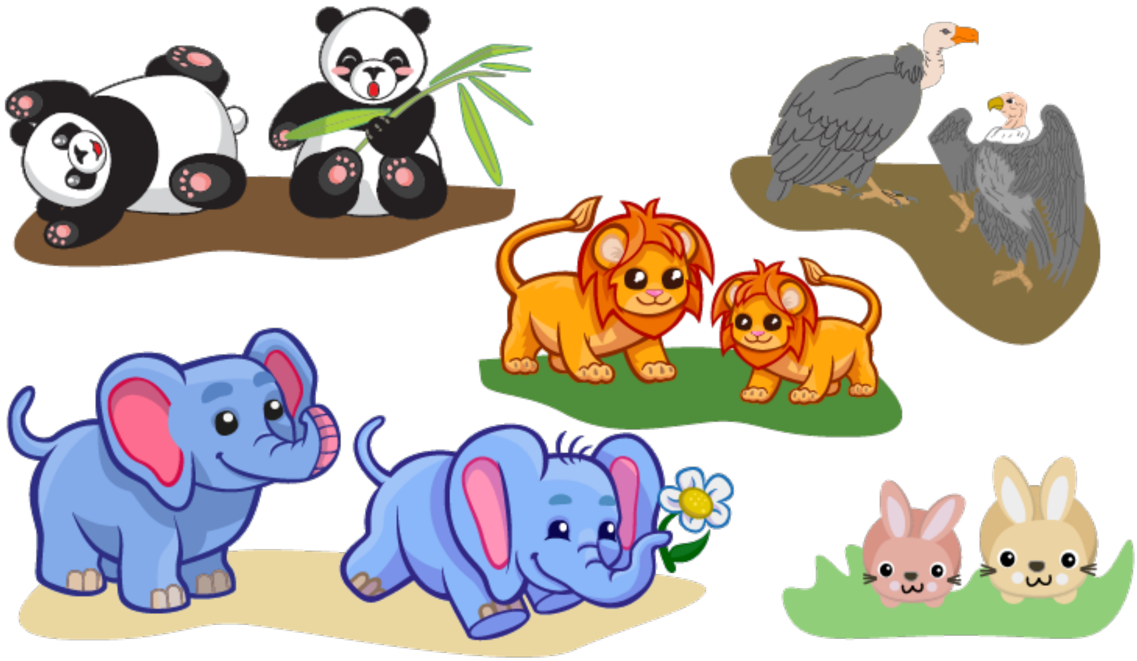
Inheritance + Composition

Motivation

Building "Animal Conserving"

A game where we take care of cute furry/ferocious animals:

What should be the classes?



What should be the classes?

```
Panda()
Lion()
Rabbit()
Vulture()
Elephant()
Food()
```

A Food class

Let's start simple:

```python
class Food:

    def __init__(self, name, type, calories):
        self.name = name
        self.type = type
        self.calories = calories
```

How would we use that class?

A Food class

Let's start simple:

```
class Food:

    def __init__(self, name, type, calories):
        self.name = name
        self.type = type
        self.calories = calories
```

How would we use that class?

```
broccoli = Food("Broccoli Rabe", "veggies", 20)
bone_marrow = Food("Bone Marrow", "meat", 100)
```

An Elephant class

```
class Elephant:
    species_name = "African Savanna Elephant"
    scientific_name = "Loxodonta africana"
    calories_needed = 8000

    def __init__(self, name, age=0):
        self.name = name
        self.age = age
        self.calories_eaten  = 0
        self.happiness = 0

    def play(self, num_hours):
        self.happiness += (num_hours * 4)
        print("WHEEE PLAY TIME!")

    def eat(self, food):
        self.calories_eaten += food.calories
        print(f"Om nom nom yummy {food.name}")
        if self.calories_eaten > self.calories_needed:
            self.happiness -= 1
            print("Ugh so full")

    def interact_with(self, animal2):
        self.happiness += 1
        print(f"Yay happy fun time with {animal2.name}")
```

How would we use that class?

