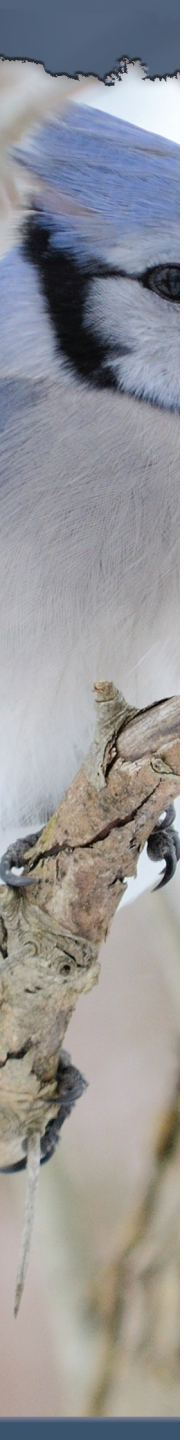
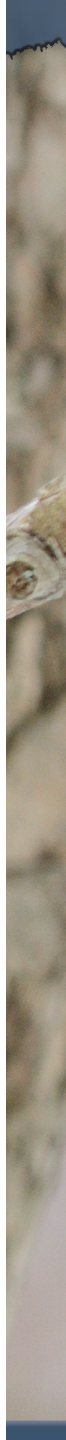
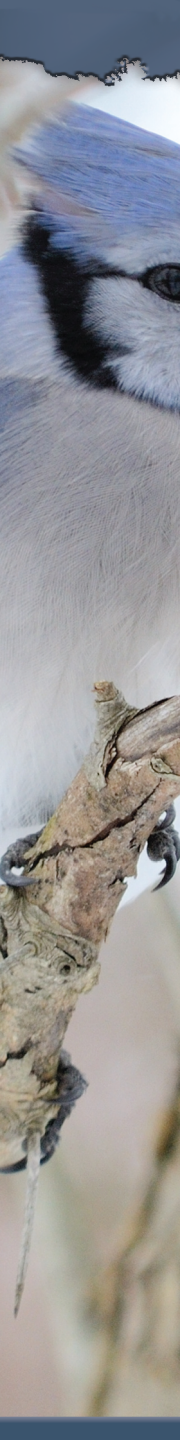


# Further abstraction techniques

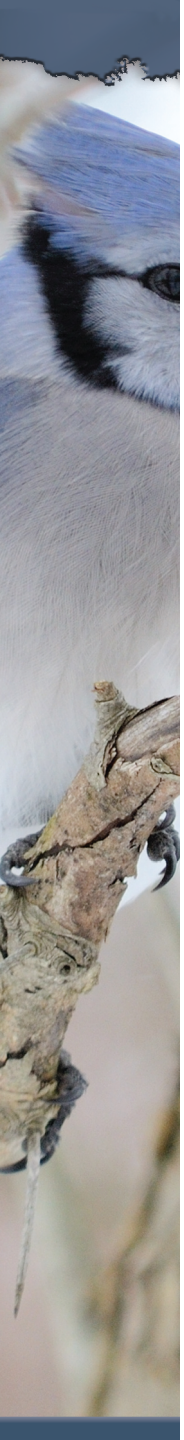
## Abstract classes and interfaces





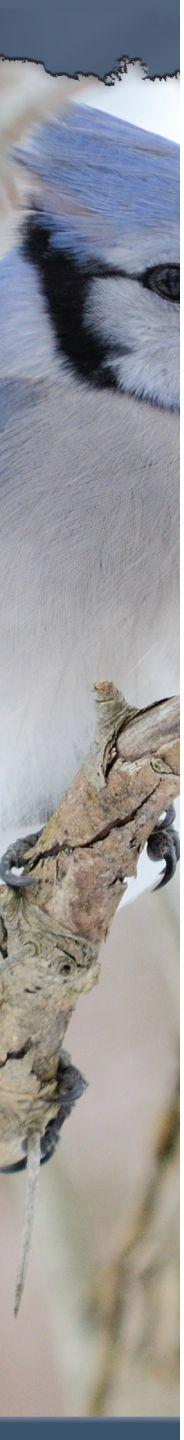
# Main concepts to be covered

- Abstract classes
- Interfaces
- Multiple inheritance



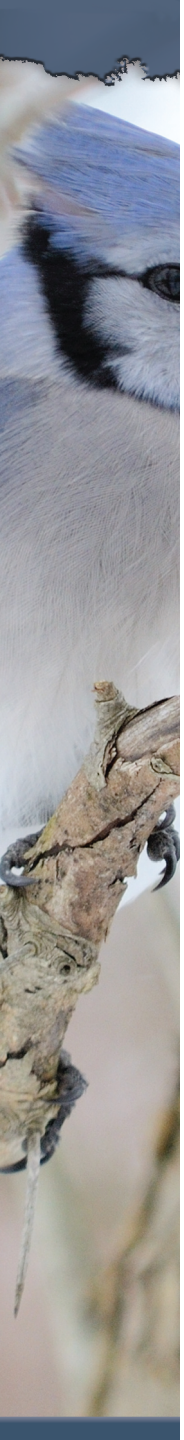
# Simulations

- Programs regularly used to simulate real-world activities:
  - city traffic;
  - the weather;
  - nuclear processes;
  - stock market fluctuations;
  - environmental impacts;
  - space flight.



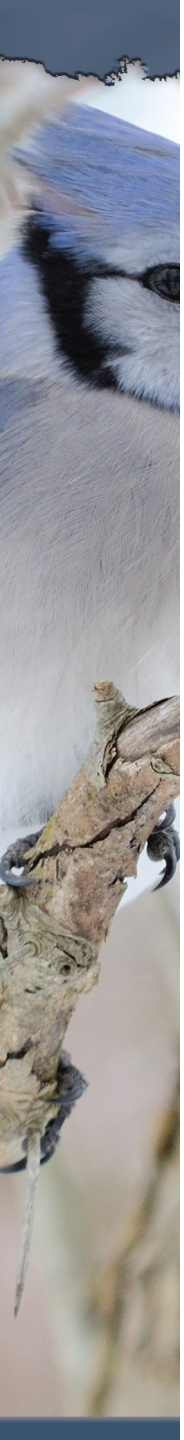
# Simulations

- They are often only partial simulations.
- They often involve simplifications.
  - Greater detail has the potential to provide greater accuracy.
  - Greater detail typically requires more resource:
    - Processing power;
    - Simulation time.



# Benefits of simulations

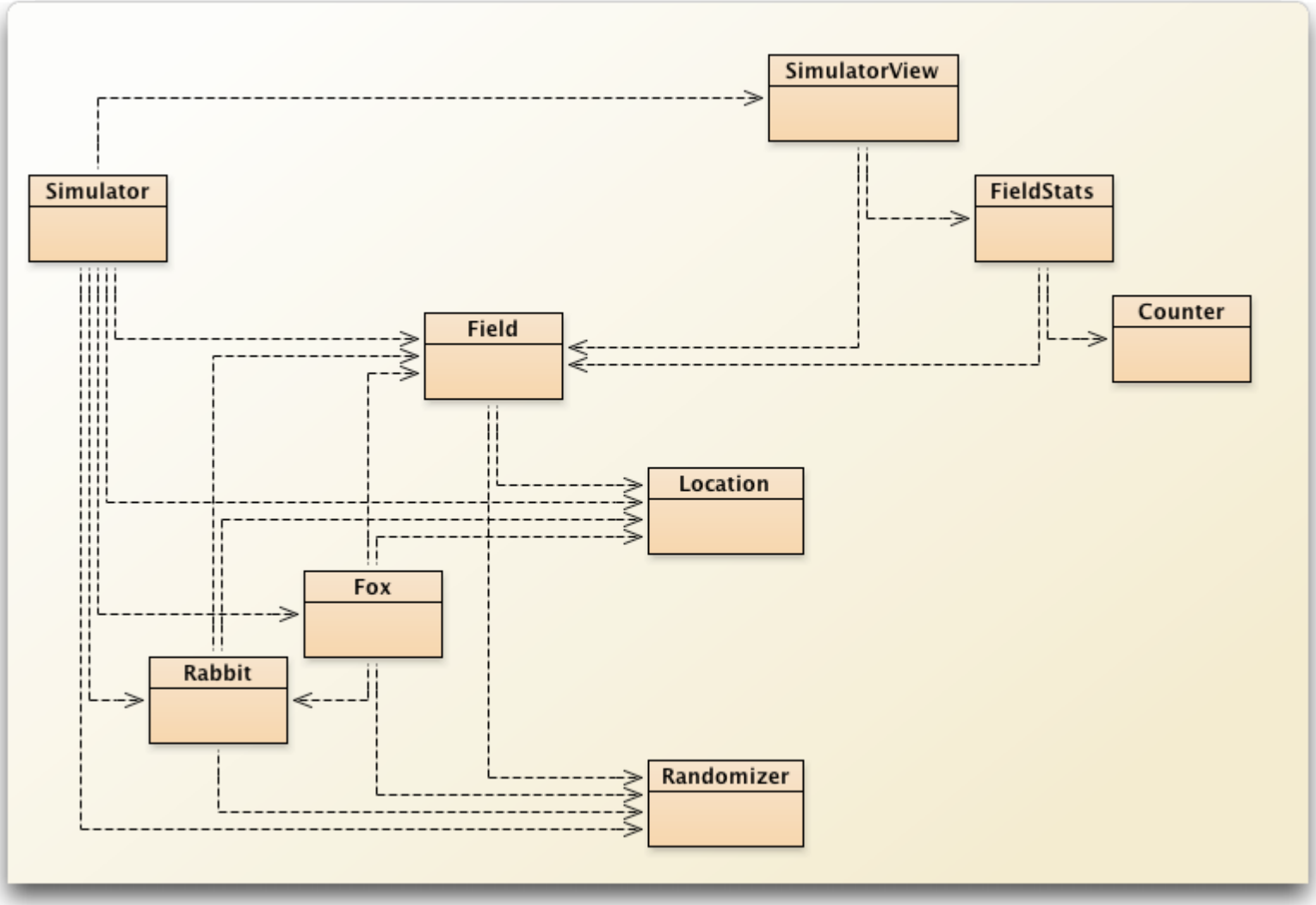
- Support useful prediction.
  - E.g., the weather.
- Allow experimentation.
  - Safer, cheaper, quicker.
- Our example:
  - ‘How will the wildlife be affected if we cut a highway through the middle of this national park?’

