# Inf1B

## Abstract Classes and Interfaces

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adapting earlier versions by Perdita Stevens, Ewan Klein, Volker Seeker, et al.

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# Abstract Classes

# Greeting

- The function `makeGreeting` gets a greeting string from an object `greeter` of class `Hello`.
- Then sends a greeting to a friend.

`Talker`

```
public static void makeGreeting(Hello greeter, String name) {
    System.out.printf(greeter.sayHello() + ", " + name + "!");
}
public static void main(String[] args) {
    Hello greeter = new Hello();
    makeGreeting(greeter, "James");
}
```

# Greeting

`Hello` class is trivial:

`Hello`

```
public class Hello {
    public String sayHello() {
        return "Hello";
    }
}
```

**Output**

```
Hello, James!
```

# Extending Greeting

- Suppose we decide to go international, and add a new class `Bonjour`.
- Similar to `Hello`, but different method name and different return string.

`Bonjour`

```
public class Bonjour {
    public String ditBonjour() {
        return "Bonjour";
    }
}
```

# Possible Solution?

- `Hello` and `Bonjour` should both be usable by `makeGreeting`
- But we can't do this straightforwardly; so create overload with a new 'French' version?

`Talker`

```
public static void makeGreeting(Hello greeter, String name) {
    System.out.printf(greeter.sayHello() + ", " + name + "!");
}

public static void main(String[] args) {
    Hello engGreeter = new Hello();
    makeGreeting(engGreeter, "James");
    Bonjour frGreeter = new Bonjour();
    makeGreeting(frGreeter, "Jacques");
}
```

# Possible Solution?

- `Hello` and `Bonjour` should both be usable by `makeGreeting`
- But we can't do this straightforwardly; so create overload with a new 'French' version?

`Talker`

```
public static void makeGreeting(Hello greeter, String name) {
    System.out.printf(greeter.sayHello() + ", " + name + "!");
}
public static void makeGreeting( Bonjour  greeter, String name) {
    System.out.printf(greeter. ditBonjour()  + ", " + name + "!")
}
public static void main(String[] args) {
    Hello engGreeter = new Hello();
    makeGreeting(engGreeter, "James");
    Bonjour frGreeter = new Bonjour();
    makeGreeting(frGreeter, "Jacques");
}
```

# Greeting

- Overloading `makeGreeting` to use `Bonjour` is wasteful — we're duplicating code.
- Can we get a more general version of `makeGreeting` which can use both `Hello` and `Bonjour`?

# Greeting

- Overloading `makeGreeting` to use `Bonjour` is wasteful — we're duplicating code.
- Can we get a more general version of `makeGreeting` which can use both `Hello` and `Bonjour`?

Step 1: Give both these classes a common API; i.e., they should use the same methods.

# Greeting

## Hello

```
public class Hello {
    public String greet() {
        return "Hello";
    }
}
```

## Bonjour

```
public class Bonjour {
    public String greet() {
        return "Bonjour";
    }
}
```

# Greeting

- How do we say, in general, what the shared API is?
- For example, how to enforce that a new class `BuonGiorno` conforms to this API?

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- How do we say, in general, what the shared API is?
- For example, how to enforce that a new class `BuonGiorno` conforms to this API?

Step 2: Pull the API into a superclass `Greeting`.

```
public class Hello extends Greeting {
    public String greet() {
        return "Hello";
    }
}

public class Bonjour extends Greeting {
    public String greet() {
        return "Bonjour";
    }
}
```

# Greeter

- How do we refactor `makeGreeting` to use objects that implement `Greeting`?

# Greeter

- How do we refactor `makeGreeting` to use objects that implement `Greeting`?

Step 3: Use `Greeting` as polymorphic type in the function signature.

## Talker

```
public static void makeGreeting( Greeting greeter, String name)
    System.out.printf(greeter.greet() + ", " + name + "!");
}
public static void main(String[] args) {
    Hello engGreeter = new Hello();
    makeGreeting(engGreeter, "James")
    Bonjour frGreeter = new Bonjour();
    makeGreeting(frGreeter, "Jacques");
}
```

# Greeting

But wait, something is not well defined. What happens in this case?

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## Talker

```
public static void makeGreeting(Greeting greeter, String name) {
    System.out.printf(greeter.greet() + ", " + name + "!");
}
public static void main(String[] args) {
    Greeting greeter = new Greeting();
    makeGreeting(greeter, "James")
}
```

# Greeting

But wait, something is not well defined. What happens in this case?

Talker

```
public static void makeGreeting(Greeting greeter, String name) {
    System.out.printf(greeter.greet() + ", " + name + "!");
}
public static void main(String[] args) {
    Greeting greeter = new Greeting();
    makeGreeting(greeter, "James")
}
```

What does it print?

# Greeting

- Print output for general superclass `Greeting` is not sensible to have.

`Greeting`

```
public class Greeting {
    public String greet() {
        return ???;
    }
}
```

# Greeting

- Print output for general superclass `Greeting` is not sensible to have.
- Therefore, we declare `Greeting` to be **abstract**

`Greeting`

```
public abstract class Greeting {
    public String greet() {
        return ???;
    }
}
```

# Greeting

- Print output for general superclass `Greeting` is not sensible to have.
- Therefore, we declare `Greeting` to be **abstract**
- and provide no superclass implementation for `greet`.