An Elephant class

```
class Elephant:
    species_name = "African Savanna Elephant"
    scientific_name = "Loxodonta africana"
    calories_needed = 8000

    def __init__(self, name, age=0):
        self.name = name
        self.age = age
        self.calories_eaten  = 0
        self.happiness = 0

    def play(self, num_hours):
        self.happiness += (num_hours * 4)
        print("WHEEE PLAY TIME!")

    def eat(self, food):
        self.calories_eaten += food.calories
        print(f"Om nom nom yummy {food.name}")
        if self.calories_eaten > self.calories_needed:
            self.happiness -= 1
            print("Ugh so full")

    def interact_with(self, animal2):
        self.happiness += 1
        print(f"Yay happy fun time with {animal2.name}")
```

How would we use that class?

```
el1 = Elephant("Willaby", 5)
el2 = Elephant("Wallaby", 3)
el1.play(2)
el1.interact_with(el2)
```

A Rabbit class

```python
class Rabbit:
    species_name = "European rabbit"
    scientific_name = "Oryctolagus cuniculus"
    calories_needed = 200

    def __init__(self, name, age=0):
        self.name = name
        self.age = age
        self.calories_eaten = 0
        self.happiness = 0

    def play(self, num_hours):
        self.happiness += (num_hours * 10)
        print("WHEEE PLAY TIME!")

    def eat(self, food):
        self.calories_eaten += food.calories
        print(f"Om nom nom yummy {food.name}")
        if self.calories_eaten > self.calories_needed:
            self.happiness -= 1
            print("Ugh so full")

    def interact_with(self, animal2):
        self.happiness += 4
        print(f"Yay happy fun time with {animal2.name}")
```

How would we use that class?

A Rabbit class

```
class Rabbit:
    species_name = "European rabbit"
    scientific_name = "Oryctolagus cuniculus"
    calories_needed = 200

    def __init__(self, name, age=0):
        self.name = name
        self.age = age
        self.calories_eaten = 0
        self.happiness = 0

    def play(self, num_hours):
        self.happiness += (num_hours * 10)
        print("WHEEE PLAY TIME!")

    def eat(self, food):
        self.calories_eaten += food.calories
        print(f"Om nom nom yummy {food.name}")
        if self.calories_eaten > self.calories_needed:
            self.happiness -= 1
            print("Ugh so full")

    def interact_with(self, animal2):
        self.happiness += 4
        print(f"Yay happy fun time with {animal2.name}")
```

How would we use that class?

```
rabbit1 = Rabbit("Mister Wabbit", 3)
rabbit2 = Rabbit("Bugs Bunny", 2)
rabbit1.eat(broccoli)
rabbit2.interact_with(rabbit1)
```

Notice similarities?

Elephant

```
# Class variables
species_name
scientific_name
calories_needed

# Instance variables
name
age
happiness

# Methods
eat(food)
play()
interact_with(other)
```

