Object-Oriented approach to code reuse. Composition and Inheritance

Lecture 4

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Why use objects?

- Organization
  - Easier to change: the code is compartmentalized
- Encapsulation
  - Can be treated as a blackbox without knowing details
- Avoiding Repetition
  - Code reuse

Reusing objects

- We can build complex programs by reusing existing objects

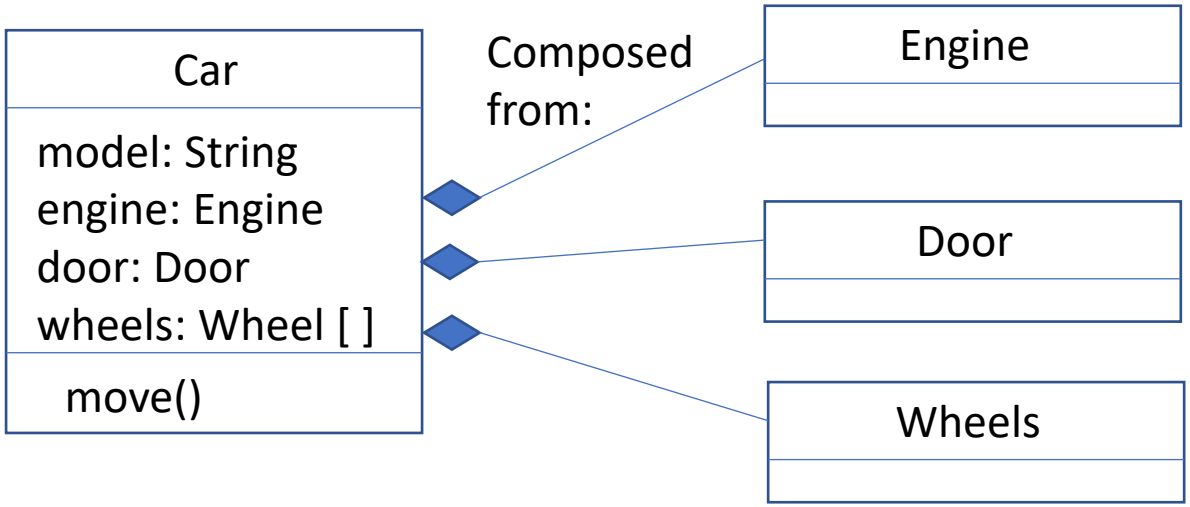
- We can reuse code in two ways:
  - Composition
  - Inheritance

Reusing objects: composition

Objects as building blocks

- Instance variables can be of any type: they can also be of a new custom type (class)
- This way we can construct complex objects which contain simpler objects inside them
- The method of constructing a program by incorporating smaller objects inside a larger one is called ***composition***
- This is **the most useful and widely used** approach in Object-Oriented Programming

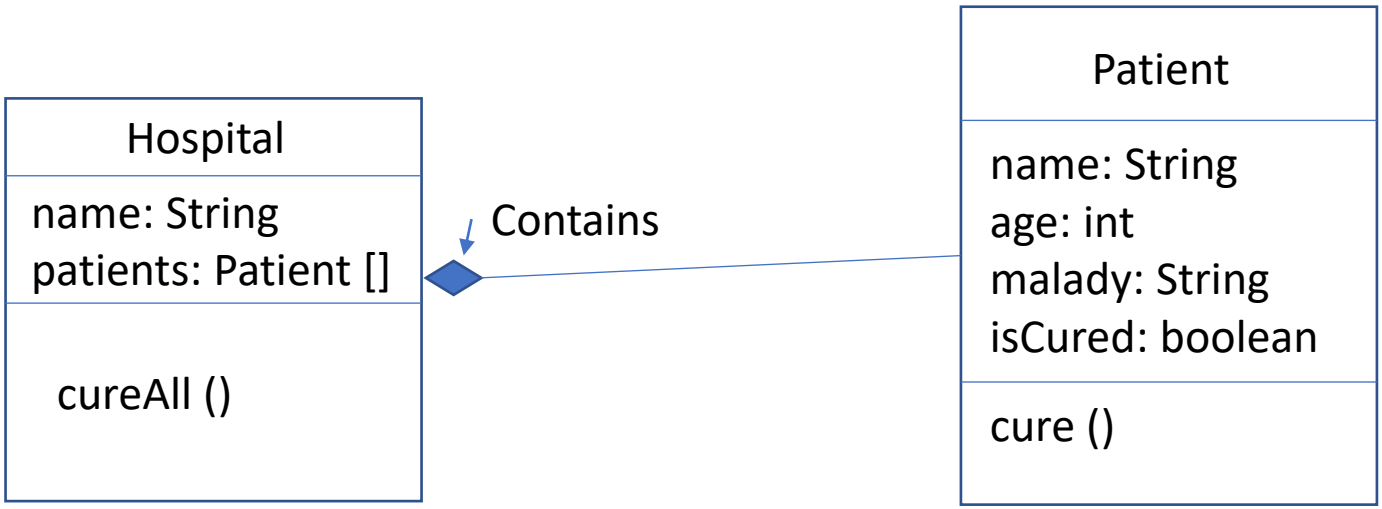
Composing with objects



People who build engines do not have to know how to make wheels

- While combining elementary objects we ensure that we expose only important properties and capabilities of these objects (contract, public interface)
- We can divide work among many programmers: each programmer can concentrate on correct implementation of each small piece

Example: hospital



Start from a *Hospital* class – pretend that *Patient* class is already working

```
public class Hospital {
    private String name;
    private Patient[] patients;
    int numPatients;
    int capacity;

    public Hospital(String name, int capacity) {
        this.name = name;
        patients = new Patient[capacity];
        this.capacity = capacity;
    }

    public void addPatient(Patient p) {
        if (this.numPatients < this.capacity)
            this.patients[numPatients++] = p;
        else
            System.out.println("…");
    }

    public void cureAll() {
        for(int i=0; i<numPatients; i++)
            patients[i].cure();
    }
```

