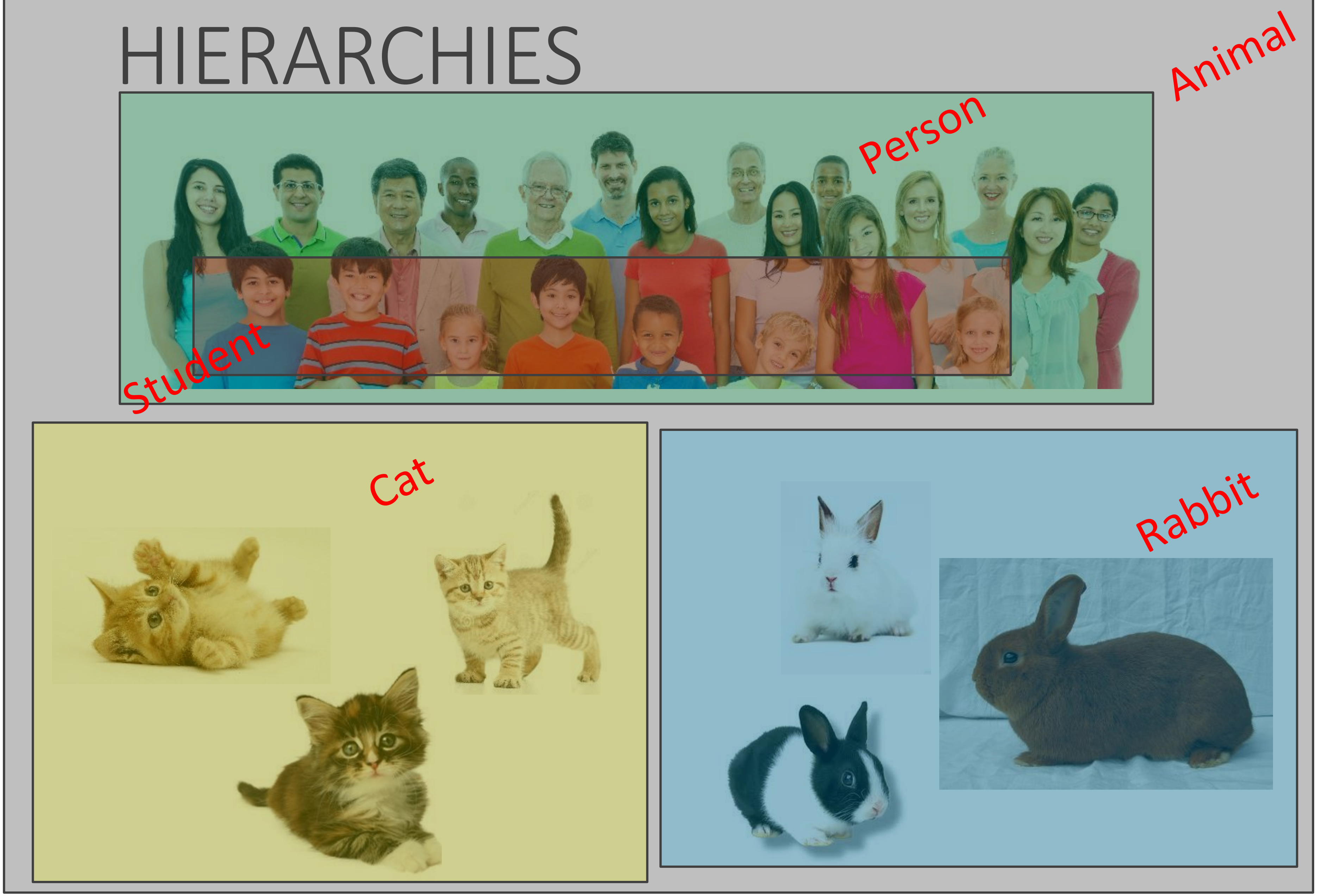
`self` AND OTHER ARGS

- **`self` determined from instance**, passed in as argument
  - for the method: `def __init__(self, age)`
    - creates self, passes it in automatically as argument

```
a = Animal(3)
```