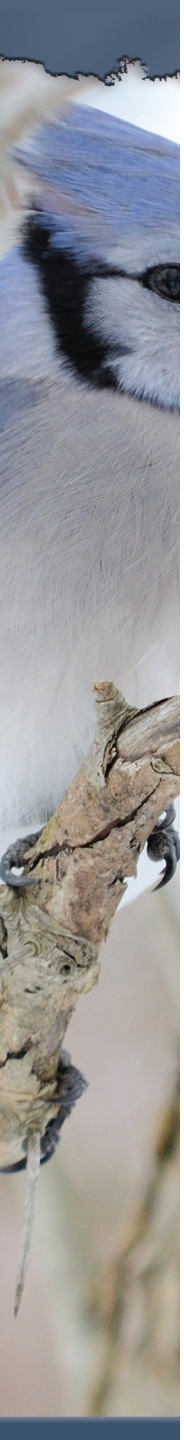


# Predator-prey simulations

- There is often a delicate balance between species.
  - A lot of prey means a lot of food.
  - A lot of food encourages higher predator numbers.
  - More predators eat more prey.
  - Less prey means less food.
  - Less food means ...

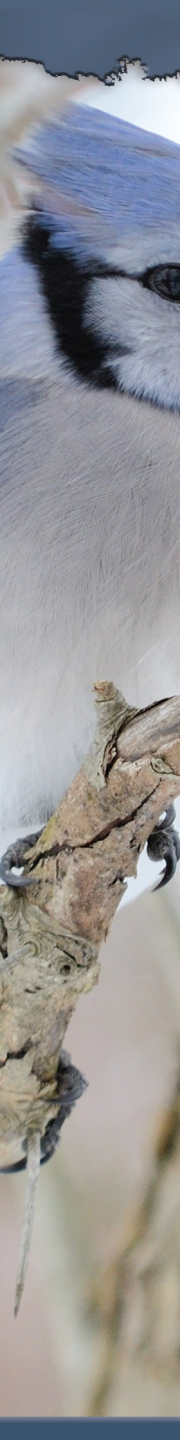
# The foxes-and-rabbits project





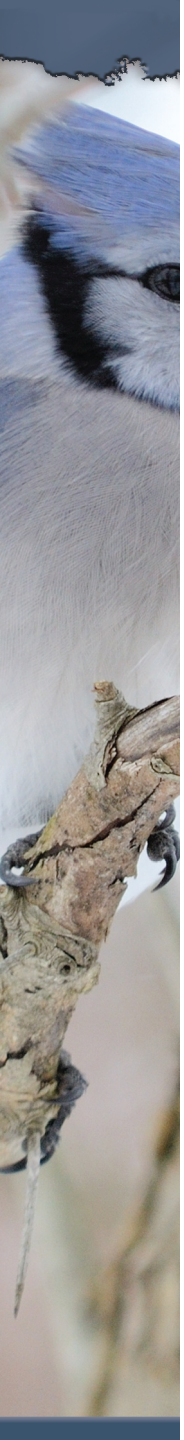
# Main classes of interest

- **`Fox`**
  - Simple model of a type of predator.
- **`Rabbit`**
  - Simple model of a type of prey.
- **`Simulator`**
  - Manages the overall simulation task.
  - Holds a collection of foxes and rabbits.



# Modeling the environment

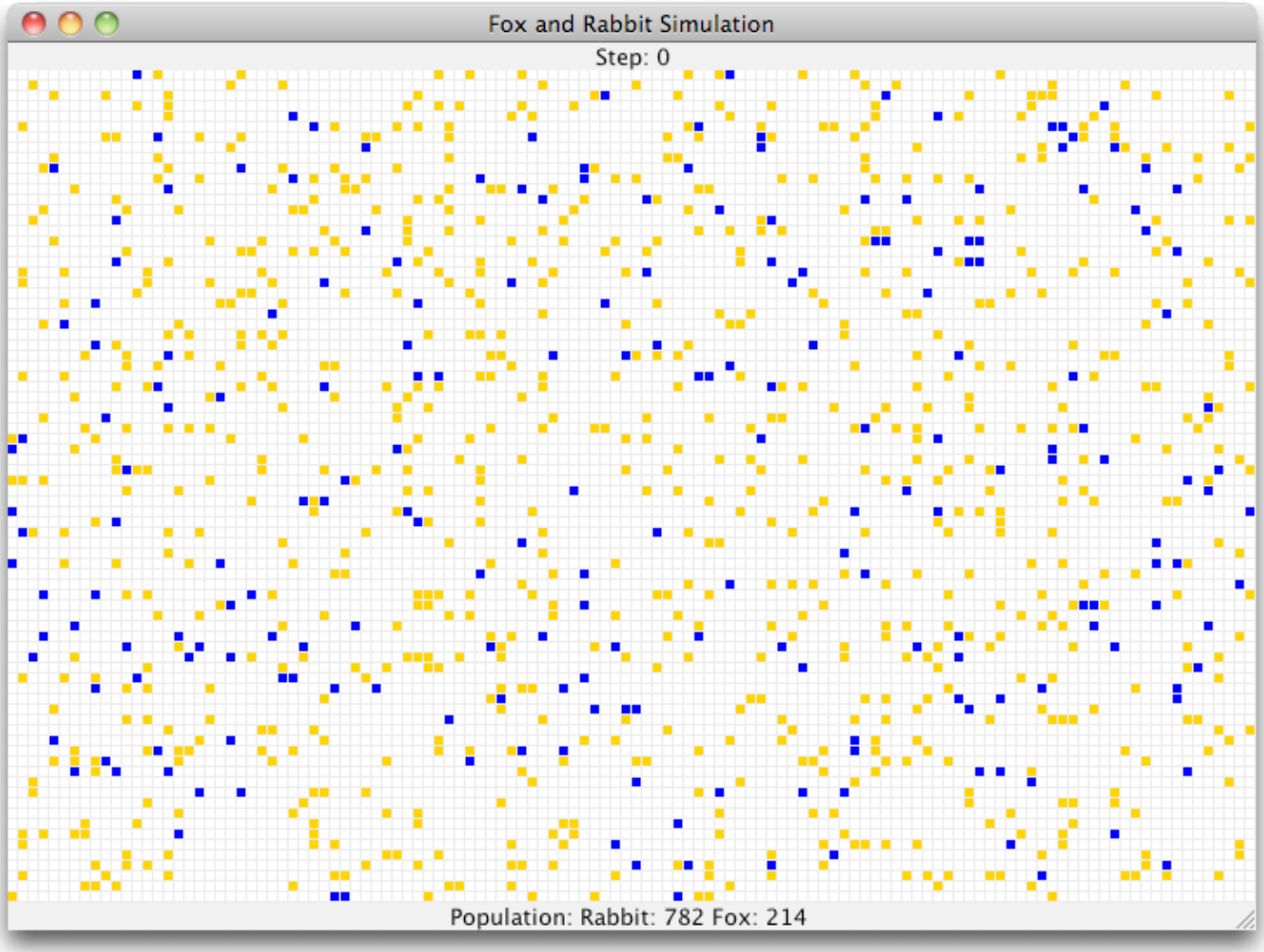
- **`Field`**
  - Represents a 2D field.
- **`Location`**
  - Represents a 2D position in the environment.

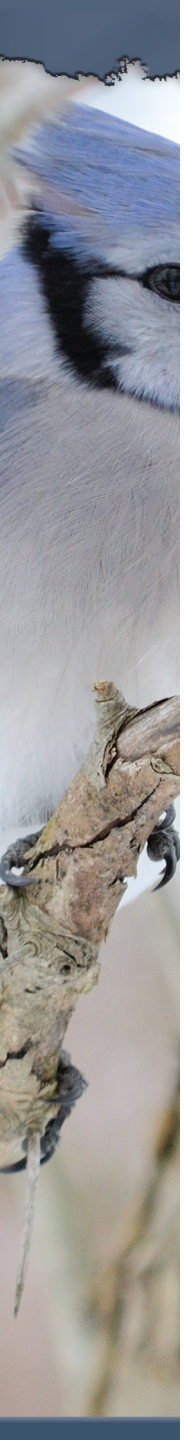


# Monitoring the simulation

- **`SimulatorView`**
  - Presents a view of the environment.
- **`FieldStats`, `Counter`**
  - Maintain statistics.
- **`Randomizer`**
  - Supports reproducibility.