`Greeting`

```
public abstract class Greeting {
    public abstract String greet();
}
```

# Greeting

- Print output for general superclass `Greeting` is not sensible to have.
- Therefore, we declare `Greeting` to be **abstract**
- and provide no superclass implementation for `greet`.

`Greeting`

```
public abstract class Greeting {
    public abstract String greet() ;
}
```

This solves our class design problem.

# Greeting

- Instantiation of an abstract class is not allowed.

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- Instantiation of an abstract class is not allowed.

Talker

```
public static void makeGreeting(Greeting greeter, String name) {
    System.out.printf(greeter.greet() + ", " + name + "!");
}
public static void main(String[] args) {
    Greeting greeter = new Greeting();
    makeGreeting(greeter, "James")
}
```

This causes a compiler error:

error: Greeting is abstract; cannot be instantiated

# Greeting

- Instantiation of an abstract class is not allowed.
- The abstract method `greet` enforces required API for each subclass.

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- Instantiation of an abstract class is not allowed.
- The abstract method `greet` enforces required API for each subclass.

```
public class Hello extends Greeting {
    // must override abstract method
    // to avoid compiler error
    public String greet() {
        return "Hello";
    }
}
```

# Animal Objects?

## Creating new objects

```
Wolf wolfie = new Wolf();

Animal leo = new Lion();

Animal weird = new Animal();
```

- `Animal` class is meant to contain information that all animals have in common.
- But this is not enough to define any one specific animal.

# Concrete vs. Abstract

## Concrete

- Examples: `Cat`, `Wolf`, `Hello`
- Specific enough to be instantiated.

## Abstract

- Examples: `Animal`, `Feline`, `Greeting`
- Not intended to have instances.
- Only useful if extended.
- Any 'instances' will have to be instances of a subclass of the abstract class.

# The Abstract Animal

## Animal

```
public abstract class Animal {
    public void sleep() {
        System.out.println("Sleeping: Zzzzz");
    }
    public void makeNoise() {
        System.out.println("Noises...");
    }
    public void roam() {
        System.out.println("Roamin' on the plain.");
    }
}
```

Just put the keyword `abstract` before the class declaration.

# The Abstract Animal

- An abstract class can be extended by other abstract classes.
- `Canine` and `Feline` can (and should) both be abstract.

## Animal

```
public abstract class Animal {
    public void sleep() {
        System.out.println("Sleeping: Zzzzz");
    }
    public void makeNoise() {
        System.out.println("Noises...");
    }
    public void roam() {
        System.out.println("Roamin' on the plain.");
    }
}
```

Just put the keyword `abstract` before the class declaration.

# The Abstract Animal

## Animal

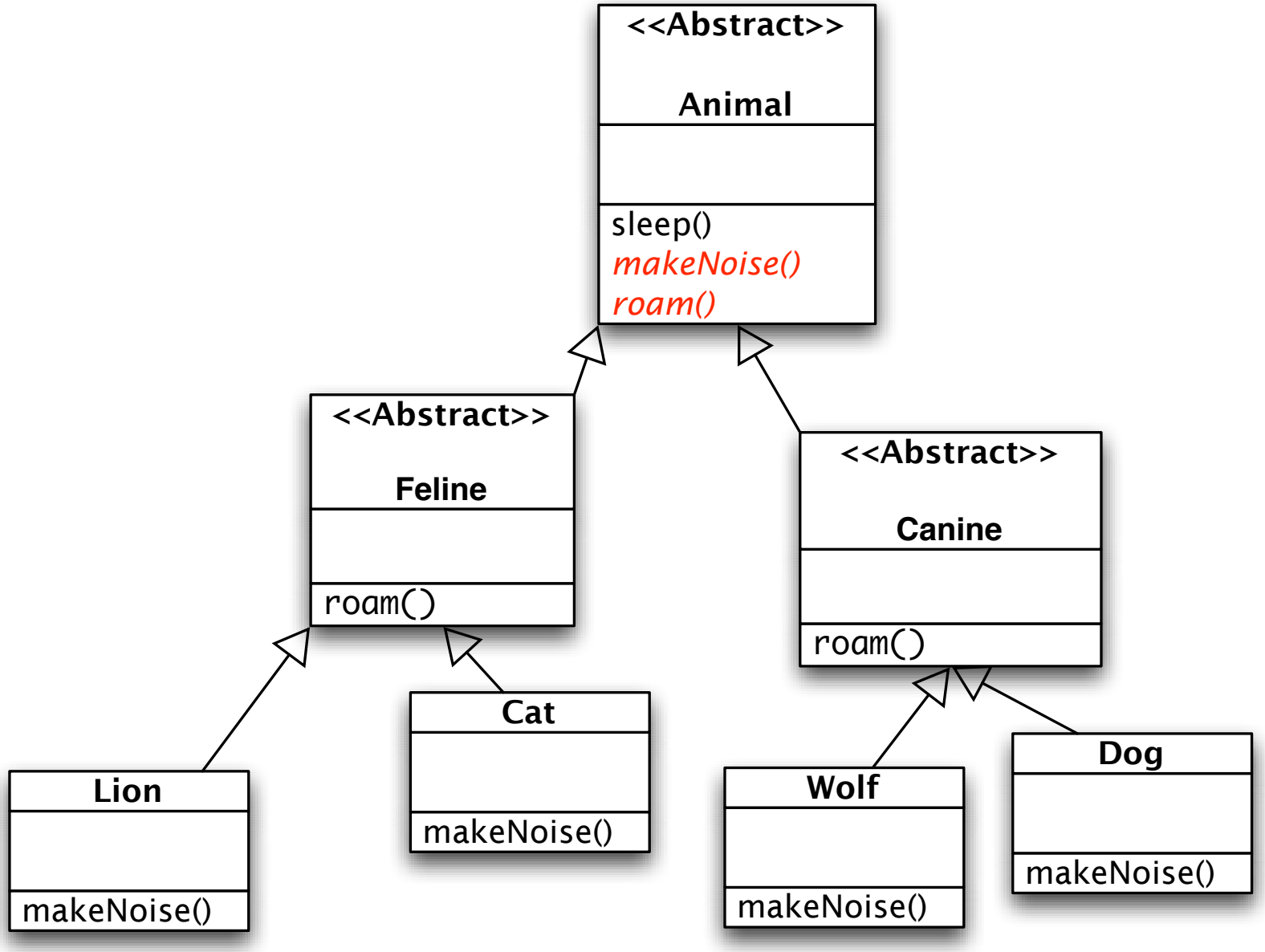
```
public abstract class Animal {
    public void sleep() {
        System.out.println(""Sleeping: Zzzzz"");
     }
    public abstract void roam();
    public abstract void makeNoise();
}
```