Patient class is defined in a separate file, that can be written by another programmer

Define class *Patient*

```
public class Patient {
    private String name;
    private int age;
    private String malady;

    public Patient(String name, int age,
                   String malady) {
        this.name = name;
        this.age = age;
        this.malady = malady;
    }

    public Patient() {
        this.name = "John Doe";
        this.age = 25;
        this.malady = "unknown";
    }

    public void cure() {
        this.malady = "healthy";
    }
}
```

Default constructor–
in case we don't know

Running the Hospital

```
public class RunHospital {
    public static void main (String [] args) {
        Hospital h = new Hospital("US Best", 10);
        h.addPatient(new Patient());
        h.addPatient(new Patient("Sally Smith", 21, "bruised ego"));
        h.addPatient(new Patient("Bob Swift", 18, "broken heart"));
        System.out.println("In the morning:");
        System.out.println(h);

        h.cureAll();
        System.out.println("In the evening:");
        System.out.println(h);
    }
}
```

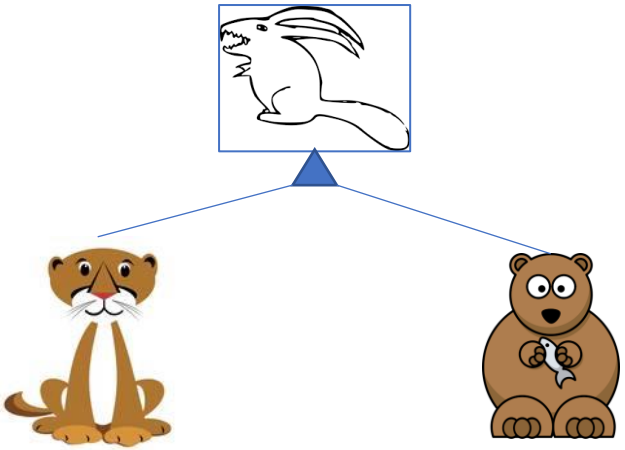
The full code demo is here

Reusing objects: inheritance

Factoring-out similarities

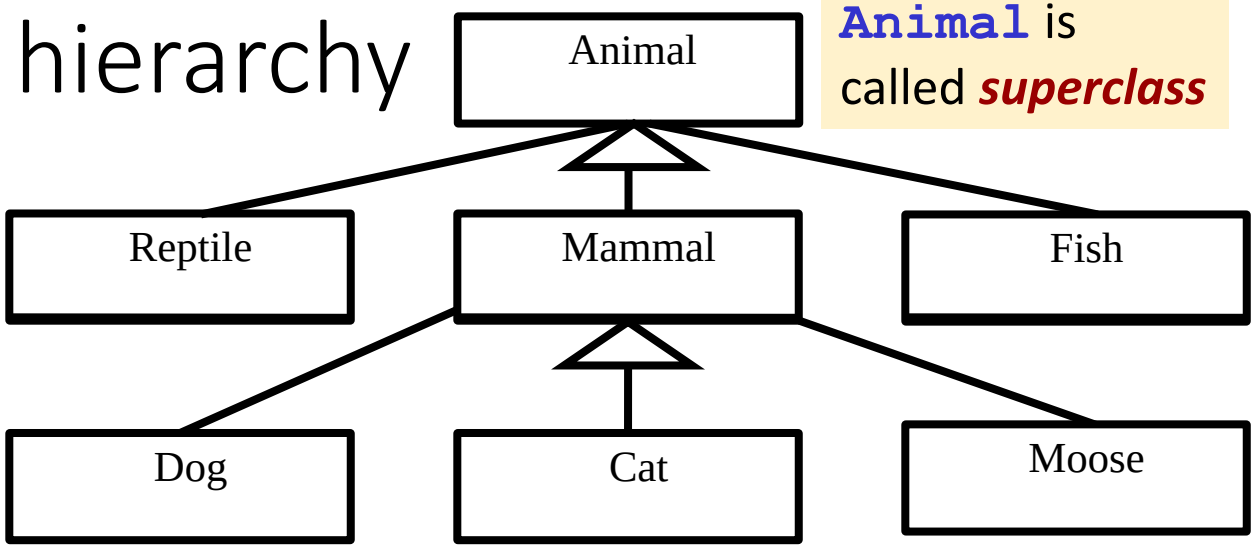
- When we define a set of new types (classes) we often find that there are similarities among them
- For example:
  - Class ***Tiger*** and class ***Bear*** – both have a lot in common:

    move(), eat(), sleep(), makeNoise()
  - Instead of repeating these methods for each class, we can factor out similarities and define these methods in a single class *Animal*



Tiger **is a**n Animal Bear **is a**n Animal

Inheritance hierarchy



`Animal` is called ***superclass***

Subclass of class Animal

- Where there's inheritance, there's an *Inheritance Hierarchy* of classes
  - **`Mammal`** "*is an*" **`Animal`**
  - **`Cat`** "*is a*" **`Mammal`**
  - Transitive relationship: **`Cat`** "*is an*" **`Animal`** too

- We can say:
  - **`Reptile, Mammal`** and **`Fish`** "*inherit from*" **`Animal`**
  - **`Dog, Cat,`** and **`Moose`** "*inherit from*" **`Mammal`**

Inheriting properties (fields) and capabilities (methods)