Rabbit

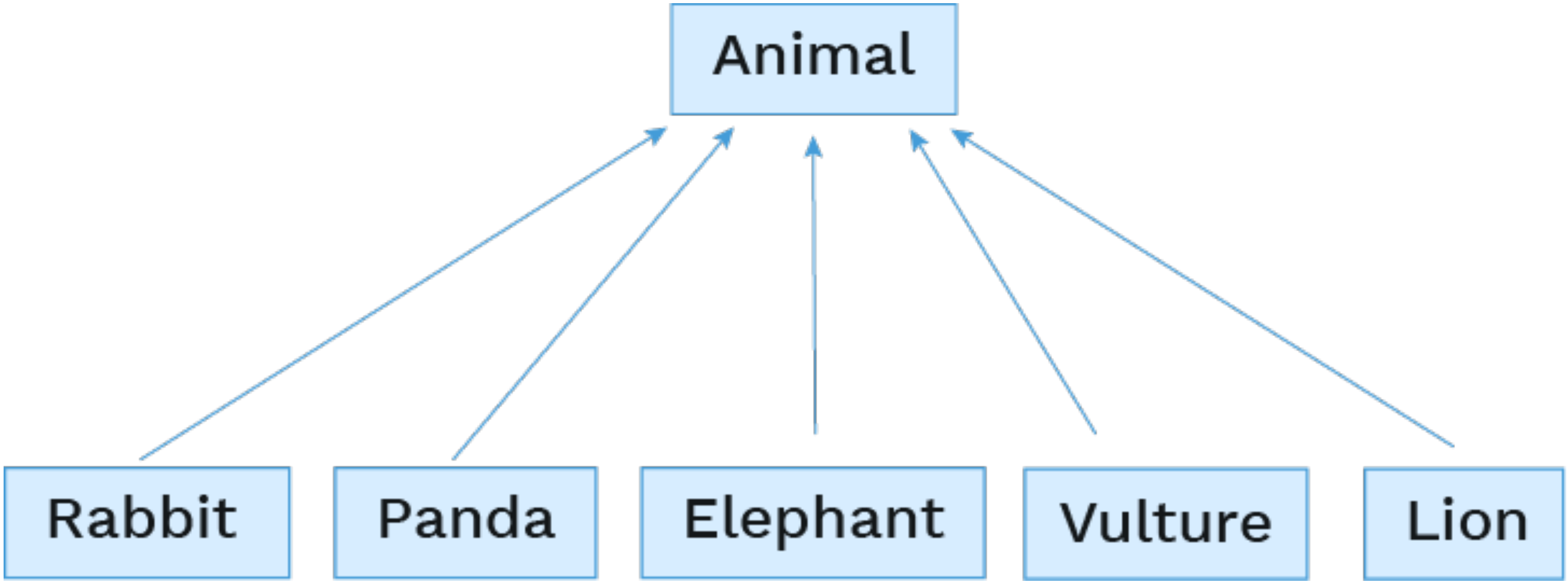
```
# Class variables
species_name
scientific_name
calories_needed

# Instance variables
name
age
happiness

# Methods
eat(food)
play()
interact_with(other)
```

`Elephant` and `Rabbit` are both animals, so they have similar attributes. Instead of repeating code, we can *inherit* the code.

Inheritance

Base classes and subclasses

When multiple classes share similar attributes, you can reduce redundant code by defining a base class and then subclasses can inherit from the base class.



Tip: The base class is also known as the **superclass**.

The base class

The base class contains method headers common to the subclasses, and code that is used by multiple subclasses.

```
class Animal:
    species_name = "Animal"
    scientific_name = "Animalia"
    play_multiplier = 2
    interact_increment = 1

    def __init__(self, name, age=0):
        self.name = name
        self.age = age
        self.calories_eaten  = 0
        self.happiness = 0

    def play(self, num_hours):
        self.happiness += (num_hours * self.play_multiplier)
        print("WHEEE PLAY TIME!")

    def eat(self, food):
        self.calories_eaten += food.calories
        print(f"Om nom nom yummy {food.name}")
        if self.calories_eaten > self.calories_needed:
            self.happiness -= 1
            print("Ugh so full")

    def interact_with(self, animal2):
        self.happiness += self.interact_increment
        print(f"Yay happy fun time with {animal2.name}")
```

The subclasses

To declare a subclass, put parentheses after the class name and specify the base class in the parentheses:

```
class Panda(Animal):
```

Then the subclasses only need the code that's unique to them. They can redefine any aspect: class variables, method definitions, or constructor. A redefinition is called **overriding**.

The simplest subclass overrides nothing:

```
class AmorphousBlob(Animal):
    pass
```

Overriding class variables

Subclasses can override existing class variables and assign new class variables:

```
class Rabbit(Animal):
    species_name = "European rabbit"
    scientific_name = "Oryctolagus cuniculus"
    calories_needed = 200
    play_multiplier = 8
    interact_increment = 4
    num_in_litter = 12

class Elephant(Animal):
    species_name = "African Savanna Elephant"
    scientific_name = "Loxodonta africana"
    calories_needed = 8000
    play_multiplier = 4
    interact_increment = 2
    num_tusks = 2
```

Overriding methods

If a subclass overrides a method, Python will use that definition instead of the superclass definition.

```
class Panda(Animal):
    species_name = "Giant Panda"
    scientific_name = "Ailuropoda melanoleuca"
    calories_needed = 6000

    def interact_with(self, other):
        print(f"I'm a Panda, I'm solitary, go away {other.name}!")
```

How would we call that method?