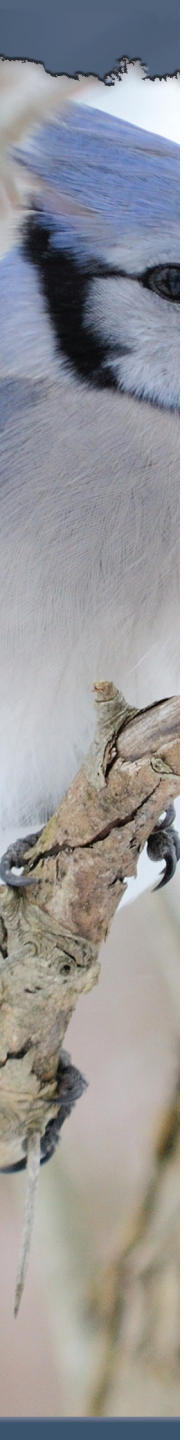
# Example of the visualization





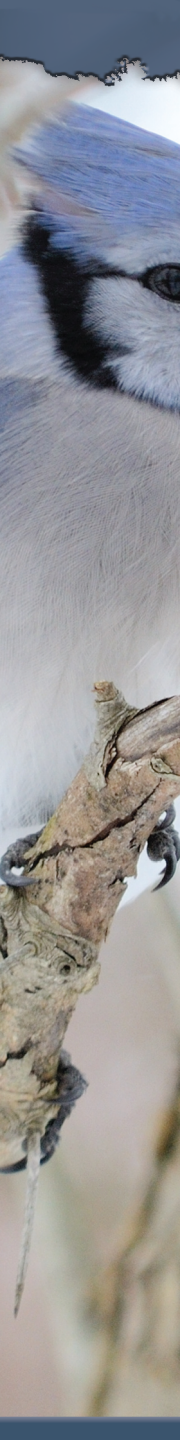
# A Rabbit's state

```
class Rabbit {
    Static fields omitted.

    // Individual characteristics (instance fields).

    // The rabbit's age.
    private int age;
    // Whether the rabbit is alive or not.
    private boolean alive;
    // The rabbit's position
    private Location location;
    // The field occupied
    private Field field;

    Methods omitted.
}
```



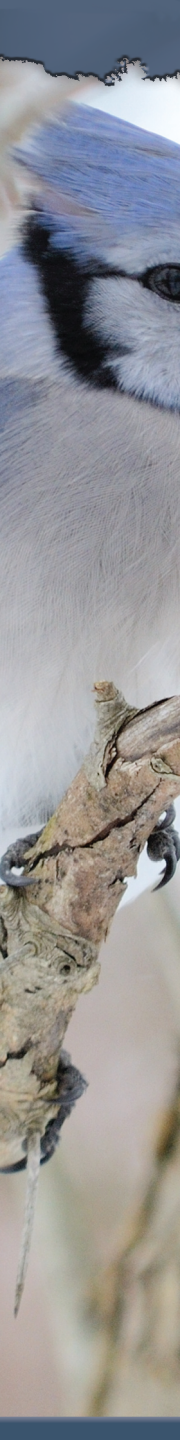
# A Rabbit's behavior

- Managed from the **`run`** method.
- Age incremented at each simulation 'step'.
  - A rabbit could die at this point.
- Rabbits that are old enough might breed at each step.
  - New rabbits could be born at this point.



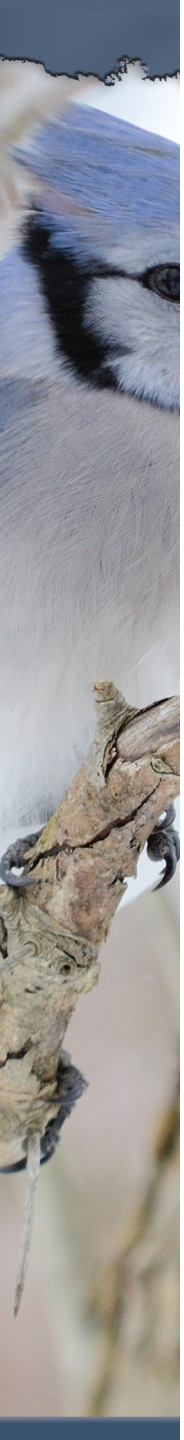
# Rabbit simplifications

- Rabbits do not have different genders.
  - In effect, all are female.
- The same rabbit could breed at every step.
- All rabbits die at the same age.
- Others?



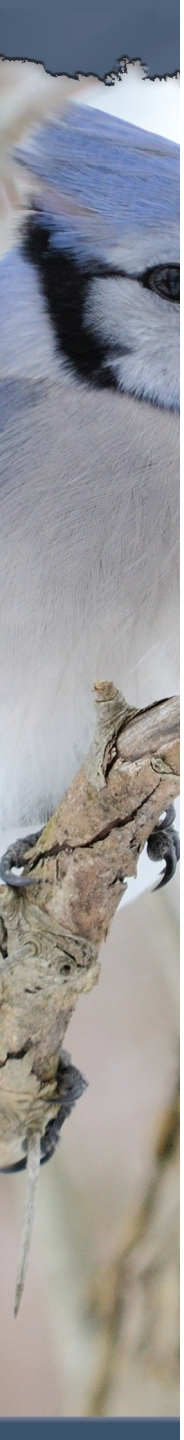
# A Fox's state

```
class Fox {
    Static fields omitted

    // The fox's age.
    private int age;
    // Whether the fox is alive or not.
    private boolean alive;
    // The fox's position
    private Location location;
    // The field occupied
    private Field field;
    // The fox's food level, which is increased
    // by eating rabbits.
    private int foodLevel;

    Methods omitted.
}
```



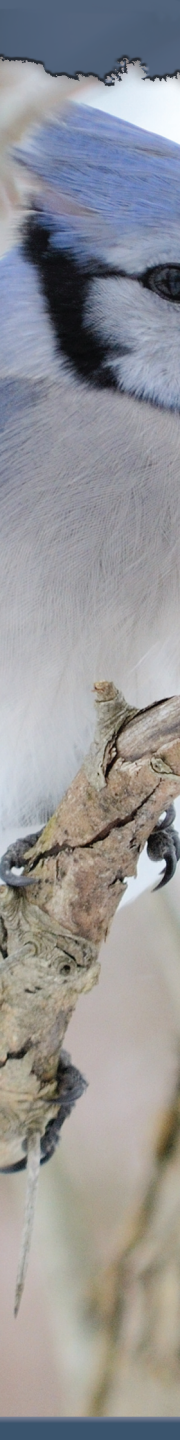
# A Fox's behavior

- Managed from the **`hunt`** method.
- Foxes also age and breed.
- They become hungry.
- They hunt for food in adjacent locations.



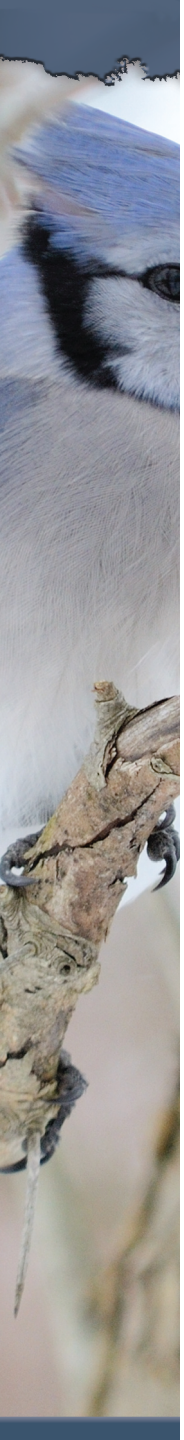
# Configuration of foxes

- Similar simplifications to rabbits.
- Hunting and eating could be modeled in many different ways.
  - Should food level be additive?
  - Is a hungry fox more or less likely to hunt?
- Are simplifications ever acceptable?



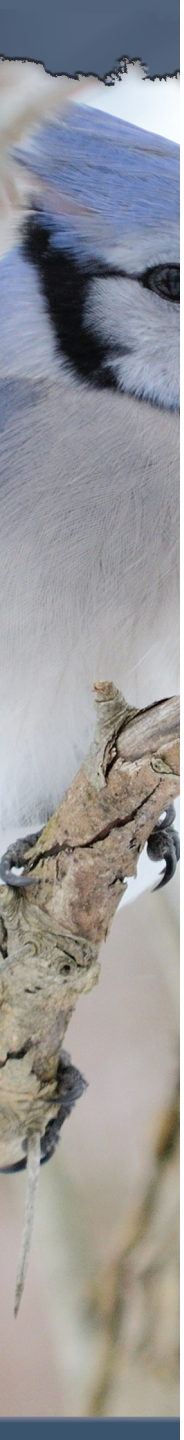
# The Simulator class

- Three key components:
  - Setup in the constructor.
  - The **`populate`** method.
    - Each animal is given a random starting age.
  - The **`simulateOneStep`** method.
    - Iterates over separate populations of foxes and rabbits.
    - Two **`Field`** objects are used: **`field`** and **`updatedField`**.



