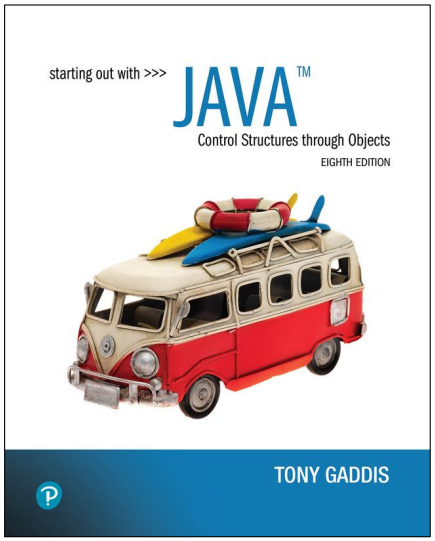
Starting Out with Java Control Structures Through Objects

Eighth Edition



Chapter 10

Inheritance

Chapter Topics

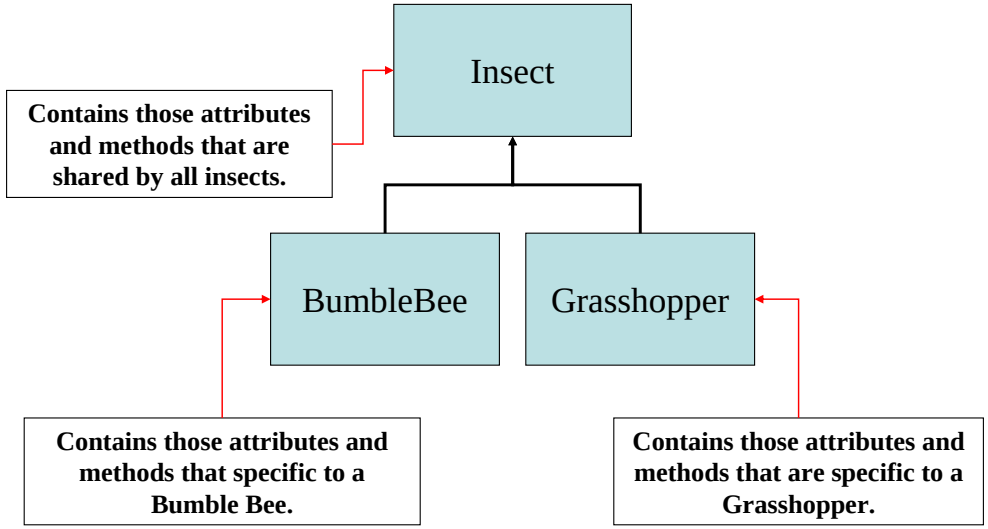
Chapter 10 discusses the following main topics:

- What Is Inheritance?
- Calling the Superclass Constructor
- Overriding Superclass Methods
- Protected Members
- Chains of Inheritance
- The `Object` Class
- Polymorphism
- Abstract Classes and Abstract Methods
- Interfaces
- Anonymous Classes
- Functional Interfaces and Lambda Expressions

What is Inheritance? Generalization vs. Specialization

- Real-life objects are typically specialized versions of other more general objects.
- The term “insect” describes a very general type of creature with numerous characteristics.
- Grasshoppers and bumblebees are insects
  - They share the general characteristics of an insect.
  - However, they have special characteristics of their own.
    - grasshoppers have a jumping ability, and
    - bumblebees have a stinger.
- Grasshoppers and bumblebees are specialized versions of an insect.

Inheritance



The "is a" Relationship (1 of 2)

- The relationship between a superclass and an inherited class is called an "is a" relationship.
  - A grasshopper "is a" insect.
  - A poodle "is a" dog.
  - A car "is a" vehicle.
- A specialized object has:
  - all of the characteristics of the general object, plus
  - additional characteristics that make it special.
- In object-oriented programming, *inheritance* is used to create an "is a" relationship among classes.