Overriding methods

If a subclass overrides a method, Python will use that definition instead of the superclass definition.

```
class Panda(Animal):
    species_name = "Giant Panda"
    scientific_name = "Ailuropoda melanoleuca"
    calories_needed = 6000

    def interact_with(self, other):
        print(f"I'm a Panda, I'm solitary, go away {other.name}!")
```

How would we call that method?

```
panda1 = Panda("Pandeybear", 6)
panda2 = Panda("Spot", 3)
panda1.interact_with(panda2)
```

Using methods from the base class

To refer to a superclass method, we can use `super()`:

```python
class Lion(Animal):
    species_name = "Lion"
    scientific_name = "Panthera"
    calories_needed = 3000

    def eat(self, food):
        if food.type == "meat":
            super().eat(food)
```

How would we call that method?

Using methods from the base class

To refer to a superclass method, we can use `super()`:

```python
class Lion(Animal):
    species_name = "Lion"
    scientific_name = "Panthera"
    calories_needed = 3000

    def eat(self, food):
        if food.type == "meat":
            super().eat(food)
```

How would we call that method?

```python
bones = Food("Bones", "meat")
mufasa = Lion("Mufasa", 10)
mufasa.eat(bones)
```

More on super()

`super().attribute` refers to the definition of `attribute` in the superclass of the first parameter to the method.

```python
def eat(self, food):
    if food.type == "meat":
        super().eat(food)
```

...is the same as:

```python
def eat(self, food):
    if food.type == "meat":
        Animal.eat(self, food)
```

`super()` is better style than `BaseClassName`, though slightly slower.

Overriding __init__

Similarly, we need to explicitly call `super().__init__()` if we want to call the `__init__` functionality of the base class.

```
class Elephant(Animal):
    species_name = "Elephant"
    scientific_name = "Loxodonta"
    calories_needed = 8000

    def __init__(self, name, age=0):
        super().__init__(name, age)
        if age < 1:
            self.calories_needed = 1000
        elif age < 5:
            self.calories_needed = 3000
```

What would this display?

```
elly = Elephant("Ellie", 3)
elly.calories_needed
```

Overriding __init__

Similarly, we need to explicitly call `super().__init__()` if we want to call the `__init__` functionality of the base class.

```
class Elephant(Animal):
    species_name = "Elephant"
    scientific_name = "Loxodonta"
    calories_needed = 8000

    def __init__(self, name, age=0):
        super().__init__(name, age)
        if age < 1:
            self.calories_needed = 1000
        elif age < 5:
            self.calories_needed = 3000
```