Now has abstract methods!

# The Abstract `Animal`

- `roam()` and `makeNoise()` are abstract methods:
  - no body;
  - must be implemented in any concrete subclass (implemented $\sim$ overridden);
  - don't have to be implemented by an abstract subclass;
  - can only be declared in an abstract class;
- `sleep()` is not abstract, so can be straightforwardly inherited.

# Abstract Classes in Animal Hierarchy



# Using Abstract Classes

- Use an abstract class when you have several similar classes that:
  - have a lot in common — the implemented parts of the abstract class
  - have some differences — the abstract methods.

# What does it print?

```
public abstract class Vehicle {
  public void drive() {
    System.out.println("drivedrive");
  }
}

public class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}

public class Main {
  public static void main(String[] args) {
    Vehicle c = new Vehicle();
    c.drive();
  }
}
```

# What does it print?

```
public abstract class Vehicle {
  public void drive() {
    System.out.println("drivedrive");
  }
}

public class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}

public class Main {
  public static void main(String[] args) {
    Vehicle c = new Vehicle();
    c.drive();
  }
}
```

Does not compile because abstract classes cannot be instantiated.

# What does it print?

```
public abstract class Vehicle {
  public abstract void drive();
}

public class Car extends Vehicle {
}

public class Main {
  public static void main(String[]
      args) {
    Car c = new Car();
    c.drive();
  }
}
```

# What does it print?

```
public abstract class Vehicle {
  public abstract void drive();
}

public class Car extends Vehicle {
}

public class Main {
  public static void main(String[]
      args) {
    Car c = new Car();
    c.drive();
  }
}
```

Does not compile because abstract methods need to be implemented in subclass.

# What does it print?

```
public abstract class Vehicle {
  public abstract void drive();
}

public abstract class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}

public class Polo extends Car {
}

public class Main {
  public static void main(String[] args) {
    Polo p = new Polo();
    p.drive();
  }
}
```