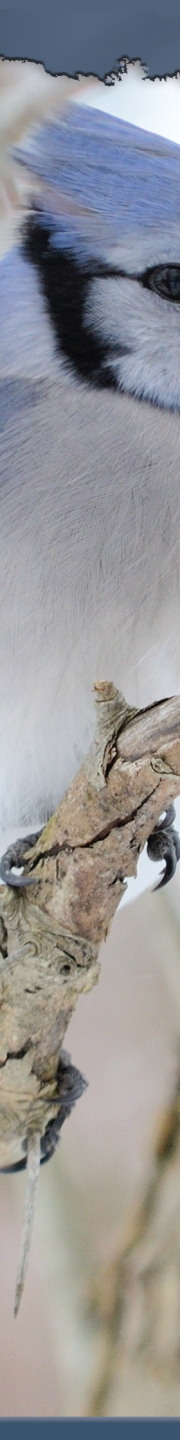
# The update step

```
for (Iterator<Rabbit> it = rabbits.iterator();
        it.hasNext(); ) {
    Rabbit rabbit = it.next();
    rabbit.run(newRabbits);
    if (! rabbit.isAlive()) {
        it.remove();
    }
}
…
for (Iterator<Fox> it = foxes.iterator();
        it.hasNext(); ) {
    Fox fox = it.next();
    fox.hunt(newFoxes);
    if (! fox.isAlive()) {
        it.remove();
    }
}
```



# Room for improvement

- **`Fox`** and **`Rabbit`** have strong similarities but do not have a common superclass.
- The update step involves similar-looking code.
- The **`Simulator`** is tightly coupled to specific classes.
  - It 'knows' a lot about the behavior of foxes and rabbits.

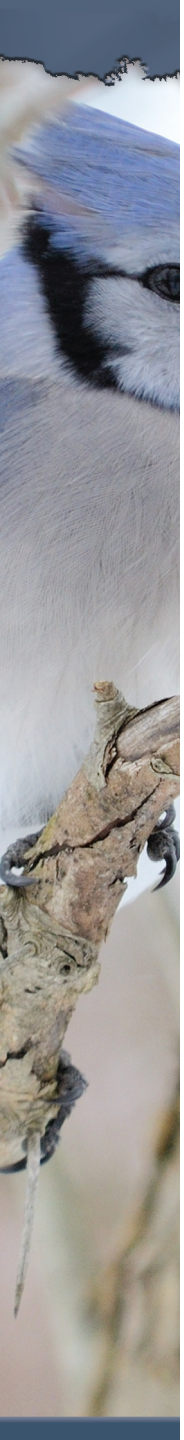


# The Animal superclass

- Place common fields in **`Animal`**:
  - **`age`**, **`alive`**, **`location`**
- Method renaming to support information hiding:
  - **`run`** and **`hunt`** become **`act`**.
- **`Simulator`** can now be significantly decoupled.

# Revised (decoupled) iteration

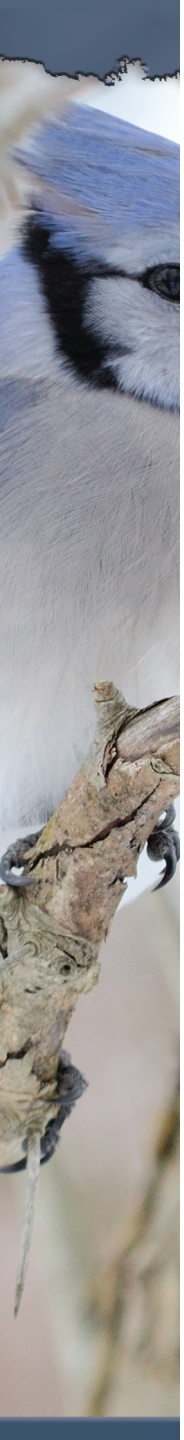
```
for (Iterator<Animal> it = animals.iterator();
        it.hasNext(); ) {
    Animal animal = iter.next();
    animal.act(newAnimals);
    // Remove dead animals from simulation
    if (! animal.isAlive()) {
        it.remove();
    }
}
```



# The `act` method of Animal

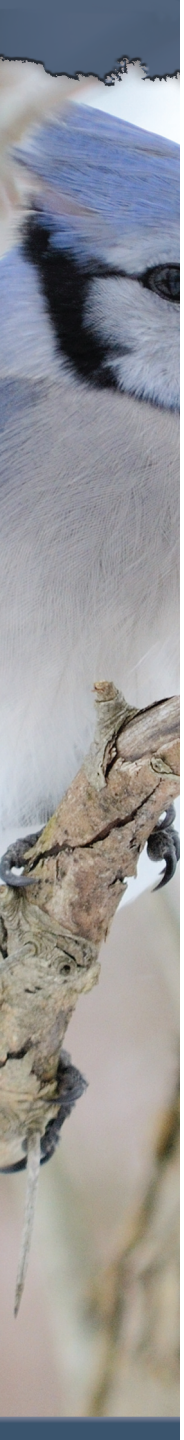
- Static type checking requires an **`act`** method in **`Animal`**.
- There is no obvious shared implementation.
- Define **`act`** as abstract:

```
abstract void act(List<Animal> newAnimals);
```



# Abstract classes and methods

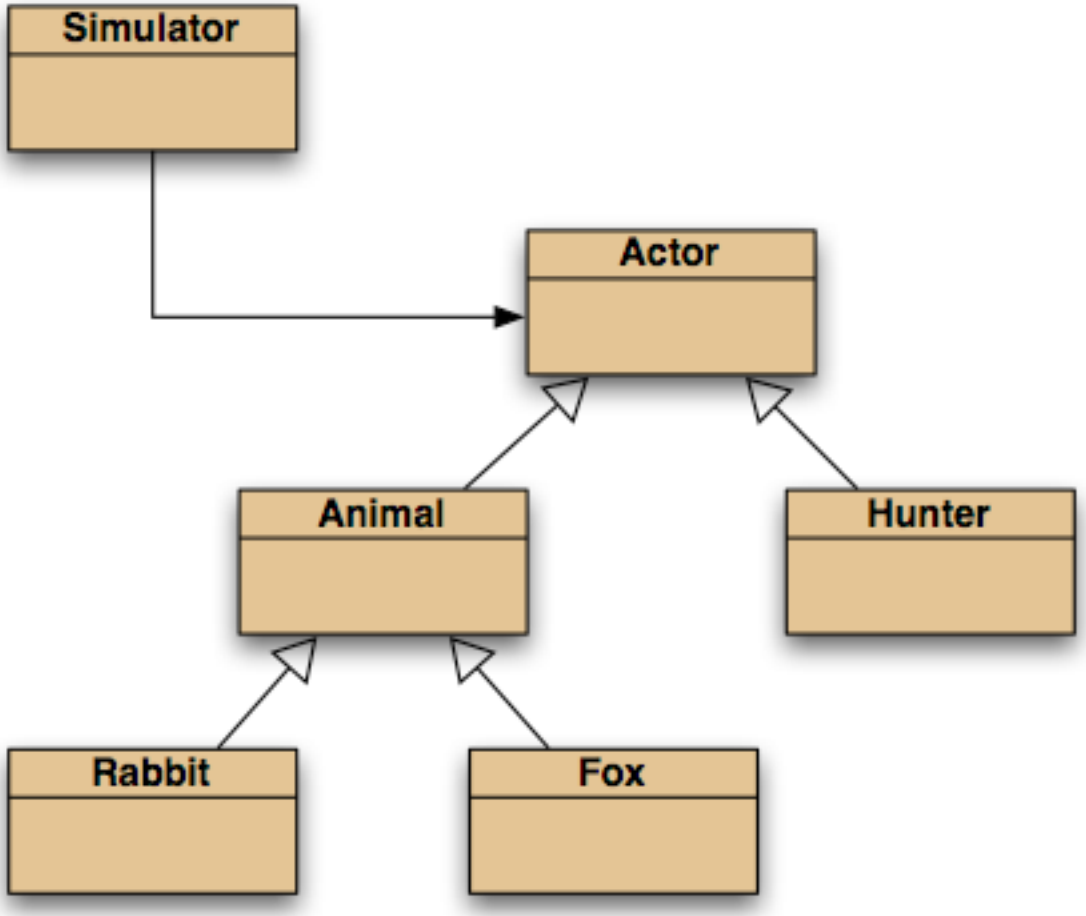
- Abstract methods have **`abstract`** in the signature.
- Abstract methods have no body.
- Abstract methods make the class abstract.
- *Abstract classes cannot be instantiated.*
- Concrete subclasses complete the implementation.