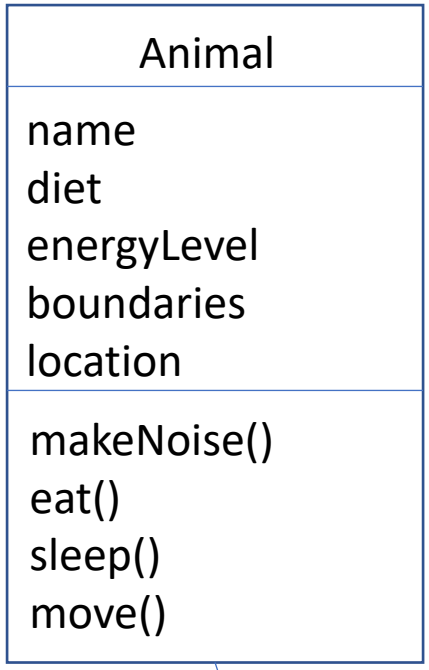
- Subclass *inherits* all capabilities of its superclass
  - if **`Animal`**s eat and sleep, then **`Reptile`**s, **`Mammal`**s, and **`Fish`** eat and sleep
  - if **`Vehicle`**s move, then **`SportsCar`**s move

- Subclass *specializes* its superclass
  - ***adding*** new fields and methods
  - ***overriding*** *(redefining)* existing methods

- **Superclass** *factors out* capabilities ***common*** among its subclasses
- **Subclasses** are defined by their ***differences*** from their superclass

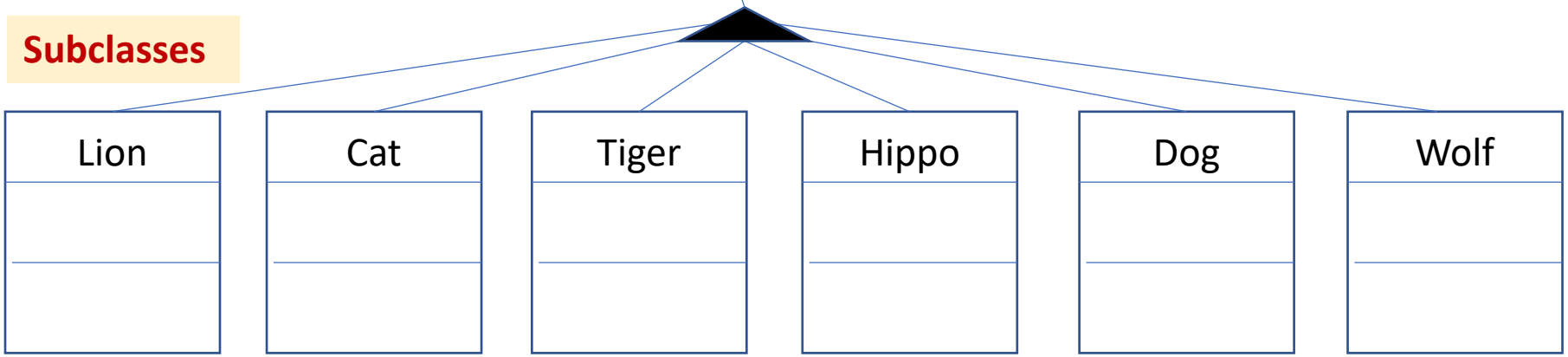
Designing with inheritance

Superclass



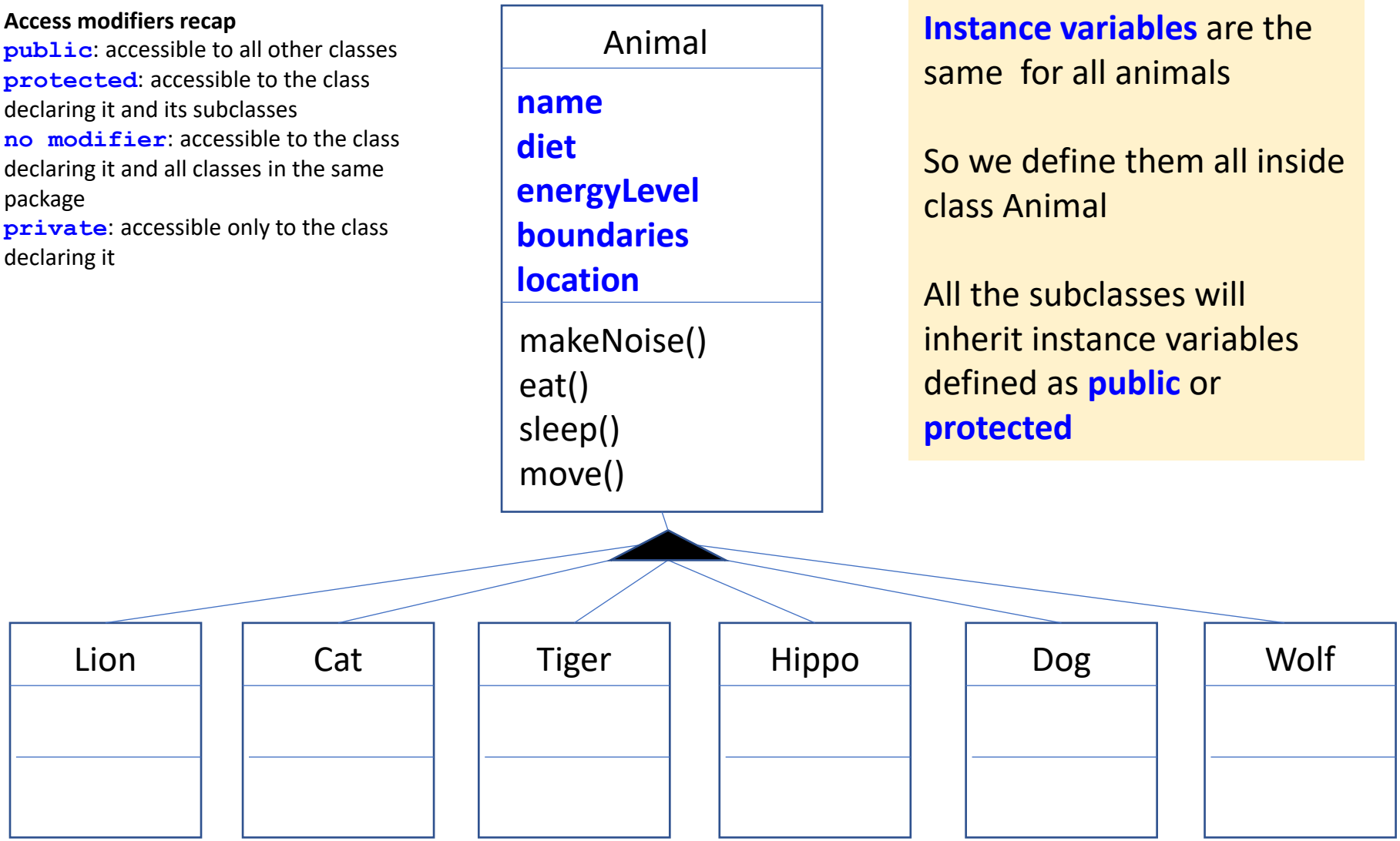

```
package zoo;

public class Animal {

}

public class Bear extends Animal{

}

public class cat extends Animal{

}
```