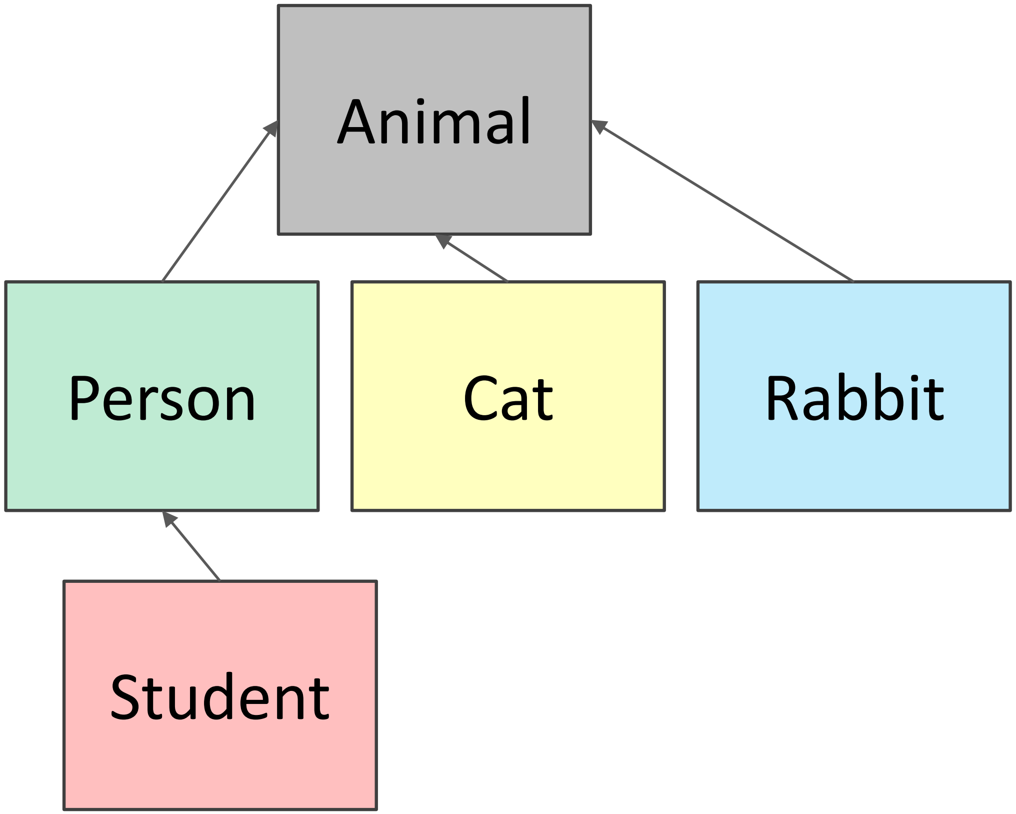
  - for the method: `def get_age(self)`
    - call method with `a.get_age()`
    - or an alternate way `Animal.get_age(a)`
- **default arguments** for formal parameters are used if no actual argument is given
  - for the method: `def set_name(self, newname="")`
    - default argument used here `a.set_name()`
    - argument passed is used here `a.set_name("fluffy")`

HIERARCHIES



HIERARCHIES

- **parent class** (superclass)
- **child class** (subclass)
  - **inherits** all data and behaviors of parent class
  - **add** more **info**
  - **add** more **behavior**
  - **override** behavior



INHERITANCE

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def __str__(self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

- everything is an object
- class `object` implements basic operations in Python, like binding variables, etc

- new object class inherits properties of underlying Python class `object`

INHERITANCE

inherits all attributes of `Animal`:
__init__()
age, name
get_age(), get_name()
set_age(), set_name()
__str__()

```
class Cat(Animal):
    def speak(self):
        print("meow”)
    def __str__(self):
        return "cat:"+str(self.name)+":"+str(self.age)
```

add new functionality via new methods

overrides __str__ from Animal

- add new functionality with `speak()`
  - instance of type `Cat` can be called with new methods
  - instance of type `Animal` throws error if called with new methods
- `__init__` is not missing, uses the `Animal` version