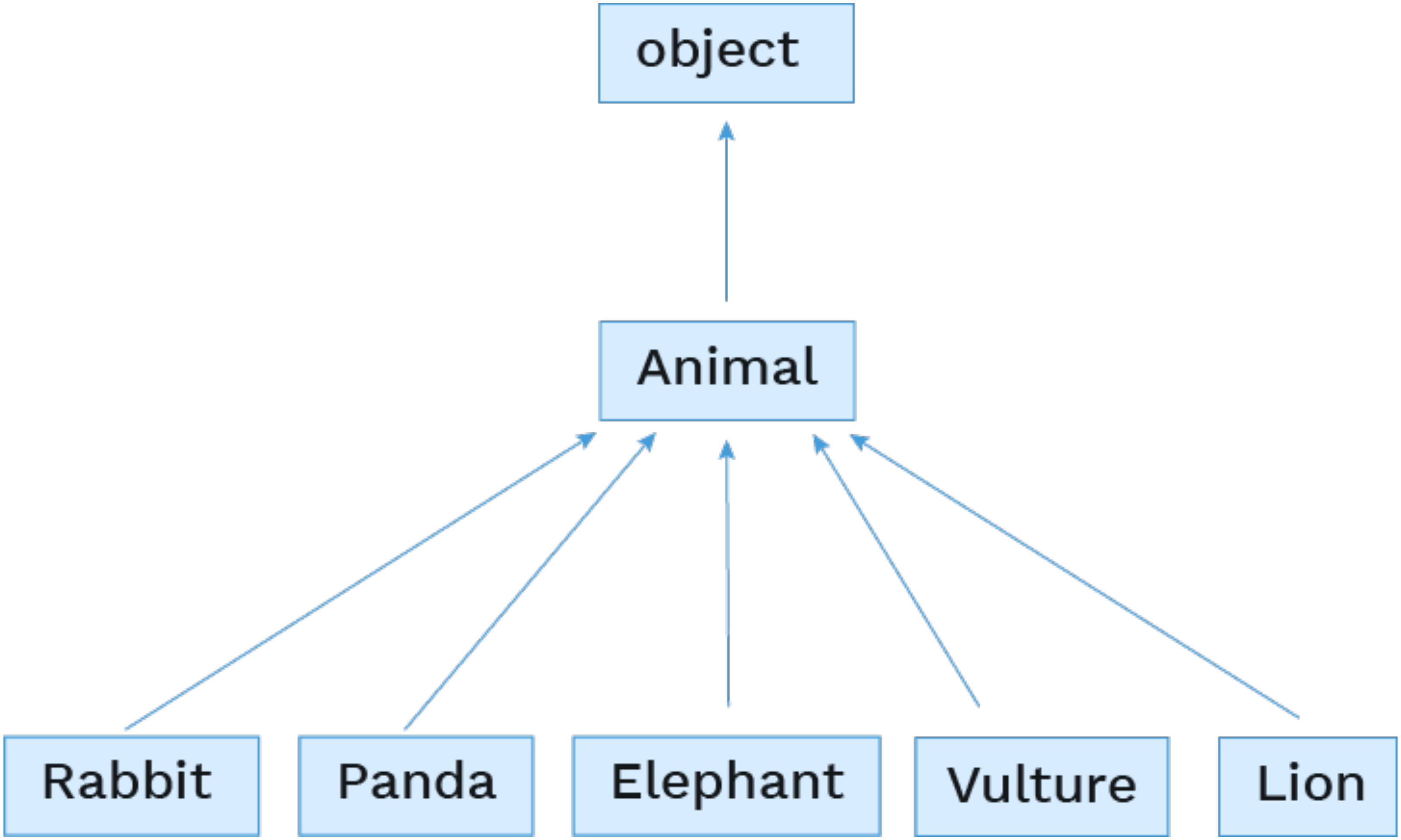
What would this display?

```
elly = Elephant("Ellie", 3)
elly.calories_needed        # 3000
```