# What does it print?

```
public abstract class Vehicle {
  public abstract void drive();
}

public abstract class Car extends Vehicle {
  public void drive() {
    System.out.println("rollroll");
  }
}

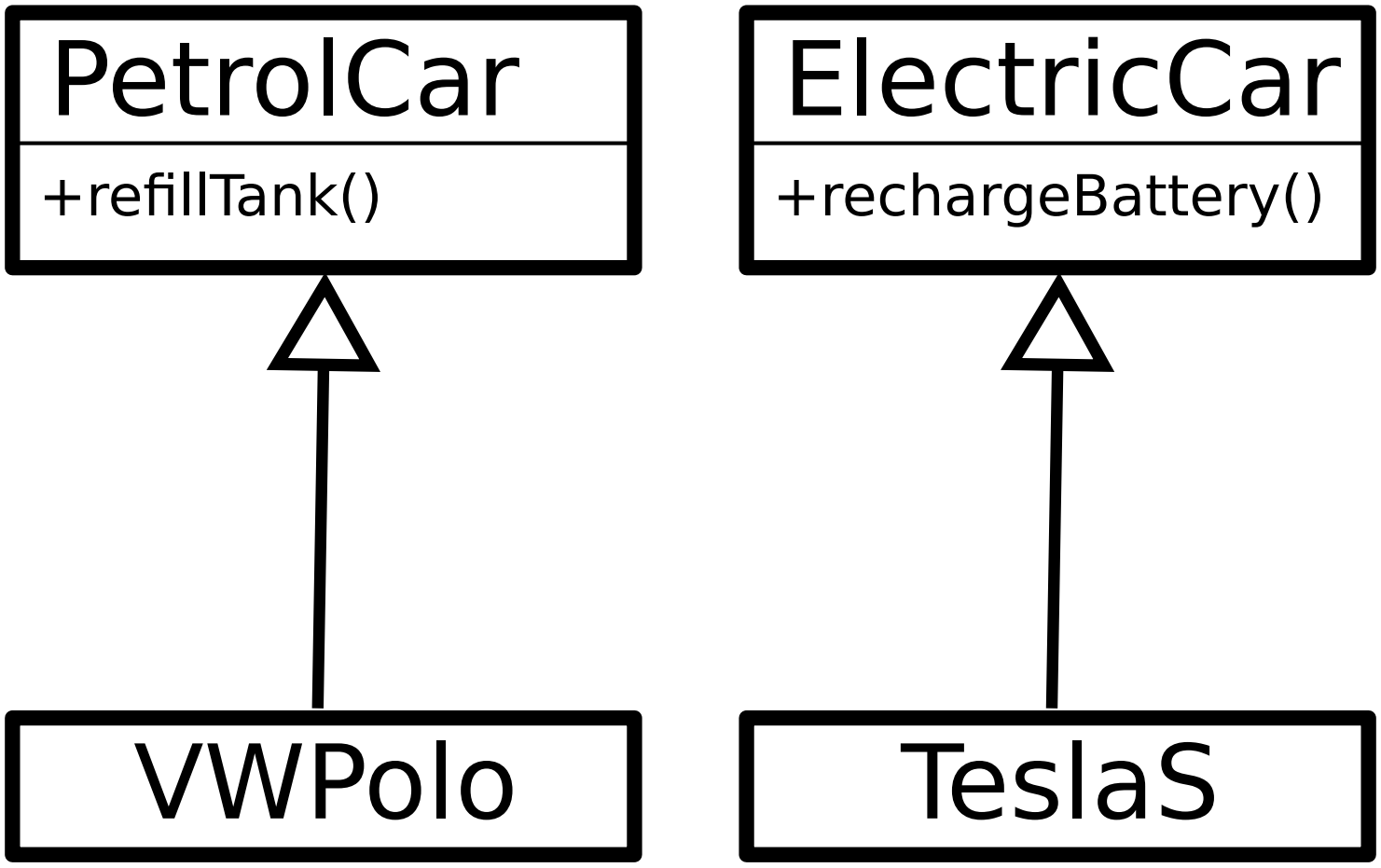
public class Polo extends Car {
}

public class Main {
  public static void main(String[] args) {
    Polo p = new Polo();
    p.drive();
  }
}
```

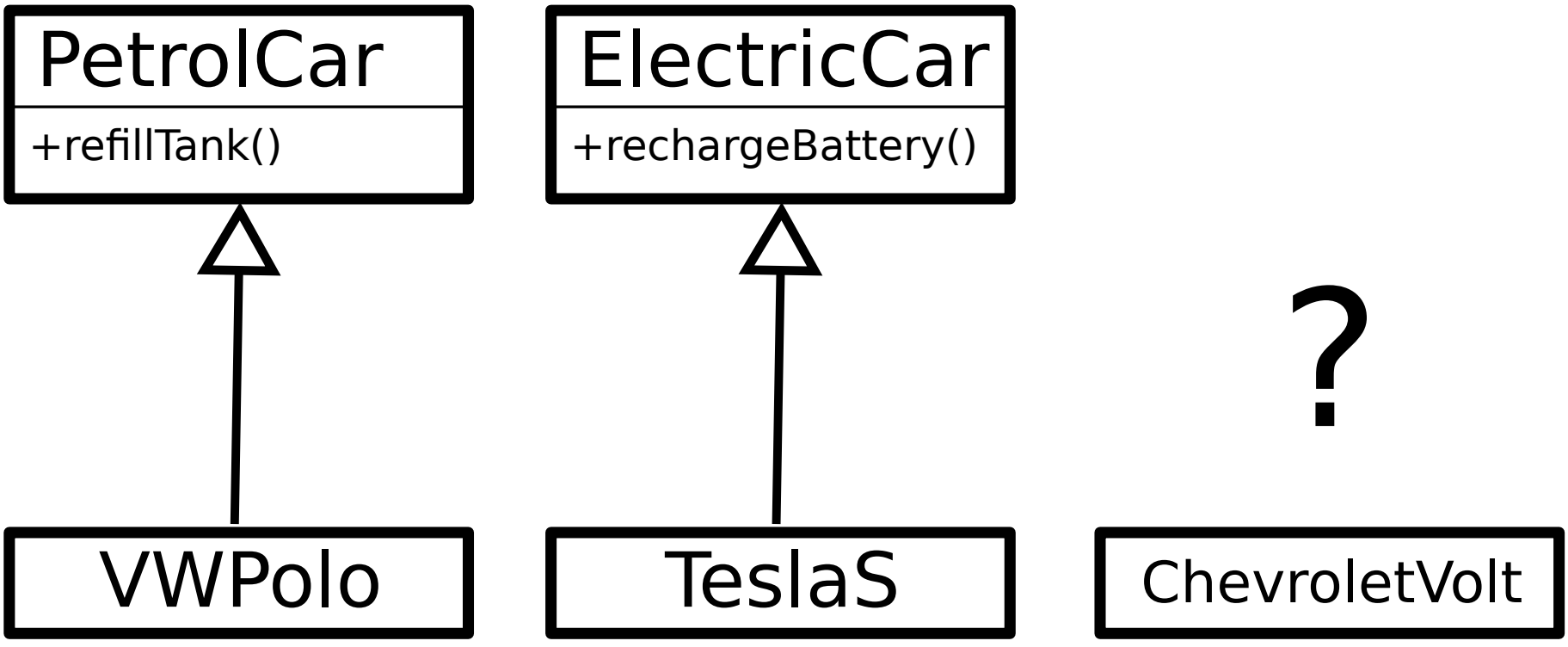
Prints **rollroll**. Car implements the abstract method and Polo inherits this implementation.