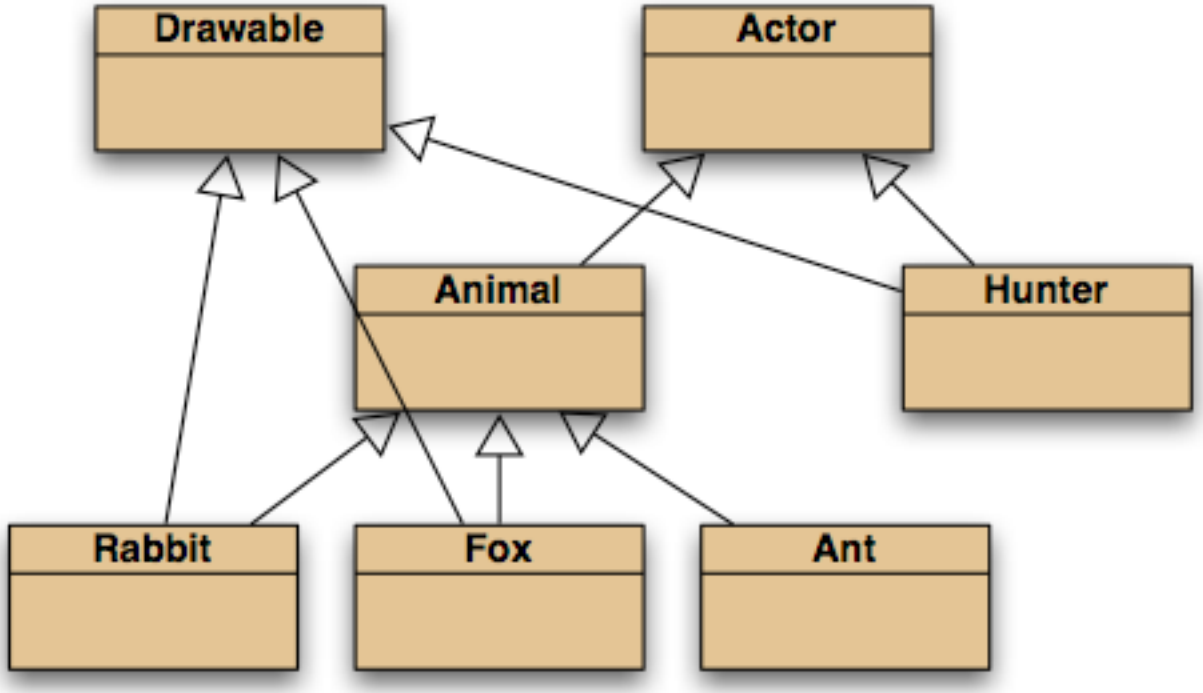
# The Animal class

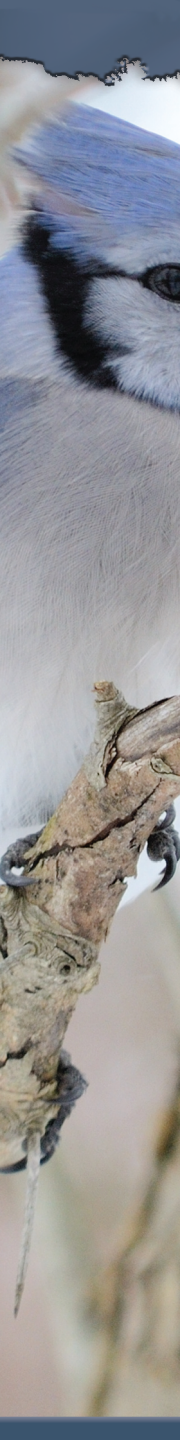
```
abstract class Animal {
    fields omitted

    /**
     * Make this animal act - that is: make it do
     * whatever it wants/needs to do.
     */
    abstract void act(List<Animal> newAnimals);

    other methods omitted
}
```

# Further abstraction



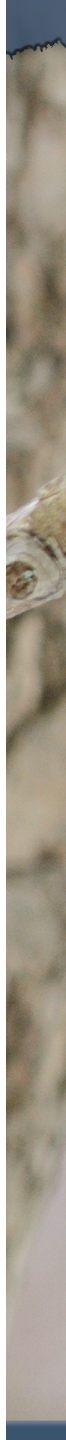
# Selective drawing (multiple inheritance)

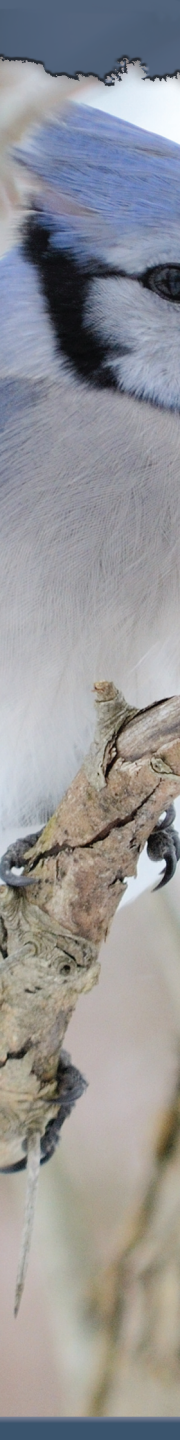




# Multiple inheritance

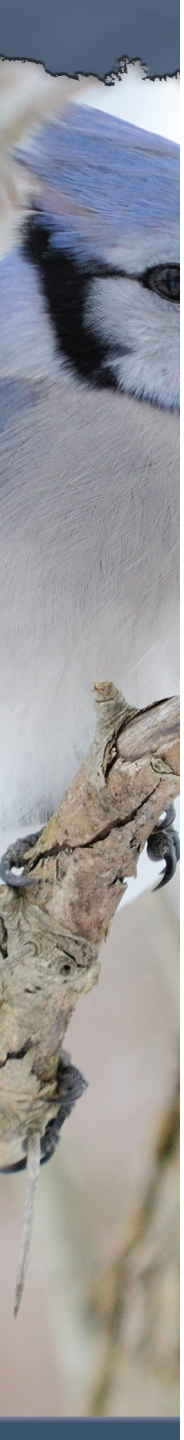
- Having a class inherit directly from multiple ancestors.
- Each language has its own rules.
  - How to resolve competing definitions?
- Java forbids it for classes.
- Java permits it for interfaces.





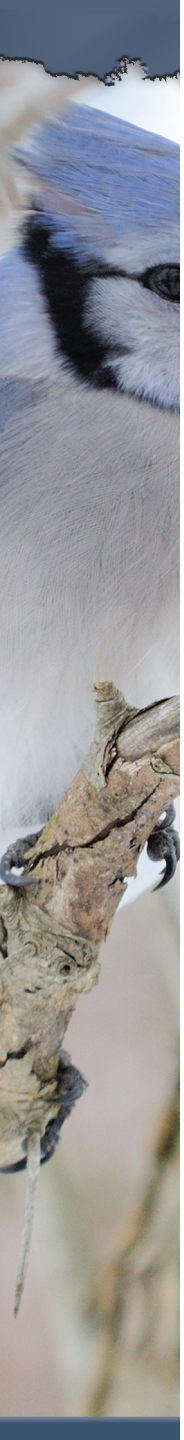
# An Actor interface

```
interface Actor {
    /**
     * Perform the actor's regular behavior.
     * @param newActors A list for storing newly created
     *                  actors.
     */
    void act(List<Actor> newActors);

    /**
     * Is the actor still active?
     * @return true if still active, false if not.
     */
    boolean isActive();
}
```



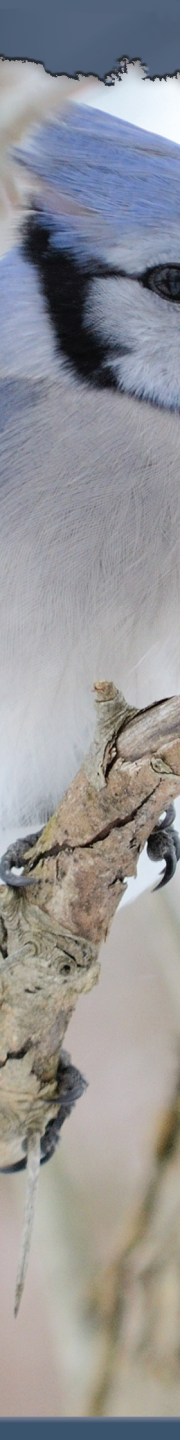
# Classes *implement* an interface

```
class Fox extends Animal
    implements Drawable {
   ...
}


class Hunter
    implements Actor, Drawable {
   ...
}
```



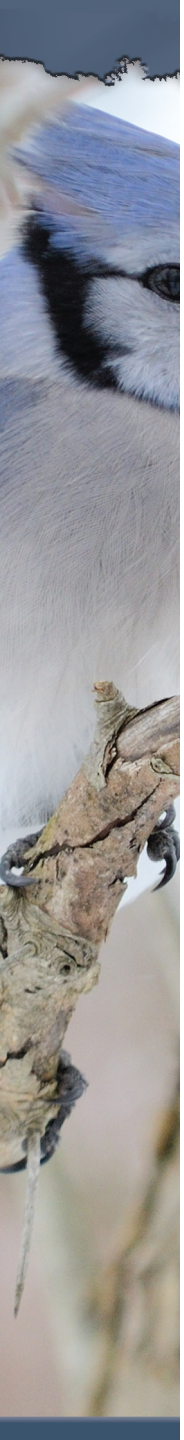
# Interfaces as types

- Implementing classes are subtypes of the interface type.
- So, polymorphism is available with interfaces as well as classes.