Layers of inheritance

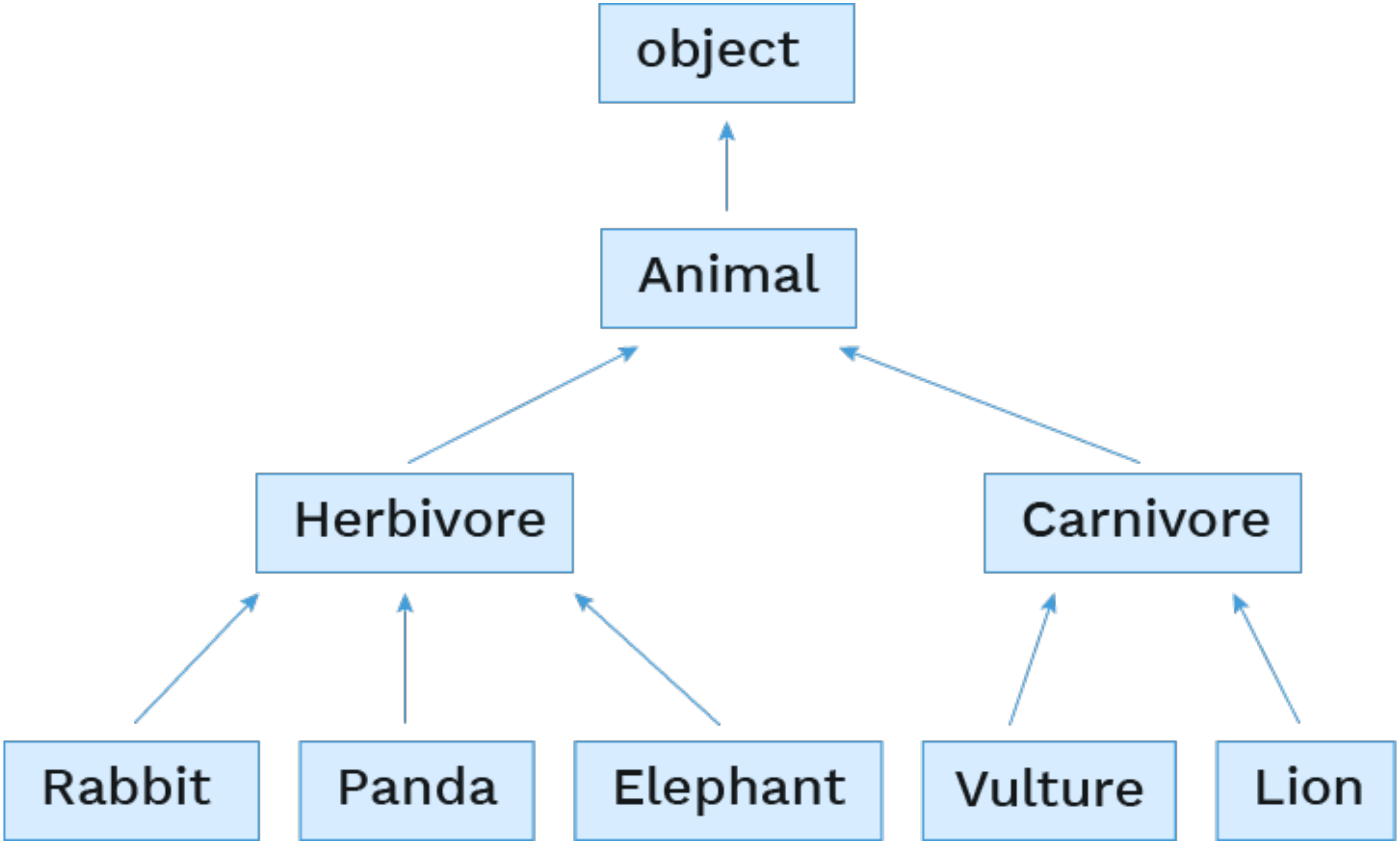
Object base class

Every Python 3 class implicitly extends the `object` class.



Adding layers of inheritance

But we can also add in more levels ourselves.



Adding layers of inheritance

First we define the new classes:

```python
class Herbivore(Animal):

    def eat(self, food):
        if food.type == "meat":
            self.happiness -= 5
        else:
            super().eat(food)

class Carnivore(Animal):

    def eat(self, food):
        if food.type == "meat":
            super().eat(food)
```

