

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



- 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**

*follow pointer to
the next index*

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

class definition (pointing to `class`)
class name (pointing to `Coordinate`)
class parent (pointing to `object`)

- 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
```

special method to
create an instance
— is double
underscore

two data attributes for
every `Coordinate` object

what data initializes a
`Coordinate` object
parameter to refer to an
instance of the class

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

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

note that argument for `self`
is automatically supplied
by Python!

- 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 associated 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, and 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

<code>__add__(self, other)</code>	→	<code>self + other</code>
<code>__sub__(self, other)</code>	→	<code>self - other</code>
<code>__eq__(self, other)</code>	→	<code>self == other</code>
<code>__lt__(self, other)</code>	→	<code>self < other</code>
<code>__len__(self)</code>	→	<code>len(self)</code>
<code>__str__(self)</code>	→	<code>print(self)</code>
... 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.getNum()
```

```
Out[13]: 1
```

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

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

```
Out[14]: 3
```

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.getDenom() * 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.getDenom() * 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

USING THE CLASS

vs

- 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



Jelly
1 year old
brown



5 years old
brown



Tiger
2 years old
brown



Bean
0 years old
black



2 years old
white



1 year old
b/w

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 definition

name

class parent

variable to refer to an instance of the class

what data initializes an `Animal` type

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

special method to create an instance

one instance

mapped to `self.age` in class def

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

```
myanimal = Animal(3)
```

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)
```

- **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

Animal

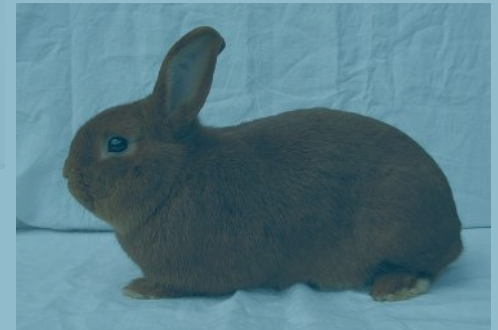


Person

Cat

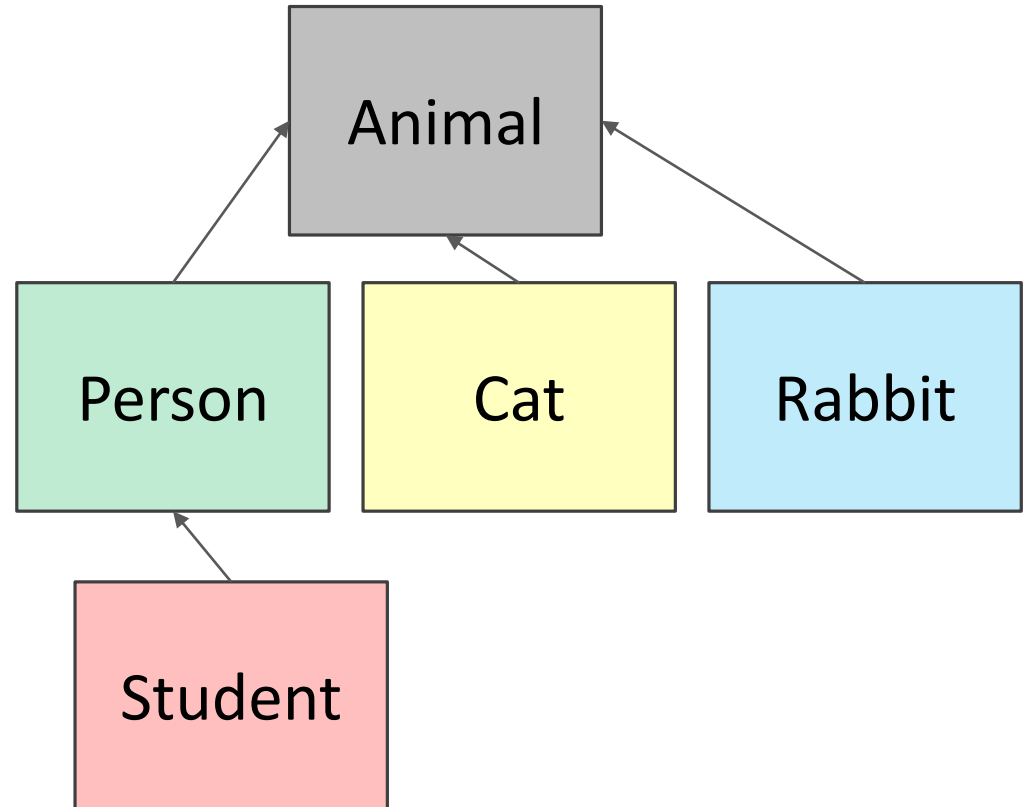


Rabbit



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
object class

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

```
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
```

*uses method from
Person*

*uses method associated
with instance*

```
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
```

*can use class
attribute to find
method*

```
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 = 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