The "is a" Relationship (2 of 2)

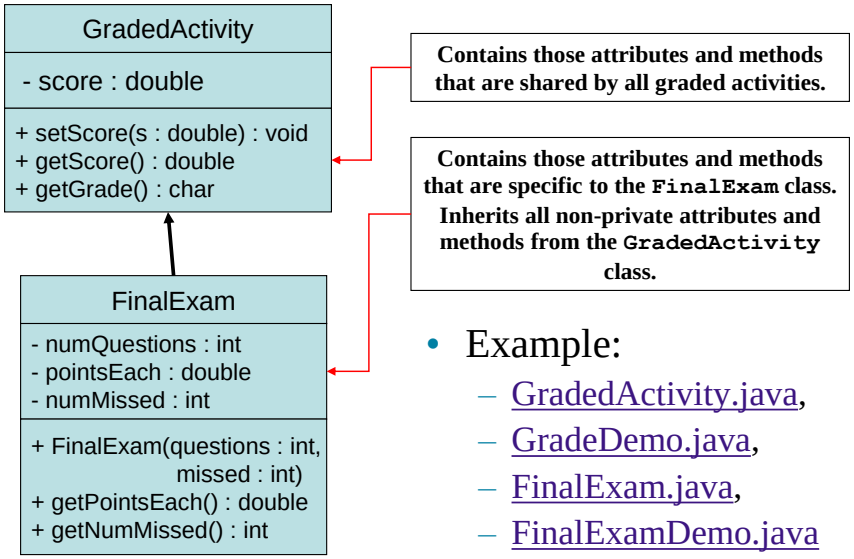
- We can *extend* the capabilities of a class.
- Inheritance involves a superclass and a subclass.
  - The *superclass* is the general class and
  - the *subclass* is the specialized class.
- The subclass is based on, or extended from, the superclass.
  - Superclasses are also called *base classes*, and
  - subclasses are also called *derived classes.*
- The relationship of classes can be thought of as *parent classes* and *child classes*.

Inheritance

- The subclass inherits fields and methods from the superclass without any of them being rewritten.
- New fields and methods may be added to the subclass.
- The Java keyword, *extends*, is used on the class header to define the subclass.

```
public class FinalExam extends
   GradedActivity
```


The `GradedActivity` Example



- Example:
  - GradedActivity.java,
  - GradeDemo.java,
  - FinalExam.java,
  - FinalExamDemo.java

Inheritance, Fields and Methods (1 of 2)

- Members of the superclass that are marked *private*:
  - are not inherited by the subclass,
  - exist in memory when the object of the subclass is created
  - may only be accessed from the subclass by public methods of the superclass.
- Members of the superclass that are marked *public*:
  - are inherited by the subclass, and
  - may be directly accessed from the subclass.

Inheritance, Fields and Methods (2 of 2)

- When an instance of the subclass is created, the non-private methods of the superclass are available through the subclass object.

```
FinalExam exam = new FinalExam();
      exam.setScore(85.0);
      System.out.println("Score = "
                  + exam.getScore());
```

- Non-private methods and fields of the superclass are available in the subclass.

```
      setScore(newScore);
```


Inheritance and Constructors

- Constructors are not inherited.
- When a subclass is instantiated, the superclass default constructor is executed first.
- Example:
  - SuperClass1.java
  - SubClass1.java
  - ConstructorDemo1.java

The Superclass's Constructor

- The `super` keyword refers to an object's superclass.
- The superclass constructor can be explicitly called from the subclass by using the `super` keyword.
- Example:
  - SuperClass2.java, SubClass2.java, ConstructorDemo2.java
  - Rectangle.java, Cube.java, CubeDemo.java