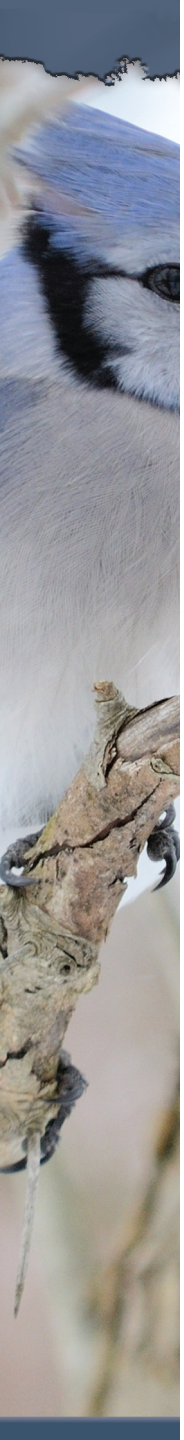
# Features of interfaces

- Use **`interface`** rather than **`class`** in their declaration.
- They do not define constructors.
- All methods are **`public`**.
- All fields are **`public`**, **`static`** and **`final`**. (Those keywords may be omitted.)
- Abstract methods may omit **`abstract`**.



# Features of interfaces

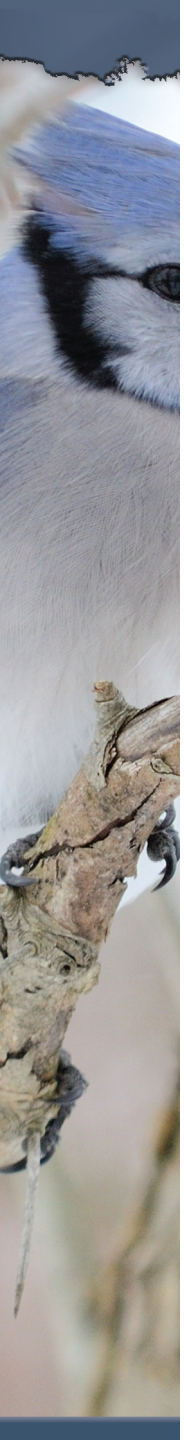
- Methods marked as **`default`** have a method body – they are not abstract.
- Methods marked as **`static`** have a method body.
- Default and static methods could complicate multiple inheritance of interfaces.



# Default methods

- Introduced in Java 8 to adapt legacy interfaces; e.g., **`java.util.List`**.
- Classes inheriting two with the same signature must override the method.
- Syntax for accessing the overriden version:

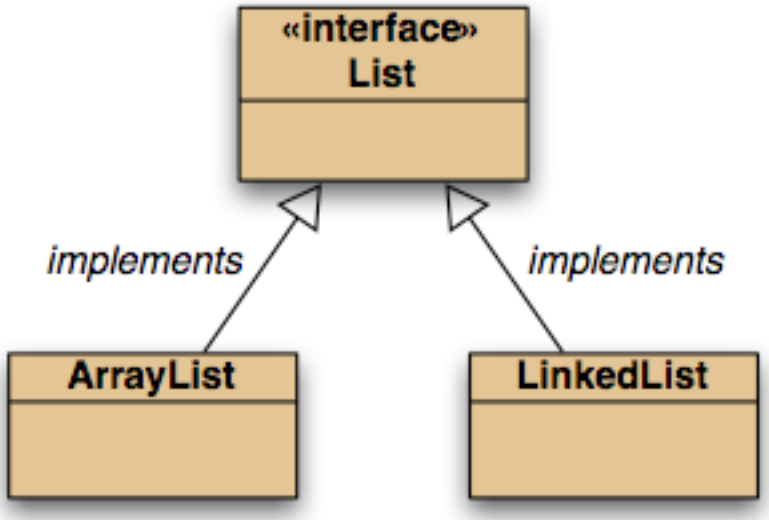
***`InterfaceType`*`.super.`*`method`*`(…)`

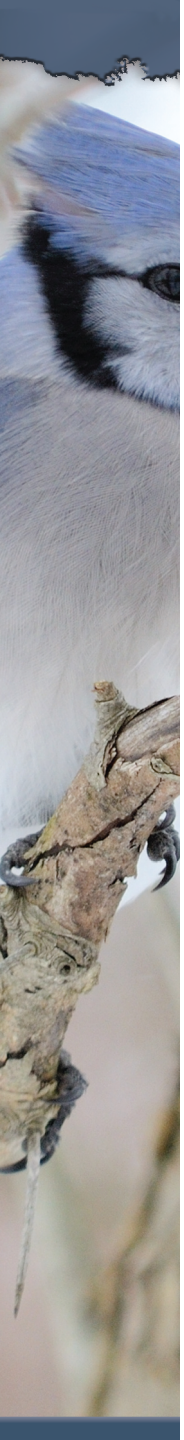


# Interfaces as specifications

- Strong separation of functionality from implementation.
  - Though parameter and return types are mandated.
- Clients interact independently of the implementation.
  - But clients can choose from alternative implementations.
- **`List`**, **`Map`** and **`Set`** are examples.

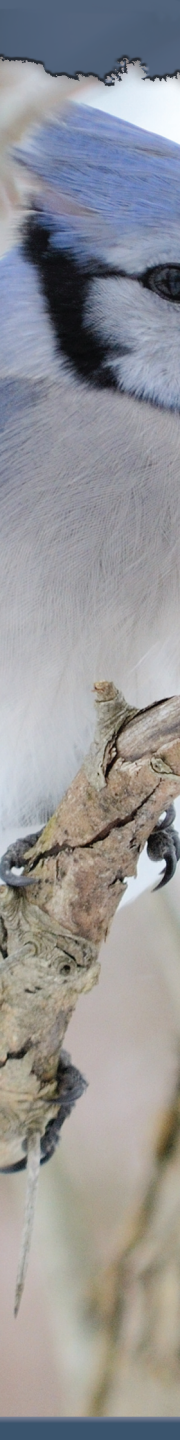
# Alternative implementations





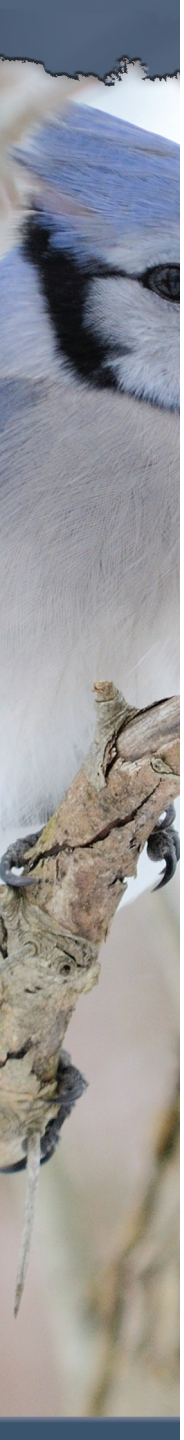
# Functional interfaces and lambdas (advanced)

- Interfaces with a single abstract method are *functional interfaces*.
- **`@FunctionalInterface`** is the associated annotation.
- A lambda may be used where a functional interface is required.
- **`java.util.function`** defines some functional interfaces.



# Common functional interfaces (advanced)

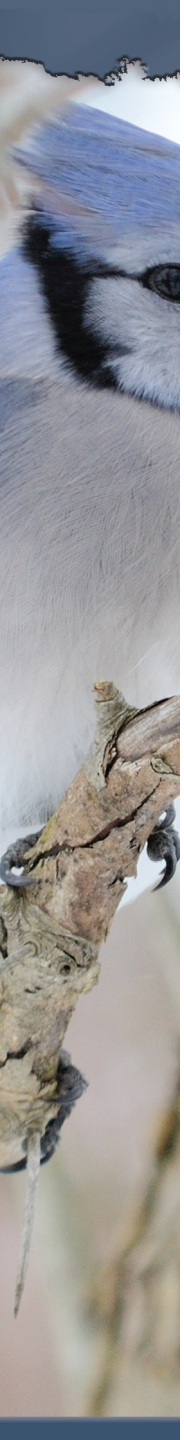
- **`Consumer`**: for lambdas with a **`void`** return type.
- **`BinaryOperator`**: for lambdas with two parameters and a matching result type.
- **`Supplier`**: for lambdas returning a result.
- **`Predicate`**: returns a **`boolean`**.