# Interfaces

# Different Types of Cars

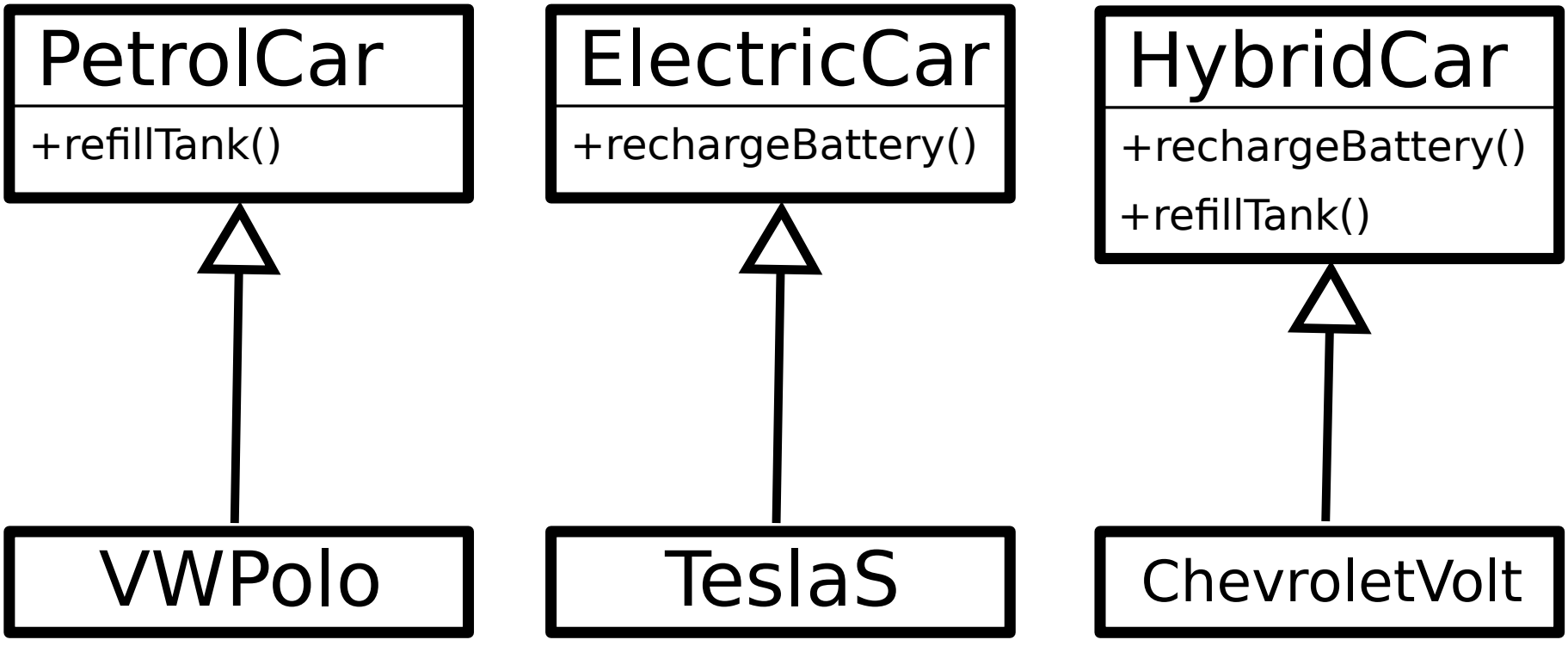


# Hybrid Car



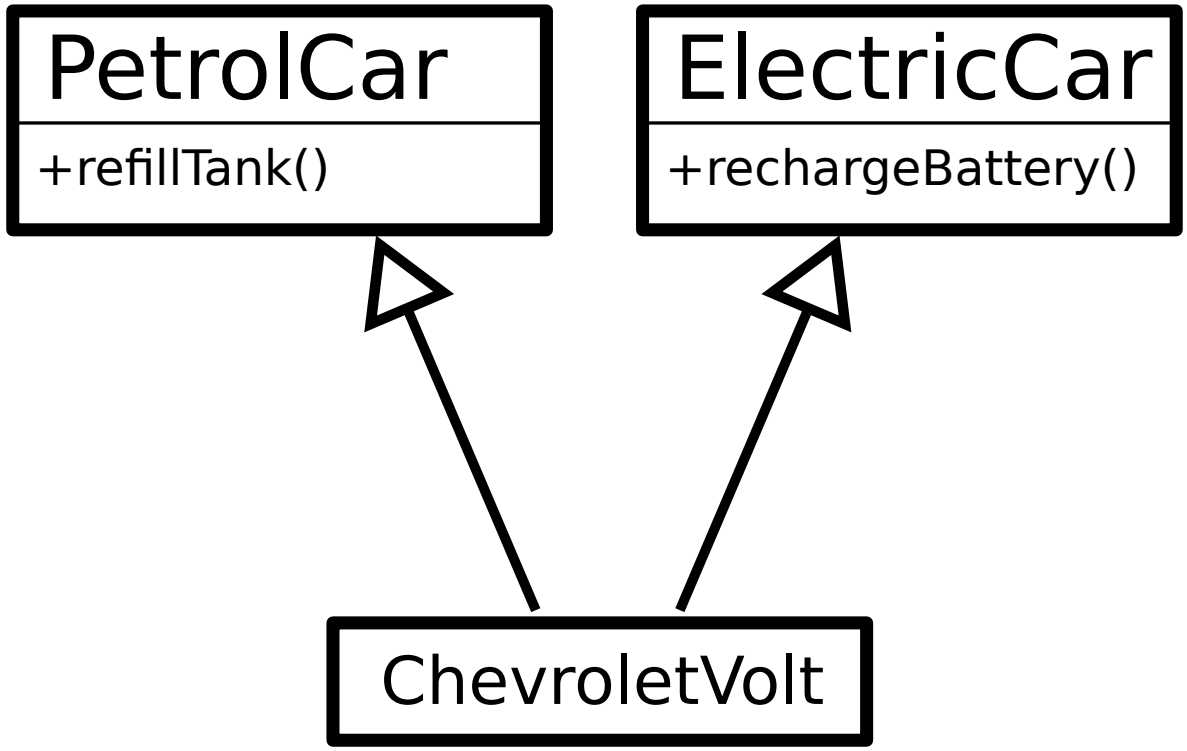

How to handle a plug-in Hybrid which has both battery and petrol, i.e. **features of both superclasses**?