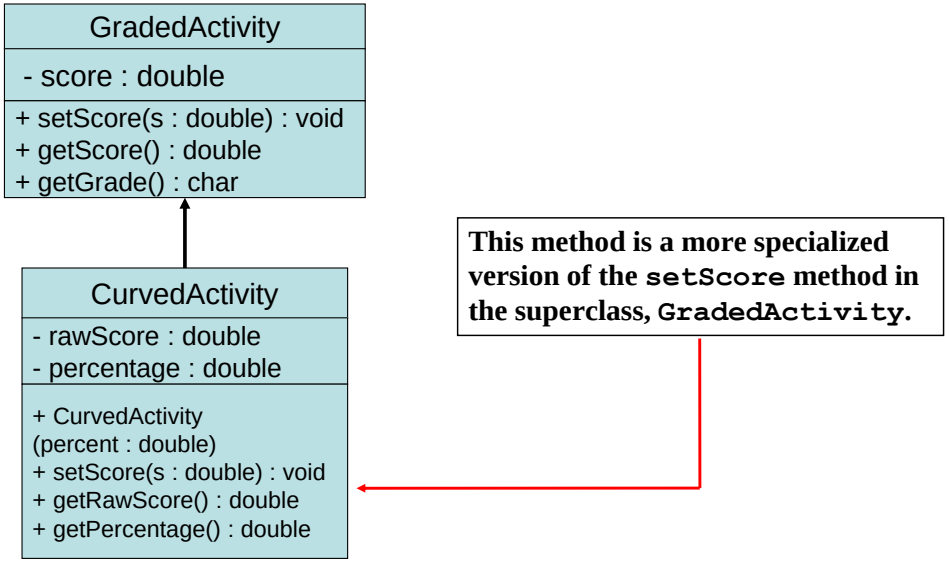
Calling The Superclass Constructor

- If a parameterized constructor is defined in the superclass,
  - the superclass must provide a no-arg constructor, or
    - subclasses must provide a constructor, and
    - subclasses must call a superclass constructor.
- Calls to a superclass constructor must be the first java statement in the subclass constructors.

Overriding Superclass Methods (1 of 5)

- A subclass may have a method with the same signature as a superclass method.
- The subclass method overrides the superclass method.
- This is known as *method overriding*.
- Example:
  - GradedActivity.java, CurvedActivity.java, CurvedActivityDemo.java

Overriding Superclass Methods (2 of 5)



Overriding Superclass Methods (3 of 5)

- Recall that a method's *signature* consists of:
  - the method's name
  - the data types method's parameters in the order that they appear.
- A subclass method that overrides a superclass method must have the same signature as the superclass method.
- An object of the subclass invokes the subclass's version of the method, not the superclass's.
- The `@Override` annotation should be used just before the subclass method declaration.
  - This causes the compiler to display a error message if the method fails to correctly override a method in the superclass.

Overriding Superclass Methods (4 of 5)

- An subclass method can call the overridden superclass method via the super keyword.

```
super.setScore(rawScore * percentage);
```

- There is a distinction between overloading a method and overriding a method.
- Overloading is when a method has the same name as one or more other methods, but with a different signature.
- When a method overrides another method, however, they both have the same signature.

Overriding Superclass Methods (5 of 5)

- Both overloading and overriding can take place in an inheritance relationship.
- Overriding can only take place in an inheritance relationship.
- Example:
  - SuperClass3.java,
  - SubClass3.java,
  - ShowValueDemo.java

Preventing a Method from Being Overridden

- The `final` modifier will prevent the overriding of a superclass method in a subclass.

```
public final void message()
```

- If a subclass attempts to override a final method, the compiler generates an error.
- This ensures that a particular superclass method is used by subclasses rather than a modified version of it.

Protected Members (1 of 2)

- Protected members of class:
  - may be accessed by methods in a subclass, and
  - by methods in the same package as the class.
- Java provides a third access specification, `protected`.
- A *protected* member's access is somewhere between *private* and *public*.
- Example:
  - GradedActivity2.java
  - FinalExam2.java
  - ProtectedDemo.java

Protected Members (2 of 2)

- Using `protected` instead of `private` makes some tasks easier.
- However, any class that is derived from the class, or is in the same package, has unrestricted access to the protected member.
- It is always better to make all fields `private` and then provide `public` methods for accessing those fields.
- If no access specifier for a class member is provided, the class member is given *package access* by default.
- Any method in the same package may access the member.