# Functional interfaces (advanced)

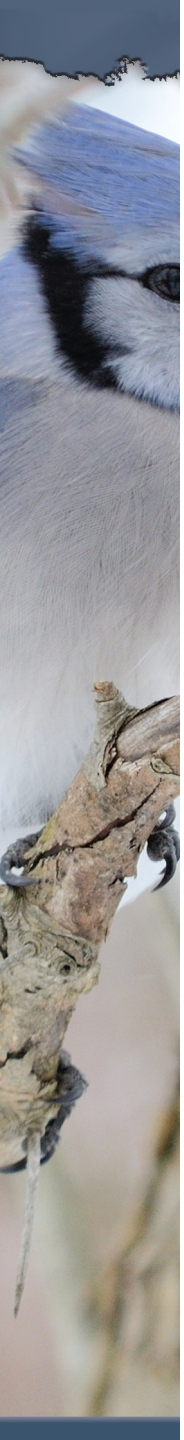
- Having functional types for lambdas means we can assign them to variables, or pass them as parameters; e.g.:

```
BinaryOperator<String> aka =
    (name, alias) -> {
        return name +  " (AKA " +
                alias + ")"; };
```



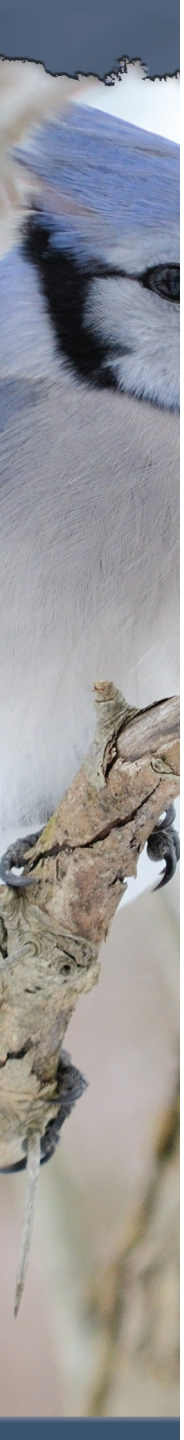
# The `Class` class

- A **`Class`** object is returned by **`getClass()`** in **`Object`**.
- The **`.class`** suffix provides a **`Class`** object:
  **`Fox.class`**
- Used in **`SimulatorView`**:
  **`Map<Class, Color> colors;`**
- **`String getName()`** for the class name.



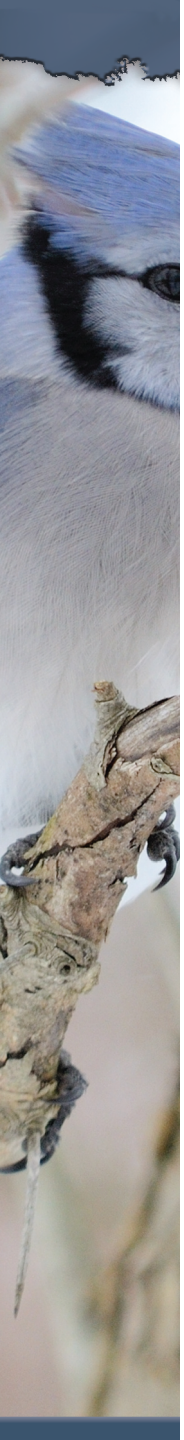
# Review

- Inheritance can provide shared implementation.
  - Concrete and abstract classes.
- Inheritance provides shared type information.
  - Classes and interfaces.



# Review

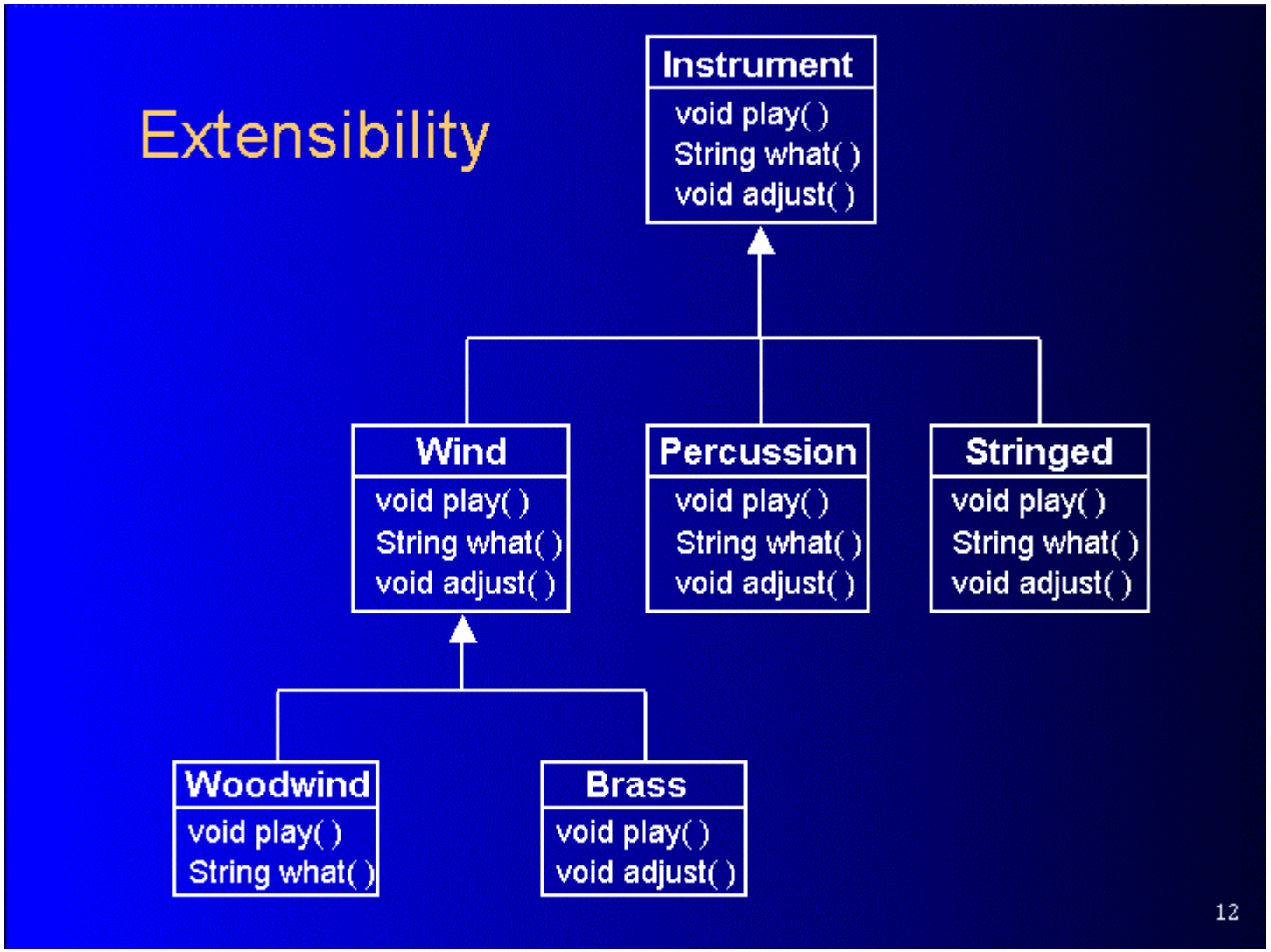
- Abstract methods allow static type checking without requiring implementation.
- Abstract classes function as incomplete superclasses.
  - No instances.
- Abstract classes support polymorphism.



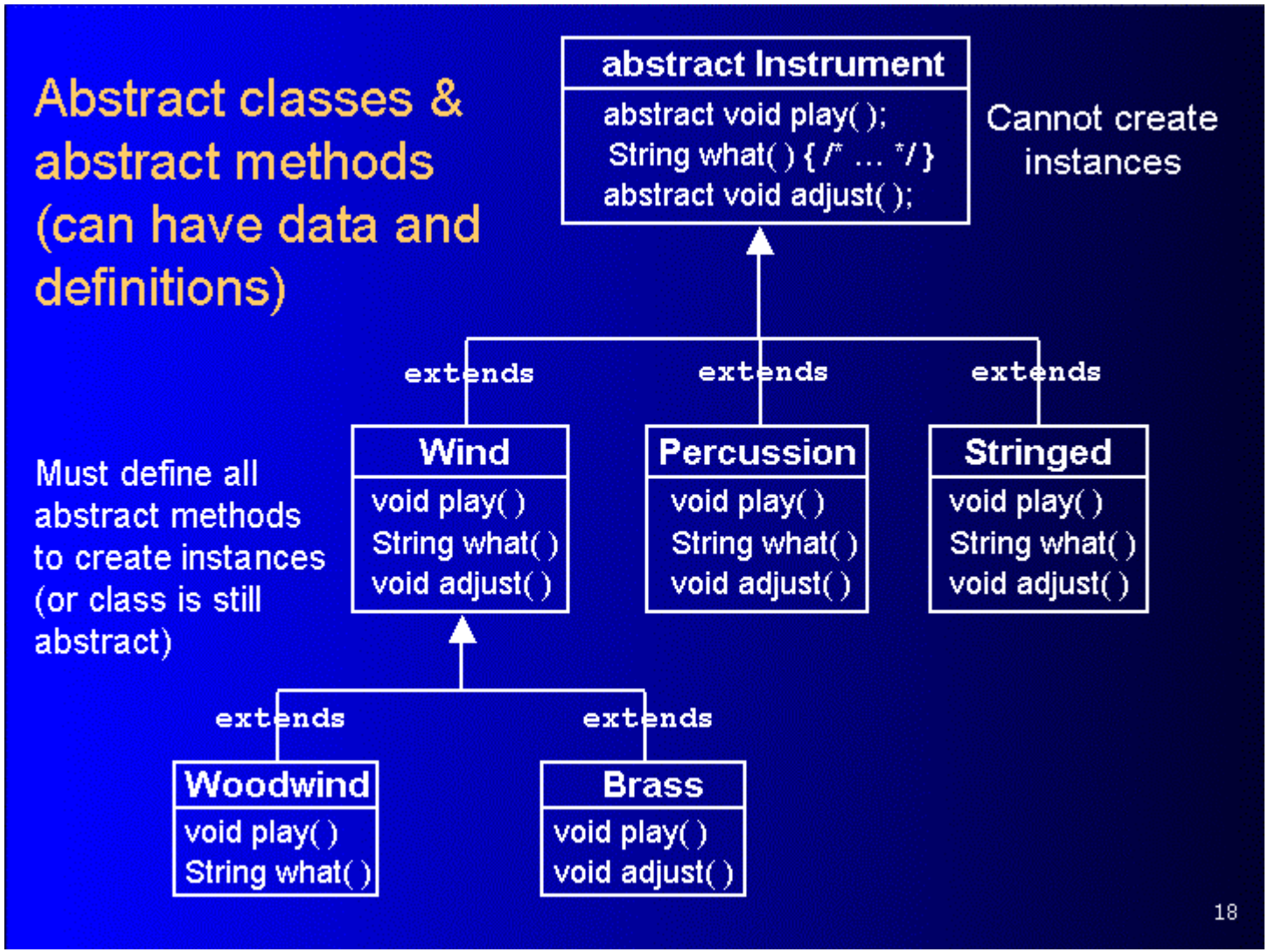
# Review

- Interfaces provide specification – usually without implementation.
  - Interfaces are abstract apart from their default methods.
- Interfaces support polymorphism.
- Java interfaces support multiple inheritance.