# Hybrid Car



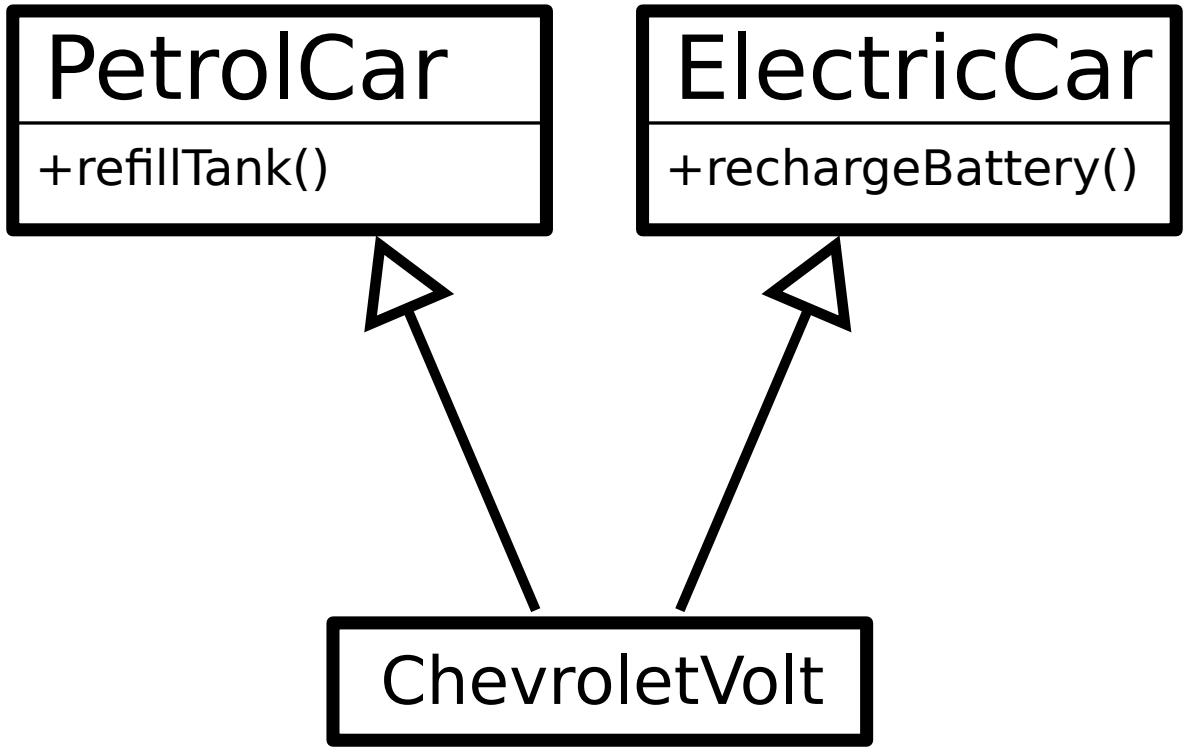

Creating a new superclass with both methods would be wasteful - **code duplication**.

# Multiple Inheritance




Inheriting from **both** classes would be best.