USING THE HIERARCHY

```
In [31]: jelly = Cat(1)
In [32]: jelly.set_name('JellyBelly')
In [33]: print(jelly)
cat:JellyBelly:1

In [34]: print(Animal.__str__(jelly))
Animal:JellyBelly:1

In [35]: blob = Animal(1)
In [36]: print(blob)
animal:None:1

In [37]: blob.set_name()
In [38]: print(blob)
animal::1
```

inherits method from `Animal`

cat `__str__` method shadows method from `Animal`

could explicitly recover underlying `Animal` method

can change values of attributes of an instance

INHERITANCE

```
class Cat(Animal):
    def speak(self):
        print("meow”)
    def __str__(self):
        return "cat:"+str(self.name)+":"+str(self.age)

class Rabbit(Animal):
    def speak(self):
        print(”meep”)
    def __str__(self):
        return ”rabbit:"+str(self.name)+":"+str(self.age)
```

USING THE HIERARCHY

```
In [31]: jelly = Cat(1)
In [34]: blob = Animal(1)
In [38]: peter = Rabbit(5)
In [39]: jelly.speak()
meow

In [40]: peter.speak()
meep

In [41]: blob.speak()
AttributeError: 'Animal' object has no
attribute 'speak'
```

uses method from `Cat`

uses method from `Rabbit`

tries to find method in `Animal`

WHICH METHOD TO USE?

- subclass can have **methods with same name** as superclass
- subclass can have **methods with same name** as other subclasses
- for an instance of a class, look for a method name in **current class definition**
- if not found, look for method name **up the hierarchy** (in parent, then grandparent, and so on)
- use first method up the hierarchy that you found with that method name

```python
class Person(Animal):
    def __init__(self, name, age):
        Animal.__init__(self, age)
        Animal.set_name(self, name)
        self.friends = []
    def get_friends(self):
        return self.friends
    def add_friend(self, fname):
        if fname not in self.friends:
            self.friends.append(fname)
    def speak(self):
        print("hello”)
    def age_diff(self, other):
        # alternate way: diff = self.age - other.age
        diff = self.get_age() - other.get_age()
        if self.age > other.age:
            print(self.name, "is", diff, "years older than", other.name)
        else:
            print(self.name, "is", -diff, "years younger than", other.name)
    def __str__(self):
        return "person:"+str(self.name)+":"+str(self.age)
```

parent class is `Animal`

call `Animal` constructor

call `Animal`'s method

add a new data attribute

new method to give age diff in a user friendly way

override `Animal`'s __str__ method

USING THE HIERARCHY

```
In [42]: eric = Person('Eric', 45)
In [43]: john = Person('John'  55)
In [44]: eric.speak()
Hello

In [45]: eric.age_diff(john)
Eric is 10 years younger than John

In [46]: Person.age_diff(john,eric)
John is 10 years older than Eric
```

uses method from `Person`

uses method associated with instance

can use class attribute to find method

```python
import random

class Student(Person):
    def __init__(self, name, age, major=None):
        Person.__init__(self, name, age)
        self.major = major
    def change_major(self, major):
       self= major
    def speak(self):
        r = random.random()
        if r < 0.25:
            print("i have homework")
        elif 0.25 <= r < 0.5:
            print("i need sleep")
        elif 0.5 <= r < 0.75:
            print("i should eat")
        else:
            print("i am watching tv")
    def __str__(self):
       return "student:"+str(self.name)+":"+str(self.age)+":"+str(self.major)
```

bring in methods from `random` class

inherits `Person` and `Animal` attributes

adds new data

- look up how to use the `random` class in the python docs
- `random()` method gives back float in [0, 1)

override `Person`'s `__str__` method

USING THE HIERARCHY

```
In [42]: eric = Person('Eric', 45)
In [47]: fred = Student('Fred', 18, 'Course VI')
In [48]: print(fred)
student:Fred:18:Course VI

In [49]: fred.speak()
i have homework
In [50]: fred.speak()
i have homework
In [51]: fred.speak()
i am watching tv
In [52]: fred.speak()
i should eat
```

uses method from `Student`

uses method from `Student`

if called multiple times, may get different behavior because of random

INSTANCE VARIABLES vs CLASS VARIABLES

- we have seen **instance variables** so far in code
- specific to an instance
- created for **each instance**, belongs to an instance
- used the generic variable name self within the class definition