Subclasses



Designing with inheritance

Access modifiers recap
`public`: accessible to all other classes
`protected`: accessible to the class declaring it and its subclasses
`no modifier`: accessible to the class declaring it and all classes in the same package
`private`: accessible only to the class declaring it

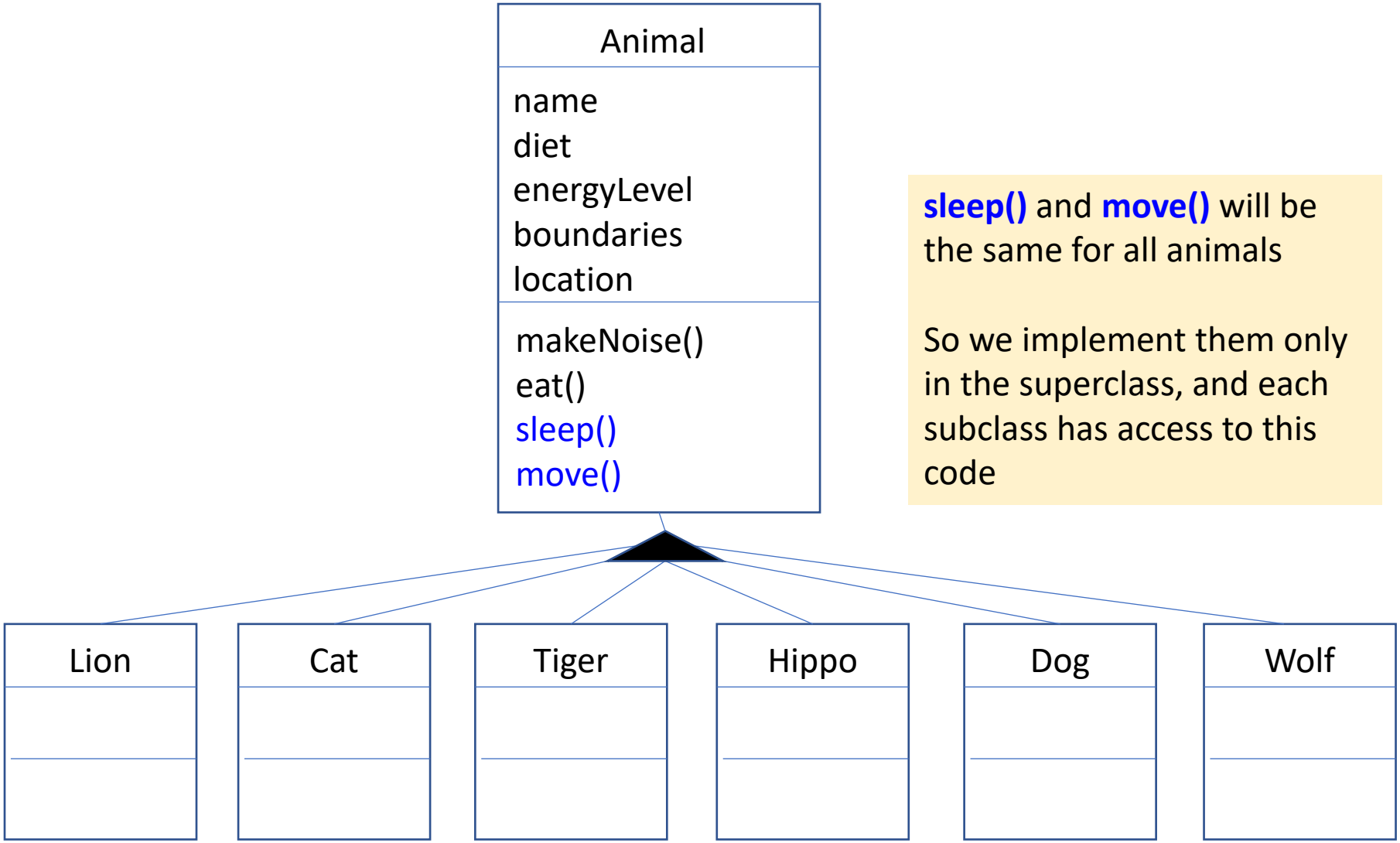


Instance variables are the same for all animals

So we define them all inside class Animal

All the subclasses will inherit instance variables defined as **public** or **protected**