# Multiple Inheritance

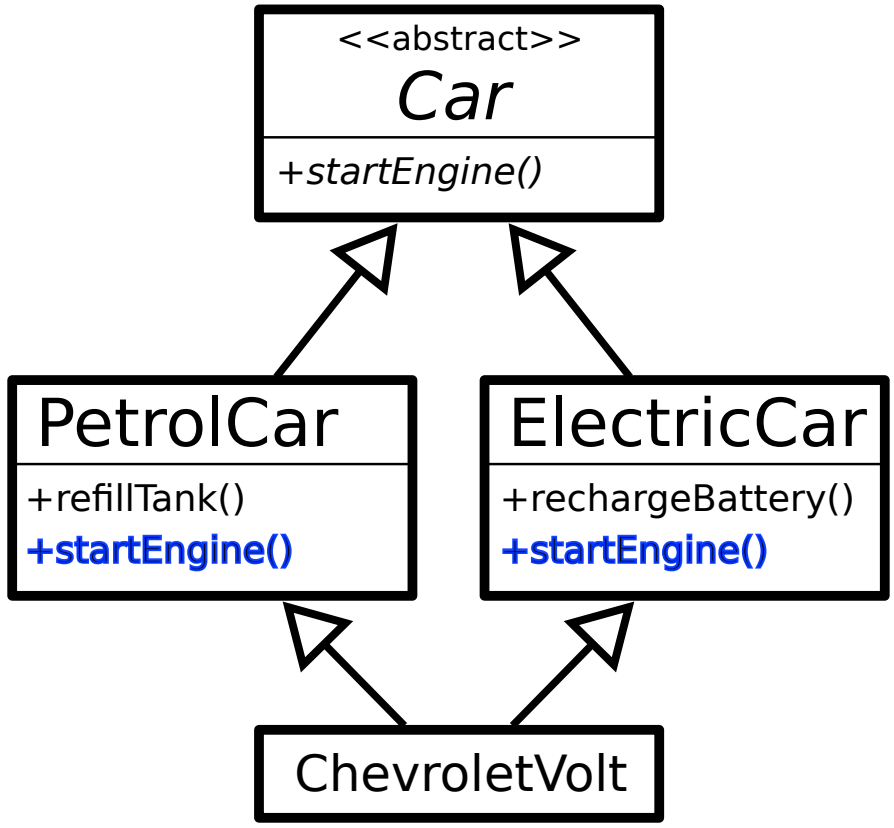



Inheriting from **both** classes would be best.

Unfortunately, multiple inheritance has some ambiguity problems.

# Ambiguity Problems with Multiple Inheritance

## The Deadly Diamond of Death




- both `PetrolCar` and `ElectricCar` override `startEngine`
- which version of `startEngine` does `ChevroletVolt` inherit?

# Multiple Inheritance Support

Some languages resolve ambiguity using a complex implementation, e.g. C++

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Java, avoids ambiguity by using **Interfaces**

# Interfaces in Java

- Interfaces are defined using the interface keyword
- like abstract classes they cannot be instantiated
- unlike abstract classes **all methods** have to be abstract

```
public interface PetrolCar {
    public abstract void refillTank();
}

public interface ElectricCar {
    public abstract void rechargeBattery();
}
```

# Interfaces in Java

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```
public interface PetrolCar {
    public abstract void refillTank();
}

public interface ElectricCar {
    public abstract void rechargeBattery();
}
```

They do not allow sharing of implementations but enforce an API.

# Interfaces in Java

- classes can **implement** interfaces by using the implements keyword
- an implementation for each method is enforced by the compiler

```
public class ChevroletVolt implements PetrolCar, ElectricCar {
    public void refillTank() {
        // refill petrol
    }

    public void rechargeBattery() {
        // recharge power
    }
}
```

# Interfaces in Java

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```
public class ChevroletVolt implements PetrolCar, ElectricCar {
    public void refillTank() {
        // refill petrol
    }

    public void rechargeBattery() {
        // recharge power
    }
}
```

Both extension and implementation is possible:

```
public class ChevroletVolt extends Chevrolet implements PetrolCar, ElectricCar
```

# Syntactic Sugar

- all methods in an interface must be public

```
public interface PetrolCar {

    public abstract void refillTank();
}
```

# Syntactic Sugar

- all methods in an interface must be public

```
public interface PetrolCar {

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}
```

# Syntactic Sugar

- all methods in an interface must be public
- all methods in an interface must be abstract

```
public interface PetrolCar {

    abstract void refillTank();
}
```

# Syntactic Sugar

- all methods in an interface must be public
- all methods in an interface must be abstract

```
public interface PetrolCar {

    void refillTank();
}
```

# Syntactic Sugar

- all methods in an interface must be public
- all methods in an interface must be abstract
- no constructors are allowed

```
public interface PetrolCar {

    void refillTank();
}
```

# Syntactic Sugar

- all methods in an interface must be public
- all methods in an interface must be abstract
- no constructors are allowed
- members are allowed but they must be public static final

```
public interface PetrolCar {
    public static final String FUEL = "Diesel";
    void refillTank();
}
```

# Syntactic Sugar

- all methods in an interface must be public
- all methods in an interface must be abstract
- no constructors are allowed
- members are allowed but they must be public static final

```
public interface PetrolCar {
    String FUEL = "Diesel";
    void refillTank();
}
```

# Avoiding Code Duplication

When using interfaces for `PetrolCar` and `ElectricCar` we would have to implement `refillTank` and `rechargeBattery` for each new superclass.

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To avoid this in Java, you could use object **Composition**.

# Avoiding Code Duplication

When using interfaces for `PetrolCar` and `ElectricCar` we would have to implement `refillTank` and `rechargeBattery` for each new superclass.