`self.variable_name`

- introduce **class variables** that belong to the class
- defined inside class but outside any class methods, outside `__init__`
- **shared** among all objects/instances of that class

RECALL THE `Animal` CLASS

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def __str__(self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

CLASS VARIABLES AND THE `Rabbit` SUBCLASS

- **subclasses inherit** all data attributes and methods of the parent class

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
```

parent class

class variable

instance variable

access class variable

incrementing class variable changes it for all instances that may reference it

- `tag` used to give **unique id** to each new rabbit instance

Rabbit GETTER METHODS

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
    def get_rid(self):
        return str(self.rid).zfill(3)
    def get_parent1(self):
        return self.parent1
    def get_parent2(self):
        return self.parent2
```

method on a string to pad the beginning with zeros for example, 001 not 1

- getter methods specific for a `Rabbit` class
- there are also getters `get_name` and `get_age` inherited from `Animal`

EXAMPLE USAGE

```
In [53]: peter = Rabbit(2)
In [54]: peter.set_name('Peter')
In [55]: hopsy = Rabbit(3)
In [56]: hopsy.set_name('Hopsy')
In [57]: cotton = Rabbit(1, peter, hopsy)
In [58]: cotton.set_name('Cottontail')

In [59]: print(cotton)
animal:Cottontail:1

In [60]: print(cotton.get_parent1())
animal:Peter:2
```

uses method from `Animal`

providing explicit arguments

calling method returns instance; print then calls that instance's method

WORKING WITH YOUR OWN TYPES

```
def __add__(self, other):
        # returning object of same type as this class
        return Rabbit(0, self, other)
```

recall Rabbit's `__init__(self, age, parent1=None, parent2=None)`

- define **+ operator** between two `Rabbit` instances
  - define what something like this does: `r4 = r1 + r2` where `r1` and `r2` are `Rabbit` instances
  - `r4` is a new `Rabbit` instance with age 0
  - `r4` has `self` as one parent and `other` as the other parent
  - in `__init__`, should change to check that **`parent1` and `parent2` are of type `Rabbit`**

EXAMPLE USAGE

```
In [53]: peter = Rabbit(2)
In [54]: peter.set_name('Peter')
In [55]: hopsy = Rabbit(3)
In [56]: hopsy.set_name('Hopsy')
In [61]: mopsy = peter + hopsy
In [62]: mopsy.set_name('Mopsy')
In [63]: print(mopsy.get_parent1())
animal:Peter:2

In [64]: print(mopsy.get_parent2())
animal:Hopsy:3
```

SPECIAL METHOD TO COMPARE TWO `Rabbits`

- decide that two rabbits are equal if they have the **same two parents**

booleans

```
def __eq__(self, other):
    parents_same = self.parent1.rid == other.parent1.rid \
                   and self.parent2.rid == other.parent2.rid
    parents_opposite = self.parent2.rid == other.parent1.rid \
                       and self.parent1.rid == other.parent2.rid
    return parents_same or parents_opposite
```

- comparing ids of parents since **ids are unique** (due to class var)
- note that comparing objects (`self.parent1==other.parent1`) will call the `__eq__` method over and over until call it on None (will get `AttributeError`)

EXAMPLE USAGE

```
In [53]: peter = Rabbit(2)
In [54]: peter.set_name('Peter')
In [55]: hopsy = Rabbit(3)
In [56]: hopsy.set_name('Hopsy')
In [57]: cotton = Rabbit(1, peter, hopsy)
In [58]: cotton.set_name('Cottontail')
In [61]: mopsy = peter + hopsy
In [62]: mopsy.set_name('Mopsy')

In [65]: print(mopsy == cotton)
True
```

SUMMARY OF CLASSES & OOP

- **bundle together objects** that share
  - common attributes and
  - procedures that operate on those attributes
- use **abstraction** to make a distinction between how to implement an object vs how to use the object
- build **layers** of object abstractions that inherit behaviors from other classes of objects
- create our **own classes of objects** on top of Python's basic classes