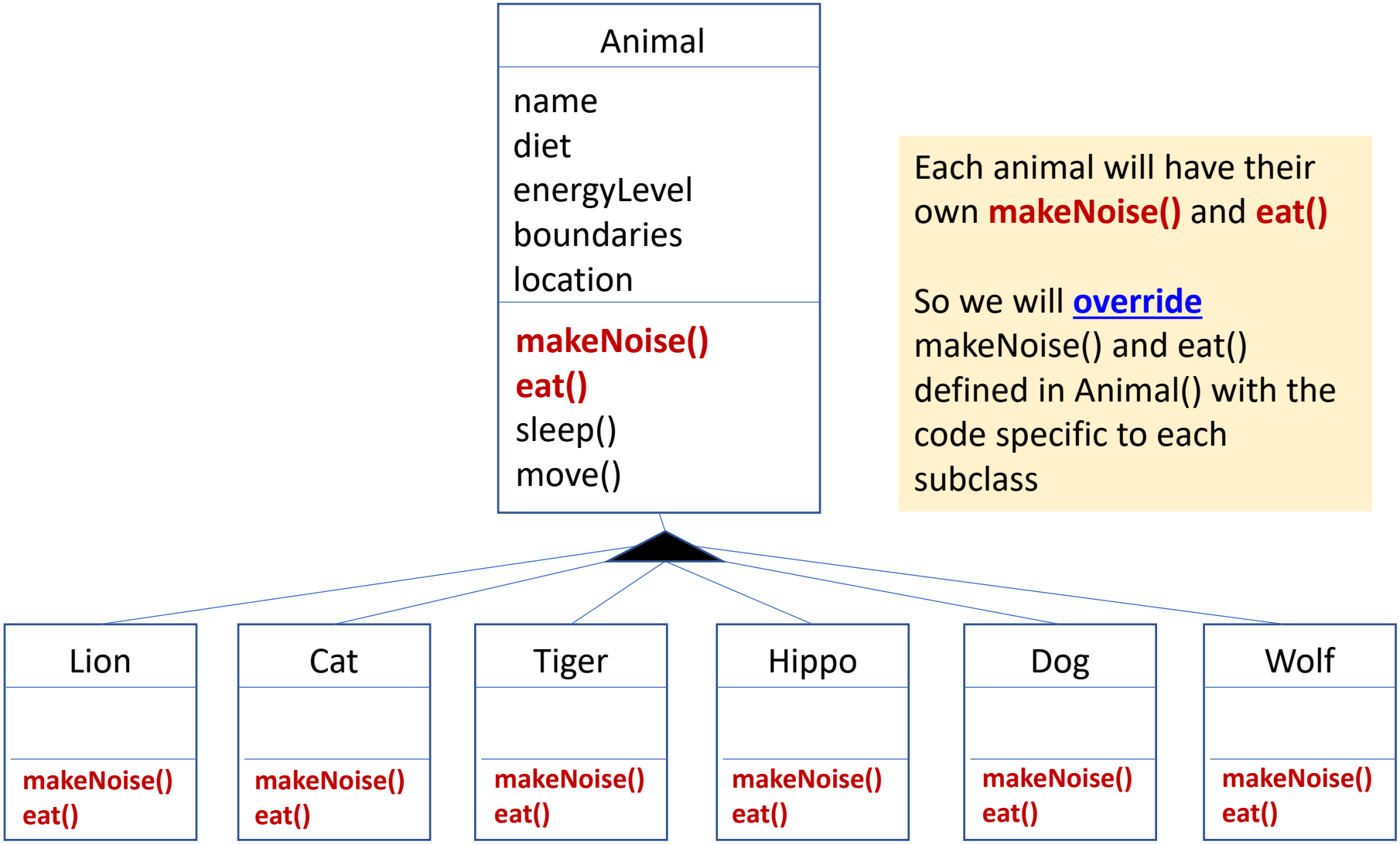
Designing with inheritance



sleep() and **move()** will be the same for all animals

So we implement them only in the superclass, and each subclass has access to this code

Designing with inheritance



Each animal will have their own **makeNoise()** and **eat()**

So we will **override** makeNoise() and eat() defined in Animal() with the code specific to each subclass

Example of a superclass and a subclass

```
public class Animal {
    protected String name;
    protected int energyLevel, x, y;
    protected String diet;

    public String getName() {return this.name;}

    public void move(int dX, int dY) {
        this.x += dX;
        this.y += dY;
        this.energyLevel-=(dX + dY);
    }

    public void eat() {
        System.out.println(name +
                  " is eating " + diet);
        this.energyLevel ++;
    }

    public void sleep() {
        this.energyLevel ++;
    }

    public void makeNoise() {
    }
}
```

```
public class Cat extends Animal{
    public Cat() {
        super("Cat", "mice");
    }

    public void eat() {
        System.out.println("Cat is eating "
                                  + diet);
        this.energyLevel += 3;
    }

    public void makeNoise() {
        System.out.println("Purrr");
    }
}
```

Inheritance: constructor

- A subclass inherits all the members (fields, methods, and nested classes) from its superclass
- **Constructors are not inherited by subclasses**, but the constructor of the superclass can be invoked from the subclass

```
public class Animal {
    public Animal() {
        this.name = "?";
        this.energyLevel = 100;
        this.x = 0;
        this.y=0;
    }

    public Animal(String name) {
        this();
        this.name = name;
    }

    public Animal(String name, String diet) {
        this(name);
        this.diet = diet;
    }
}
```

```
public class Cat extends Animal{
    public Cat() {
        super("Cat", "mice");
    }
    …
}
```

What is printed?

```
public class A {
    int iVar;

    public void hello() {
        System.out.println("Hello from A: " + iVar);
    }

    public void work() {
        iVar ++;
    }
}

public class B extends A{
    public void work() {
        iVar += 5;
    }
}

public class C extends A {
    public void hello () {
        System.out.println("Hello from C: " + iVar);
    }

}
```

```
IN MAIN:
A a = new A();
B b = new B();
C c = new C();

a.work();
b.work();

a.hello();
b.hello();
c.hello();
```

- A

```
Hello from A: 1
Hello from B: 5
Hello from C: 0
```

- B

```
Hello from A: 6
Hello from B: 5
Hello from C: 6
```

- C

```
Hello from A: 1
Hello from A: 5
Hello from C: 0
```

- D

None of the above

Polymorphism

- The reference and the object can be of different types in Java:

```
Animal c = new Cat();
```