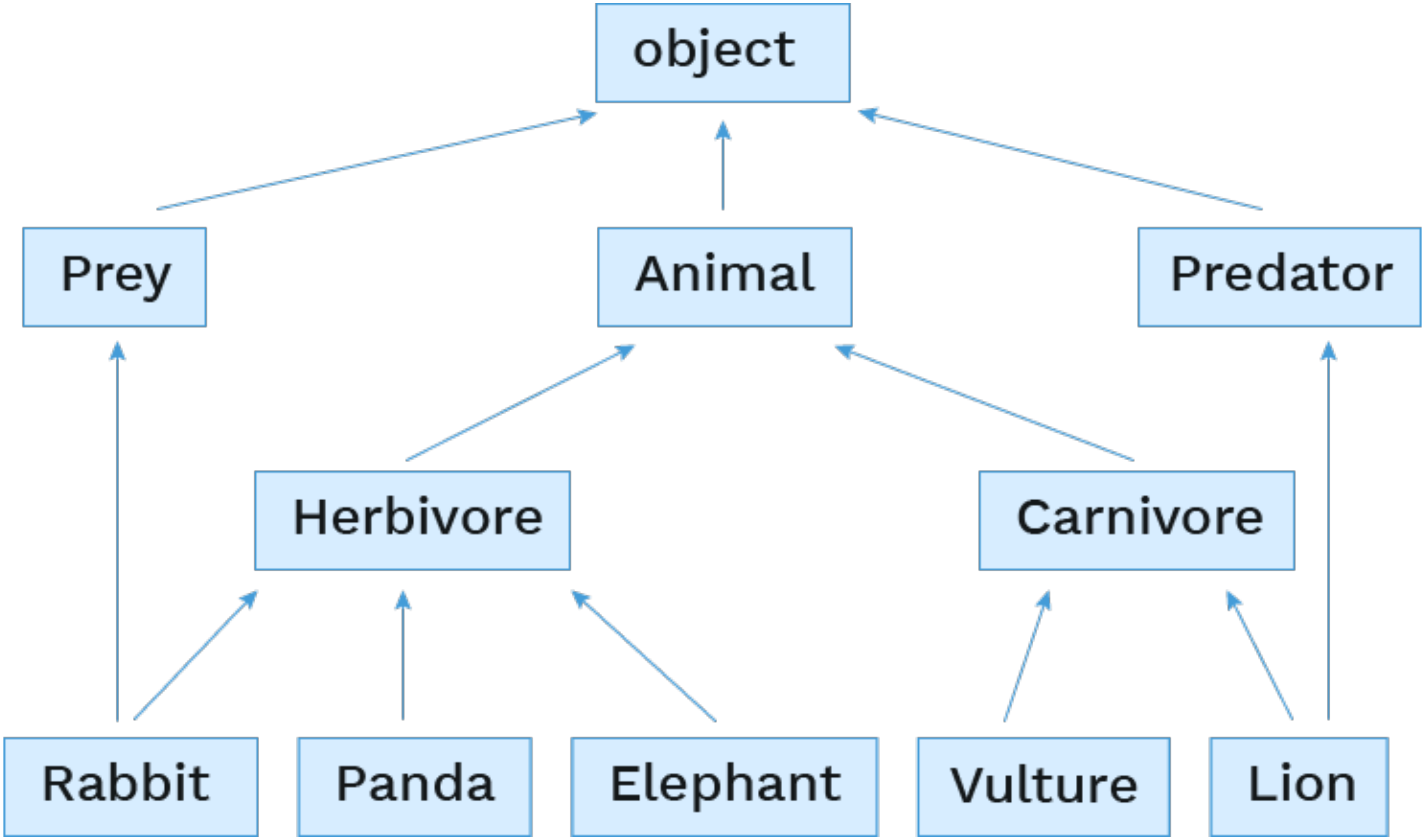
Then we change the base classes for the subclasses:

```python
class Rabbit(Herbivore):
class Panda(Herbivore):
class Elephant(Herbivore):

class Vulture(Carnivore):
class Lion(Carnivore):
```

Multiple inheritance

Multiple inhteritance

A class may inherit from multiple base classes in Python.



The new base classes

First we define the new base classes:

```python
class Predator(Animal):

    def interact_with(self, other):
        if other.type == "meat":
            self.eat(other)
            print("om nom nom, I'm a predator")
        else:
            super().interact_with(other)

class Prey(Animal):
    type = "meat"
    calories = 200
```

Inheriting from multiple base classes

Then we inherit from them by putting both names in the parentheses:

```
class Rabbit(Prey, Herbivore):
class Lion(Predator, Carnivore):
```

Python can find the attributes in any of the base classes:

```
>>> r = Rabbit("Peter", 4)
>>> r.play()
>>> r.type
>>> r.eat(Food("carrot", "veggies"))
>>> l = Lion("Scar", 12)
>>> l.eat(Food("zazu", "meat"))
>>> l.encounter(r)
```

Inheriting from multiple base classes

Then we inherit from them by putting both names in the parentheses:

```
class Rabbit(Prey, Herbivore):
class Lion(Predator, Carnivore):
```

Python can find the attributes in any of the base classes:

```
>>> r = Rabbit("Peter", 4)           # Animal __init__
>>> r.play()                         # Animal method
>>> r.type                           # Prey class variable
>>> r.eat(Food("carrot", "veggies")) # Herbivore method
>>> l = Lion("Scar", 12)             # Animal __init__
>>> l.eat(Food("zazu", "meat"))      # Carnivore method
>>> l.encounter(r)                   # Predator method
```