Access Specifiers

Access Modifier	Accessible to a subclass inside the same package?	Accessible to all other classes inside the same package?
default (no modifier)	Yes	Yes
Public	Yes	Yes
Protected	Yes	Yes
Private	No	No

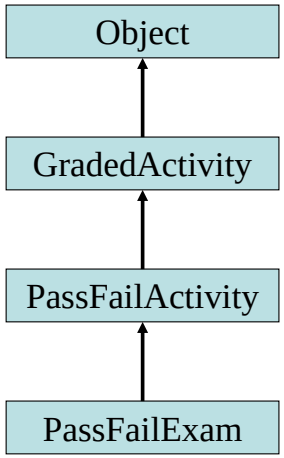
Access Modifier	Accessible to a subclass outside the package?	Accessible to all other classes outside the package?
default (no modifier)	No	No
Public	Yes	Yes
Protected	Yes	No
Private	No	No

Chains of Inheritance (1 of 2)

- A superclass can also be derived from another class.

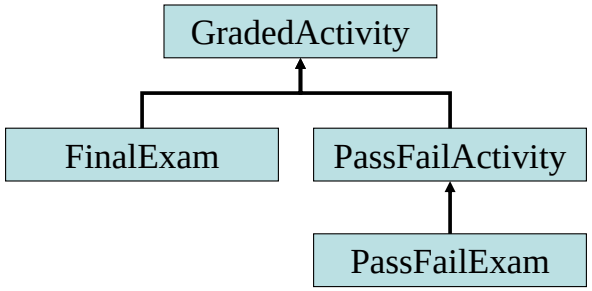
Example:

GradedActivity.java
PassFailActivity.java
PassFailExam.java
PassFailExamDemo.java



Chains of Inheritance (2 of 2)

- Classes often are depicted graphically in a *class hierarchy*.
- A class hierarchy shows the inheritance relationships between classes.



The `Object` Class (1 of 2)

- All Java classes are directly or indirectly derived from a class named `Object`.
- `Object` is in the `java.lang` package.
- Any class that does not specify the `extends` keyword is automatically derived from the `Object` class.

```
public class MyClass
    {
        // This class is derived from Object.
    }
```

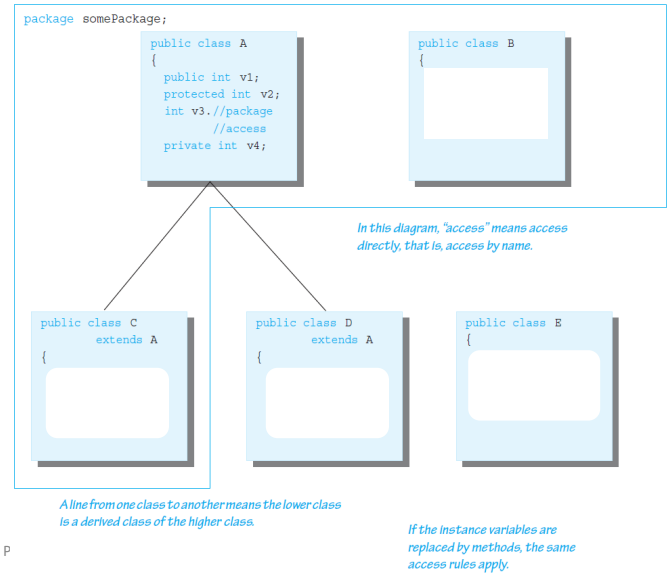
- Ultimately, every class is derived from the `Object` class.

The `Object` Class (2 of 2)

- Because every class is directly or indirectly derived from the `Object` class:
  - every class inherits the `Object` class's members.
    - example: `toString` and `equals`.
- In the `Object` class, the `toString` method returns a string containing the object's class name and a hash of its memory address.
- The `equals` method accepts the address of an object as its argument and returns true if it is the same as the calling object's address.
- Example: ObjectMethods.java

Access Modifiers

Display 7.9 Access Modifiers



Polymorphism (1 of 4)

- A reference variable can reference objects of classes that are derived from the variable's class.

```
GradedActivity exam;
```

- We can use the exam variable to reference a `GradedActivity` object.

```
exam = new GradedActivity();
```

- The `GradedActivity` class is also used as the superclass for the `FinalExam` class.
- An object of the `FinalExam` class ***is a*** `GradedActivity` object.