Superclass **Subclass**

- We can treat the same object both as a subclass and as a superclass
- `c` can be used both as an *Animal* and as a *Cat*
- `c` has “many forms” – **polymorphism**
- We can use polymorphic variables as **method arguments**, **return types** or **array types**

Polymorphism: example

- Because *Dog, Cat* and *Lion* are also *Animals*, we can store them in array of *Animals*
- *makeNoise* is is declared in *Animal* (though it has an empty body), so we can call it on each element of the *Animal* array

```
public class Animals {
    public static void main(String [] args) {
        Animal [] animals = new Animal[3];

        animals[0] = new Dog();
        animals[1] = new Cat();
        animals[2] = new Lion();

        for (Animal a: animals) {
            System.out.println(a);
            a.makeNoise();
        }
    }
}
```

Each animal makes their own noise

Why use inheritance

- Get rid of duplicate code by factoring out and implementing common behavior
- Modify in one place, and the change is ‘magically’ carried out to all subclasses
- Add new subclasses easily, and they have some methods and properties right away
- Guarantee that all classes grouped under a certain supertype have a common protocol

When to use inheritance

- When one class is a more specific version of another:

SportsCar extends *Car*

- When you have a method that is the same for a set of classes:

Square, *Circle*, *Triangle* all need to have *move()* method in the animation program, so make *Shape* their superclass

- Test:
  - if you can say: **X IS A Y**, then use **inheritance**
  - If you can say: **X HAS A Y** use **composition**

“IS A” test

- Which of the following is the correct use of inheritance:

A. class *Oven* extends *Kitchen*

B. class *Guitar* extends *Instrument*

C. class *Ferrari* extends *Engine*

D. class *Person* extends *Student*

E. None of the above

Java classes: single-root hierarchy

- All classes in Java (including our new custom classes) are subclasses of a single root superclass called *Object*
- When we create a new class that does not extend anything, this means implicitly:

```
public class Dog extends Object
```

- This means that *Dog* inherits all the methods of *Object* (see here)

So what's in *Object?*

- Important public methods implemented in Object:

```
public String toString();
public boolean equals(Object obj);
public int hashCode();
```

- If you do not override these methods, you inherit them from the Object class

`toString()`

- *System.out* printing methods automatically call the *toString* method on their parameters
- By default, the *toString* method of an *Object* class returns a name of the new class and the memory location of the object
- If we do not override the *toString* method, then *toString()* of the nearest superclass will be used

Printing Dog using default *toString()*

```
public class Dog {
    private String name;
    private int height;

    public Dog(String name, int height) {
        this.name = name;
        this.height = height;
    }

    public static void main (String [] args){
        Dog d = new Dog("Fido", 15);
        System.out.println(d);
    }
}
```

```
Dog@3fee733d
```

Overriding default *toString*()

- We override the *toString* of Object
- We return a meaningful string representation of Dog's state (instance variables)

```
public class Dog {
    private String name;
    private int height;

    public String toString() {
        return "Here is Dog "+this.name+ " "
                + this.height +" inches tall";
    }

    public static void main (String [] args) {
        Dog d = new Dog("Fido", 15);
        System.out.println(d);
    }
}
```

```
Here is Dog Fido 15 inches tall
```

`equals()`

- In class Object `o1.equals(Object o2)` returns true only if both *o1* and *o2* are references to the same place in memory – that is the default equals tests equality of references
- We want to be able to compare objects themselves not their addresses
- For this we override the default behavior of `equals()` according to the logic of our program

- Note that == is still reserved for comparing references

Comparing Dogs

```
public class Dog {
    private String name;
    private String diet="BONE";
    private int height;
    private String owner;

    public Dog(String name, int height) {
        this.name = name;
        this.height = height;
    }

    public static void main(String [] args) {
        Dog a = new Dog("Fido", 20);
        Dog b = new Dog("Ball", 10);
        Dog c = new Dog("Fido", 20);
        Dog d = a;

        System.out.println(a.equals(b));
        System.out.println(a.equals(c));
        System.out.println(a.equals(d));
    }
}
```

- What is printed?
- A

  false
  false
  false
- B

  false
  true
  true

- C

  false
  false
  true
- D

  None of the above

Comparing GoodDogs

```
public class GoodDog {
    private String name;
    private String owner;
    private int height;

    public GoodDog(String name, int height, String owner) {
        this.name = name;
        this.height = height;
        this.owner = owner;
    }

    public boolean equals(GoodDog other) {
        return (this.name.equals(other.name)
                && this.owner.equals(other.owner));
    }

    public static void main(String [] args) {
        GoodDog a = new GoodDog("Fido", 20, "Sam");
        GoodDog b = new GoodDog("Fido", 20, "Bob");
        GoodDog c = new GoodDog("Fido", 20, "Sam");
        GoodDog d = a;

        System.out.println(a.equals(b));
        System.out.println(a.equals(c));
        System.out.println(a.equals(d));
    }
}
```

- What is printed?
- A

  ```
  false
  false
  false
  ```

- B

  ```
  false
  true
  true
  ```

- C

  ```
  false
  false
  true
  ```

- D

  None of the above

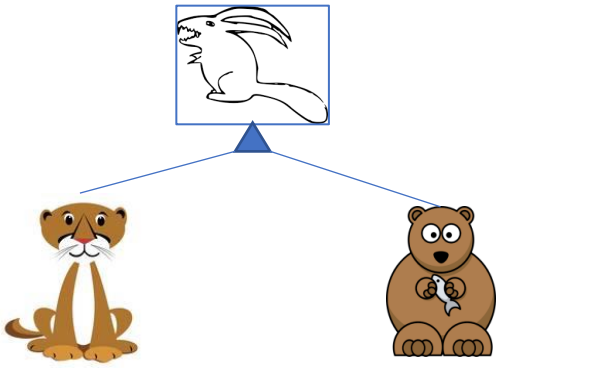
How does Animal() look like?