To avoid this in Java, you could use object **Composition**.

```
public class ChevroletVolt implements PetrolCar, ElectricCar {
    private final BatteryCharger charger;
    private final FuelPump pump;

    public void refillTank() {
        pump.refill();
    }

    public void rechargeBattery() {
        charger.charge();
    }
}
```

# Inheritance in Java API

Inheritance using interfaces and abstract classes is used a lot in the Java API.

Have a browse:

`https://docs.oracle.com/en/java/javase/15/docs/api/`

# Comparable Interface

You have an `ArrayList` of cows and you want to order them by size.

```
public class Cow extends Animal {
    private int size;
    private float milkYield;
    private String name;
    ...
}
```

# Comparable Interface

Java provides a convenient method `Collections.sort()` in `java.util.Collections`.

```
ArrayList<Cow> herd = collectCows();
Collections.sort(herd); // sorts the herd
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# Comparable Interface

Java provides a convenient method `Collections.sort()` in `java.util.Collections`.

```
ArrayList<Cow> herd = collectCows();
Collections.sort(herd); // sorts the herd
```

How does the `sort` method know that you want to order by `size` and not by `milkYield` or `name`?

# Comparable Interface

The `sort` method expects objects to implement the **java.lang.Comparable** interface.

The `Comparable` interface forces subclasses to implement the **compareTo** method.

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The `Comparable` interface forces subclasses to implement the **compareTo** method.

```
public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
    private String name;

    @Override
    public int compareTo(Cow other) {
        ...
    }
    ...
}
```

# compareTo Method

`compareTo` is expected to be used in the following way:

- if `this` is less than `other`, return a negative number
- if `this` is greater than `other`, return a positive number
- if `this` is equal to `other`, return zero

# compareTo Method

compareTo is expected to be used in the following way:

- if this is less than other, return a negative number
- if this is greater than other, return a positive number
- if this is equal to other, return zero

```
public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
    private String name;

    @Override
    public int compareTo(Cow other) {
        if (size < other.size) return -1;
        else if (size > other.size) return 1;
        else return 0;
    }
    ...
}
```

# compareTo Method

`compareTo` is expected to be used in the following way:

- if `this` is less than `other`, return a negative number
- if `this` is greater than `other`, return a positive number
- if `this` is equal to `other`, return zero

```
public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
    private String name;

    @Override
    public int compareTo(Cow other) {
        return size - other.size;
    }
    ...
}
```

This works but is bad style!

# compareTo Method

`compareTo` is expected to be used in the following way:

- if `this` is less than `other`, return a negative number
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public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
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    @Override
    public int compareTo(Cow other) {
        return size - other.size;
    }
    ...
}
```

This works but is bad style!

Integer overflow possible

# CompareTo Method

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- if `this` is less than `other`, return a negative number
- if `this` is greater than `other`, return a positive number
- if `this` is equal to `other`, return zero

```
public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
    private String name;

    @Override
    public int compareTo(Cow other) {
        return Integer.compare(size, other.size);
    }
    ...
}
```

Java's boxed primitives have static `compare` methods.

# CompareTo Method

`CompareTo` is expected to be used in the following way:

- if `this` is less than `other`, return a negative number
- if `this` is greater than `other`, return a positive number
- if `this` is equal to `other`, return zero

```
public class Cow extends Animal implements Comparable<Cow>{
    private int size;
    private float milkYield;
    private String name;

    @Override
    public int compareTo(Cow other) {
        return name.compareTo(other.name);
    }
    ...
}
```

Many API classes such as boxed primitives or `String` implement the `Comparable` interface already.

# What does it print?

```
public interface Drivable {
  public void startEngine() {
    System.out.println("WrummWrumm");
  }
  public abstract void drive();
}

public class Car implements Drivable {
  public void drive() {
    super.startEngine();
    System.out.println("rollroll");
  }
}

public class Main {
  public static void main(String[] args) {
    Car c = new Car();
    c.drive();
  }
}
```

# What does it print?

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    System.out.println("rollroll");
  }
}

public class Main {
  public static void main(String[] args) {
    Car c = new Car();
    c.drive();
  }
}
```

Does not compile because interfaces are not allowed to implement methods.

# What does it print?

```
public interface Drivable {
  public abstract void drive();
}

public class Car implements Drivable {
  public void drive() {
    System.out.println("rollroll");
  }
}

public class Polo extends Car {
  public void drive() {
    System.out.println("PoloPower");
  }
}

public class Main {
  public static void main(String[] args) {
    Polo p = new Polo();
    p.drive();
  }
}
```

# What does it print?

```
public interface Drivable {
  public abstract void drive();
}

public class Car implements Drivable {
  public void drive() {
    System.out.println("rollroll");
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}

public class Polo extends Car {
  public void drive() {
    System.out.println("PoloPower");
  }
}

public class Main {
  public static void main(String[] args) {
    Polo p = new Polo();
    p.drive();
  }
}
```

Prints **PoloPower**. Car implements the drive method and Polo overrides it.

# Summary

- abstract classes can be used to implement common behaviour without allowing instantiation (concrete vs. abstract)
- abstract methods can be used to enforce API on subclasses
- interfaces allow multiple inheritance but cannot be used to implement behaviour

# Reading

Objects First

Chapter 12 *Further Abstraction Techniques*