Polymorphism (2 of 4)

- A `GradedActivity` variable can be used to reference a `FinalExam` object.

```
GradedActivity exam = new FinalExam(50, 7);
```

- This statement creates a `FinalExam` object and stores the object's address in the exam variable.
- This is an example of polymorphism.
- The term *polymorphism* means the ability to take many forms.
- In Java, a reference variable is *polymorphic* because it can reference objects of types different from its own, as long as those types are subclasses of its type.

Polymorphism (3 of 4)

- Other legal polymorphic references:

```
GradedActivity exam1 = new FinalExam(50, 7);
GradedActivity exam2 = new PassFailActivity(70);
GradedActivity exam3 = new PassFailExam(100, 10, 70);
```

- The `GradedActivity` class has three methods: `setScore`, `getScore`, and `getGrade`.
- A `GradedActivity` variable can be used to call only those three methods.

```
GradedActivity exam = new PassFailExam(100, 10, 70);
System.out.println(exam.getScore()); // This works.
System.out.println(exam.getGrade()); // This works.
System.out.println(exam.getPointsEach()); // ERROR!
```


Polymorphism and Dynamic Binding

- If the object of the subclass has overridden a method in the superclass:
  - If the variable makes a call to that method the subclass's version of the method will be run.

```
GradedActivity exam = new PassFailActivity(60);
exam.setScore(70);
System.out.println(exam.getGrade());
```

- Java performs *dynamic binding* or *late binding* when a variable contains a polymorphic reference.
- The Java Virtual Machine determines at runtime which method to call, depending on the type of object that the variable references.

Polymorphism (4 of 4)

- It is the object's type, rather than the reference type, that determines which method is called.
- Example:
  - Polymorphic.java
- You cannot assign a superclass object to a subclass reference variable.

Abstract Classes

- An abstract class cannot be instantiated, but other classes are derived from it.
- An *Abstract class* serves as a superclass for other classes.
- The abstract class represents the generic or abstract form of all the classes that are derived from it.
- A class becomes abstract when you place the abstract key word in the class definition.

```
public abstract class ClassName
```


Abstract Methods (1 of 2)

- An abstract method has no body and must be overridden in a subclass.
- An *abstract method* is a method that appears in a superclass, but expects to be overridden in a subclass.
- An abstract method has only a header and no body.

```
AccessSpecifier abstract ReturnType
   MethodName(ParameterList);
```

- Example:
  - Student.java, CompSciStudent.java, CompSciStudentDemo.java

Abstract Methods (2 of 2)

- Notice that the key word `abstract` appears in the header, and that the header ends with a semicolon.

```
public abstract void setValue(int value);
```

- Any class that contains an abstract method is automatically abstract.
- If a subclass fails to override an abstract method, a compiler error will result.
- Abstract methods are used to ensure that a subclass implements the method.


```
public abstract class Turtle {
   public abstract long eat()      // DOES NOT COMPILE
   public abstract void swim() {}; // DOES NOT COMPILE
   public abstract int getAge() {  // DOES NOT COMPILE
      return 10;
   }
   public void sleep;              // DOES NOT COMPILE
   public void goInShell();        // DOES NOT COMPILE
}
```

Abstract Method Definition Rules

- Abstract methods can be defined only in abstract classes or interfaces.
- Abstract methods cannot be declared private or final.
- Abstract methods must not provide a method body/implementation in the abstract class in which they are declared.
- Implementing an abstract method in a subclass follows the same rules for overriding a method, including covariant return types, exception declarations, etc.

Constructor in Abstract Class

- Even though abstract classes cannot be instantiated, they are still initialized through constructors by their subclasses.

```
abstract class Bear {
   abstract CharSequence chew();
   public Bear() {
      System.out.println(chew());
   }
}

public class Panda extends Bear {
   String chew() { return "yummy!"; }
   public static void main(String[] args) {
      new Panda();
   }
}
```

Does this compile?