- We factored out all the common code into class Animal

- However a generic Animal does not know how:

  ```
  makeNoise()
  getPicture()
  getColor()
  …
  ```

- All these methods are not applicable to a generic class Animal



Lion **is a** Animal Bear **is a** Animal

We want to prevent anyone from making an instance of Animal()

Animal class is too abstract!

Define Animal as abstract class

```
public abstract class Animal {
    protected String name;
    protected int energyLevel;
    ...

    public void move(int dX, int dY) {
        this.x += dX;
        this.y += dY;
        this.energyLevel --;
    }

    public void eat() {
        ...
        this.energyLevel ++;
    }

    public void sleep() {
        this.energyLevel ++;
    }

    public abstract void makeNoise();

    public abstract Picture getPicture();
```

- Shared code which is applicable to all subclasses is still in concrete methods
- We can declare all the other methods **abstract**
- Abstract methods do not have body
- If the class has at least one abstract method, it must be declared abstract
- You must implement all abstract methods in a subclass

No instances of abstract animals

```
public abstract class Animal {
    protected String name;
    protected int energyLevel;
    ...

    public void move(int dX, int dY) {
        this.x += dX;
        this.y += dY;
        this.energyLevel --;
    }

    public void eat() {
        ...
        this.energyLevel ++;
    }

    public void sleep() {
        this.energyLevel ++;
    }

    public abstract void makeNoise();

    public abstract Picture getPicture();
```

- You cannot create instances of an abstract class:

```
Animal a = new Animal();
```

This will not compile

Why use Abstract classes

- Inheritance allows to store shared code in a superclass
- Sometimes we cannot find any generic code useful to all subclasses
- In this case we declare a method in the superclass abstract (and the entire superclass becomes abstract)
- Even though there is no code in an abstract method, it still defines a common protocol that can be used in polymorphic programs: each subclass of Animal knows to makeNoise()
- Compiler forces all the subclasses to implement the abstract methods

Factoring out partial commonalities

- The Animal class defines a contract for all Lion, Hippo, Cat and Dog types
- We can use this hierarchy for Animal Simulation program

- But now I want to reuse some of the code for my Pet Store program
- I want to add *play()* method to some animals but not to all
- Basically I want some of the animals have an additional contract defined in superclass *Pet*

Java solution to multiple-inheritance problem

- Java does not allow a class to extend more than one superclass = it does not allow multiple inheritance
- However we can guarantee Pet behavior for all pet animals if we define all shared methods in a special Java class – *Interface*

  Not a GUI interface, not a colloquial use as in “public methods provide interface”, but a special Java keyword *Interface*

Pet interface

- In *Interface* **all** methods are abstract
- All subclasses must implement all of them
- Subclass **extends** a Superclass and **implements** Interface

```
public interface Pet {
    public void play();
}

public class Dog extends Animal
                         implements Pet{
    …
    public void makeNoise() {
        System.out.println("Wuff");
    }

    public void play() {
        System.out.println("Dog playing");
        this.makeNoise();
    }

}

public class Cat extends Animal
                         implements Pet{
```

Why use Interface

```
public class PetStore {
    public static void main
                (String [] args) {
        Pet [] pets = new Pet [4];

        pets[0] = new Cat();
        pets[1] = new Cat();
        pets[2] = new Cat();
        pets[3] = new Dog();

        for (Pet p: pets) {
            p.play();
        }
    }
}
```

If all the methods in Interface are abstract – how is this the code reuse?

- A subclass can extend one superclass and implement multiple interfaces
- Common interface can be used for polymorphism

Which of the following is True?

A. You can't make an object of an Abstract class but you can of an Interface.

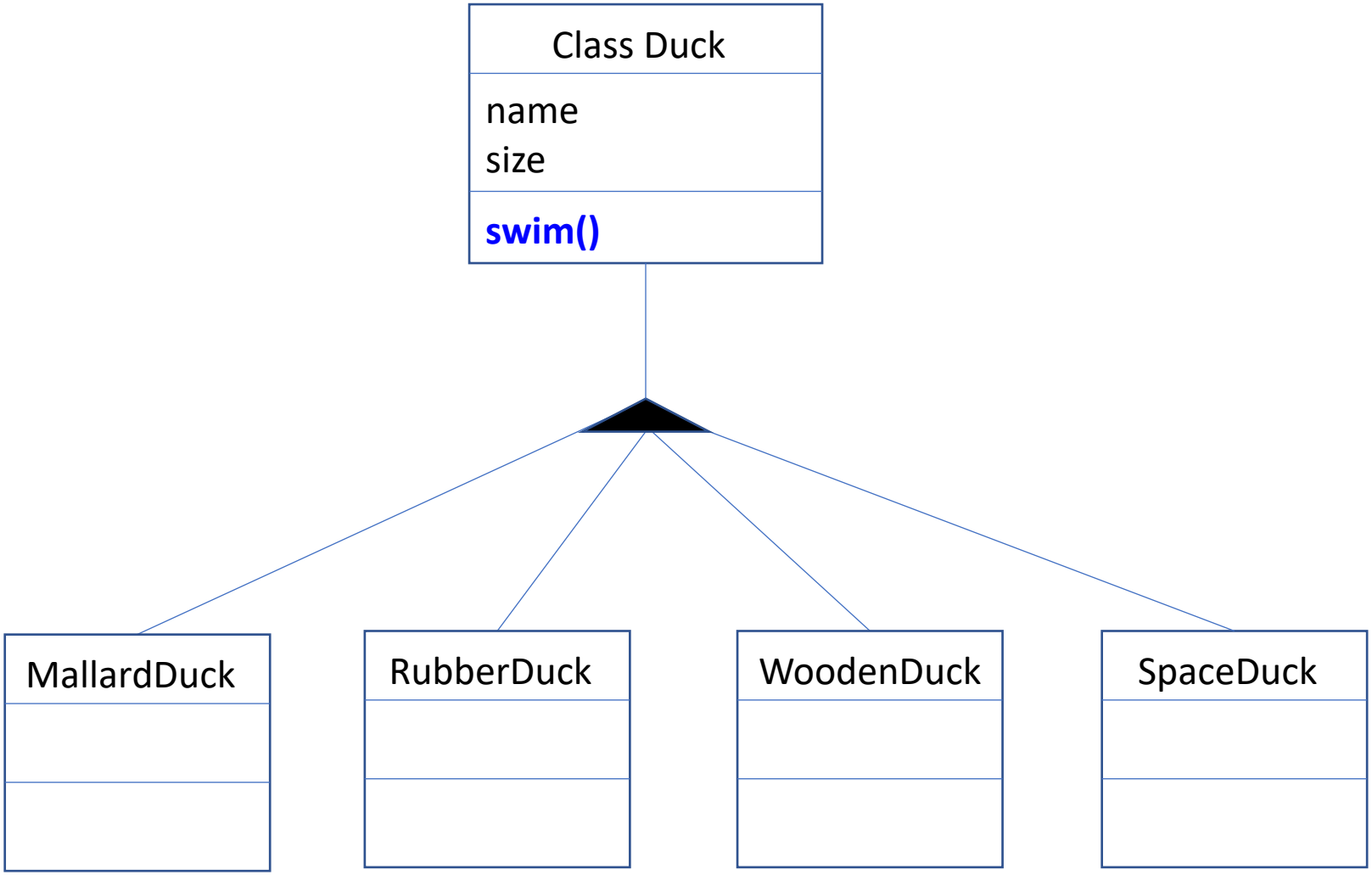
B. You can't make an object of an Interface but you can of an Abstract class.