Refresher: Identity

Checking identity

`exp0 is exp1`

evaluates to `True` if both `exp0` and `exp1` evaluate to the same object

```
mufasa = Lion("Mufasa", 15)
nala = Lion("Nala", 16)

mufasa is mufasa
mufasa is Nala
mufasa is not Nala
nala is not None
```

Checking identity

`exp0 is exp1`

evaluates to `True` if both `exp0` and `exp1` evaluate to the same object

```
mufasa = Lion("Mufasa", 15)
nala = Lion("Nala", 16)

mufasa is mufasa      # True
mufasa is Nala        # False
mufasa is not Nala    # True
nala is not None      # True
```

Composition

Composition

An object can contain references to objects of other classes.

What examples of composition are in an animal conservatory?

- An animal has a mate.
- An animal has a mother.
- An animal has children.
- A conservatory has animals.

Referencing other instances

An instance variable can refer to another instance:

```
class Animal:

    def mate_with(self, other):
        if other is not self and other.species_name == self.species_name:
            self.mate = other
            other.mate = self
```

How would we call that method?

Referencing other instances

An instance variable can refer to another instance:

```
class Animal:

    def mate_with(self, other):
        if other is not self and other.species_name == self.species_name:
            self.mate = other
            other.mate = self
```

How would we call that method?

```
mr_wabbit = Rabbit("Mister Wabbit", 3)
jane_doe = Rabbit("Jane Doe", 2)
mr_wabbit.mate_with(jane_doe)
```

Referencing a list of instances

An instance variable can also refer to a list of instances:

```
class Rabbit(Animal):

    def reproduce_like_rabbits(self):
        if self.mate is None:
            print("oh no! better go on ZoOkCupid")
            return
        self.babies = []
        for _ in range(0, self.num_in_litter):
            self.babies.append(Rabbit("bunny", 0))
```

How would we call that function?

Referencing a list of instances

An instance variable can also refer to a list of instances:

```
class Rabbit(Animal):

    def reproduce_like_rabbits(self):
        if self.mate is None:
            print("oh no! better go on ZoOkCupid")
            return
        self.babies = []
        for _ in range(0, self.num_in_litter):
            self.babies.append(Rabbit("bunny", 0))
```

How would we call that function?

```
mr_wabbit = Rabbit("Mister Wabbit", 3)
jane_doe = Rabbit("Jane Doe", 2)
mr_wabbit.mate_with(jane_doe)
jane_doe.reproduce_like_rabbits()
```

Relying on a common interface

If all instances implement a method with the same function signature, a program can rely on that method across instances of different subclasses.

```
def partytime(animals):
    """Assuming ANIMALS is a list of Animals, cause each
    to interact with all the others exactly once."""
    for i in range(len(animals)):
        for j in range(i + 1, len(animals)):
            animals[i].interact_with(animals[j])
```

How would we call that function?

Relying on a common interface

If all instances implement a method with the same function signature, a program can rely on that method across instances of different subclasses.

```
def partytime(animals):
    """Assuming ANIMALS is a list of Animals, cause each
    to interact with all the others exactly once."""
    for i in range(len(animals)):
        for j in range(i + 1, len(animals)):
            animals[i].interact_with(animals[j])
```

How would we call that function?

```
jane_doe = Rabbit("Jane Doe", 2)
scar = Lion("Scar", 12)
elly = Elephant("Elly", 5)
pandy = Panda("PandeyBear", 4)
partytime([jane_doe, scar, elly, pandy])
```

Composition vs. Inheritance

Inheritance is best for representing "is-a" relationships

- Rabbit is a specific type of Animal
- So, Rabbit inherits from Animal

Composition is best for representing "has-a" relationships

- A conservatory has a collection of animals it cares for
- So, a conservatory has a list of animals as an instance variable

Quiz

What would Python print?

```
class Parent:
    def f(s):
        print("Parent.f")

    def g(s):
        s.f()

class Child(Parent):
    def f(me):
        print("Child.f")

a_child = Child()
a_child.g()
```

Find out in PythonTutor