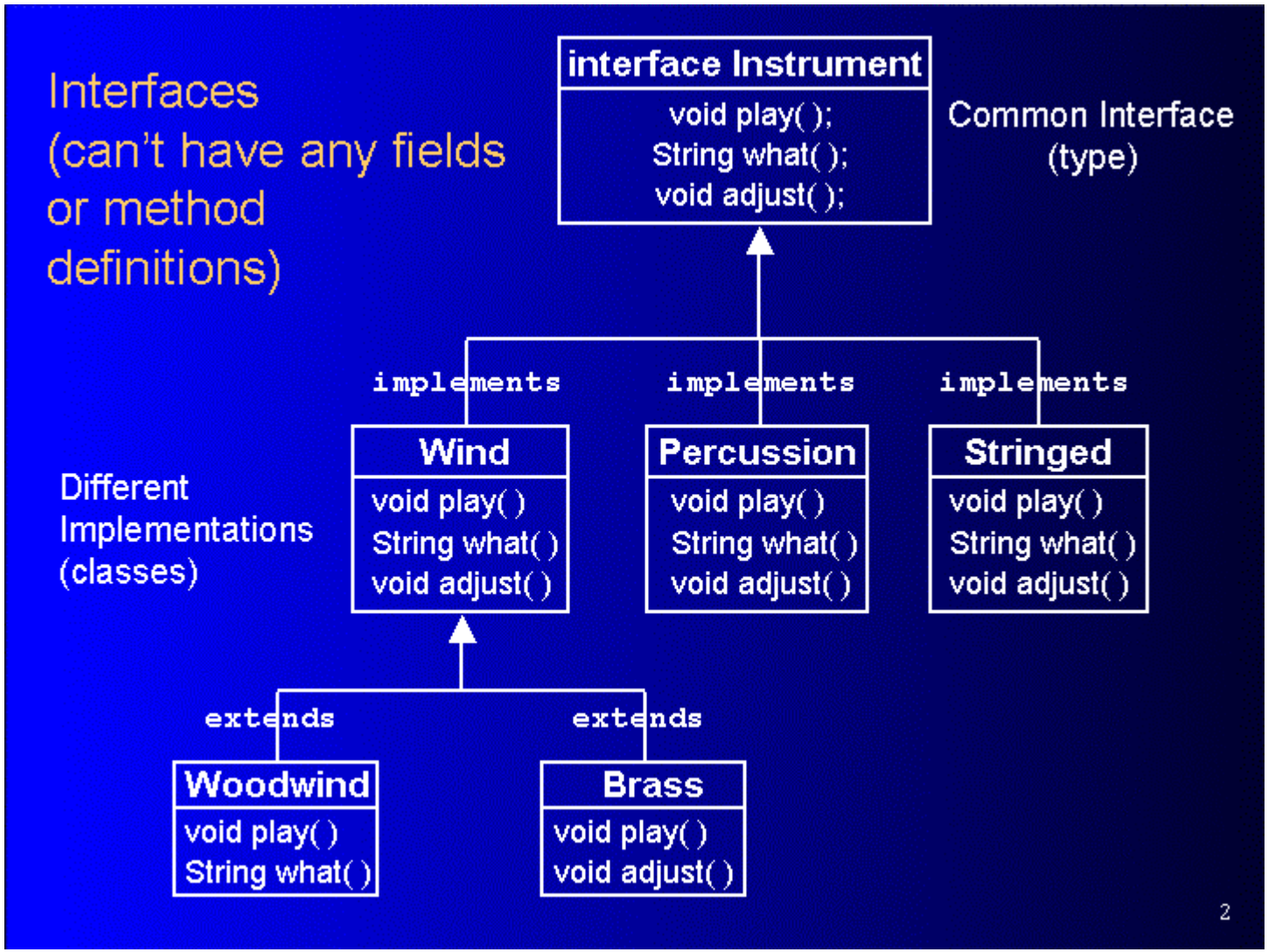
# Example – orchestra with concrete classes



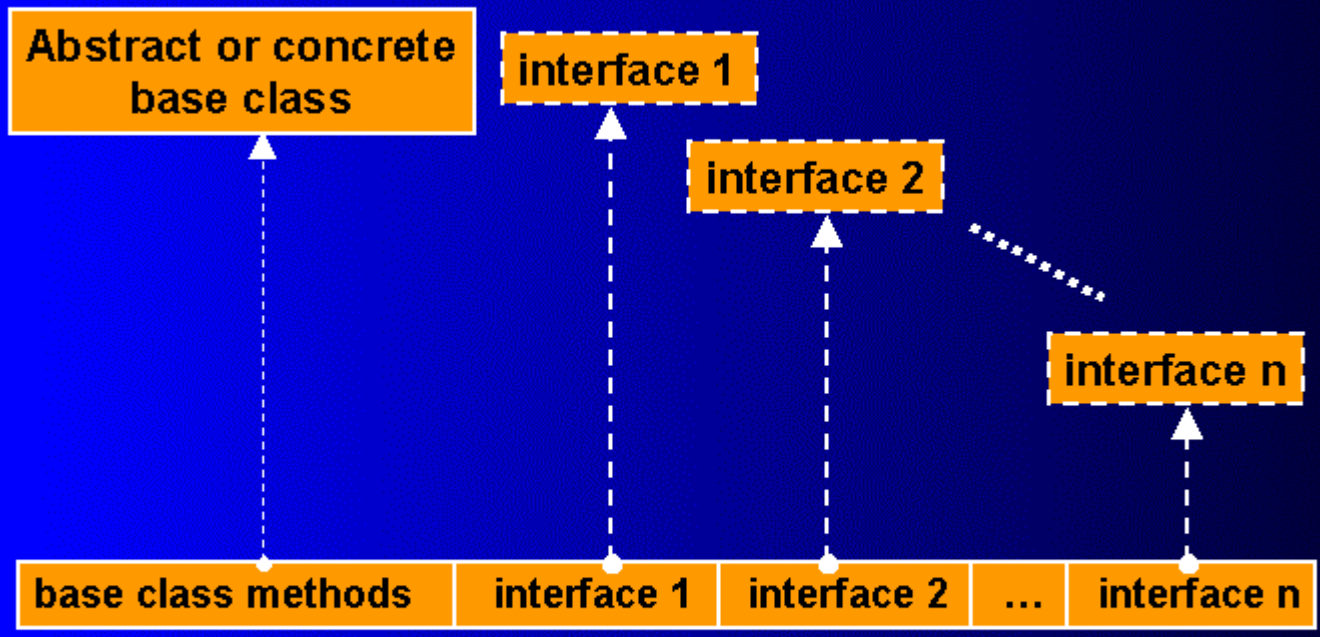
# Example – orchestra with abstract classes



# Example – orchestra with interfaces



# “Multiple Inheritance” in Java




New class has combined interfaces of all types, but uses only one physical implementation: that of the concrete base class

```
interface CanFight {
  void fight();
}
interface CanSwim {
  void swim();
}
interface CanFly {
  void fly();
}
class ActionCharacter {
  public void fight() {}
}
class Hero extends ActionCharacter
    implements CanFight, CanSwim, CanFly {
  public void swim() {}
  public void fly() {}
}
```

```
public class Adventure {
  static void t(CanFight x) { x.fight(); }
  static void u(CanSwim x) { x.swim(); }
  static void v(CanFly x) { x.fly(); }
  static void w(ActionCharacter x) { x.fight(); }
  public static void main(String args[]) {
    Hero h = new Hero();
    t(h); // Treat it as a CanFight
    u(h); // Treat it as a CanSwim
    v(h); // Treat it as a CanFly
    w(h); // Treat it as an ActionCharacter
  }
}
```

# Java "Multiple Inheritance"

- To add extra interfaces, *not* to combine implementations (use composition for that)
- Use it if you need to upcast to more than one base type
- Guideline: use interfaces when possible, avoid abstract classes
  - You never know when you'll need to combine interfaces; any sort of concreteness prevents it