C. You must implement all the abstract methods of the Interface, but you do not have to implement all the abstract methods of an Abstract class.

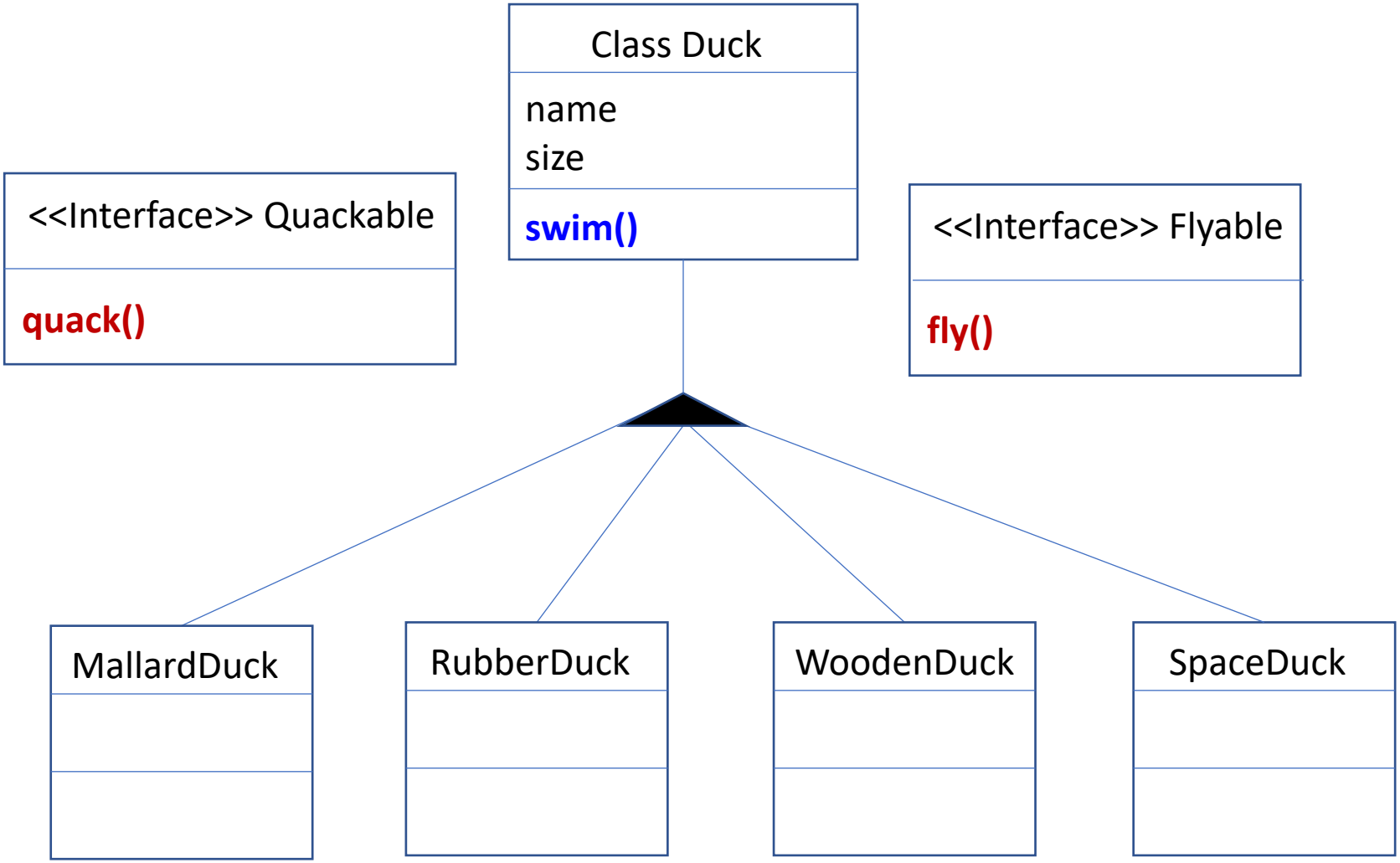
D. You can have both abstract and concrete methods in both Interface and Abstract class.

E. None of the above

Interface example: 1/3



Interface example: 2/3



Interface example: 3/3