Abstract Method

Will these compile?

```
public abstract class Tortoise {
   public abstract final void walk();
}
```

```
public abstract class Whale {
   private abstract void sing();
}
```

```
abstract class Hippopotamus {
   abstract static void swim();
}
```


Abstract Method

Will these compile?

```
public abstract class Tortoise {
   public abstract final void walk();
}
```

```
public abstract class Whale {
   private abstract void sing();
}
```

```
abstract class Hippopotamus {
   abstract static void swim();
}
```

Interfaces (1 of 3)

- An *interface* is similar to an abstract class that has all abstract methods.
  - It cannot be instantiated, and
  - all of the methods listed in an interface must be written elsewhere.
- The purpose of an interface is to specify behavior for other classes.
- It is often said that an interface is like a “contract,” and when a class implements an interface it must adhere to the contract.
- An interface looks similar to a class, except:
  - the keyword `interface` is used instead of the keyword `class`, and
  - the methods that are specified in an interface have no bodies, only headers that are terminated by semicolons.

Interfaces (1 of 3)

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- An interface looks similar to a class, except:
  - the keyword `interface` is used instead of the keyword `class`, and
  - the methods that are specified in an interface have no bodies, only headers that are terminated by semicolons.

Interfaces (2 of 3)

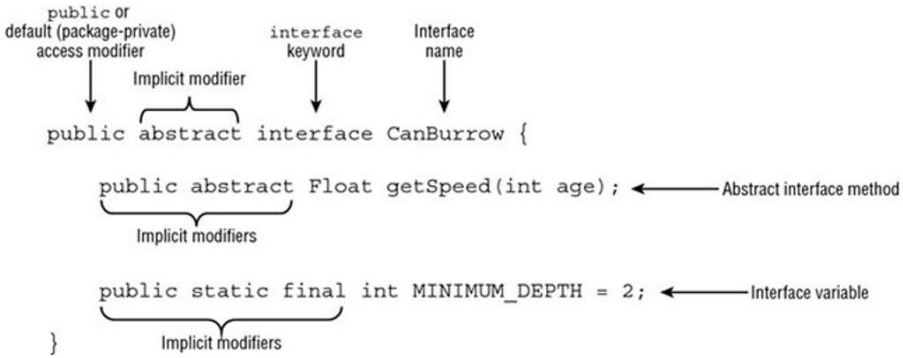
- The general format of an interface definition:

```
public interface InterfaceName
{
   (Method headers...)
}
```

- All methods specified by an interface are public by default.
- A class can implement one or more interfaces.

Interfaces

- Define an interface



Interfaces

- The following two interface definitions are equivalent

```
public interface Soar {
   int MAX_HEIGHT = 10;
   final static boolean UNDERWATER = true;
   void fly(int speed);
   abstract void takeoff();
   public abstract double dive();
}

public abstract interface Soar {
   public static final int MAX_HEIGHT = 10;
   public final static boolean UNDERWATER = true;
   public abstract void fly(int speed);
   public abstract void takeoff();
   public abstract double dive();
}
```


Interfaces

- Which line or lines of this top-level interface declaration do not compile?

```
1: private final interface Crawl {
2:     String distance;
3:     private int MAXIMUM_DEPTH = 100;
4:     protected abstract boolean UNDERWATER = false;
5:     private void dig(int depth);
6:     protected abstract double depth();
7:     public final void surface(); }
```

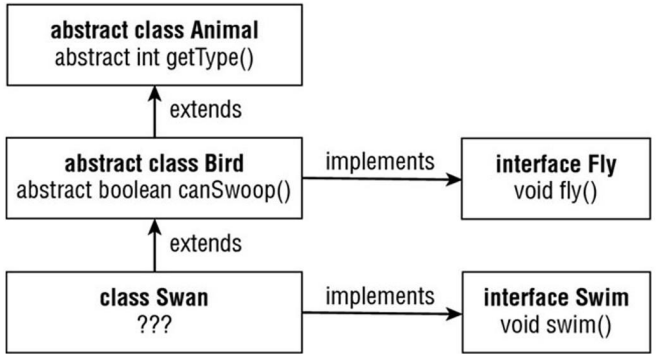

Interfaces

- Which line or lines of this top-level interface declaration do not compile? All

```
1: private final interface Crawl {
2:     String distance;
3:     private int MAXIMUM_DEPTH = 100;
4:     protected abstract boolean UNDERWATER = false;
5:     private void dig(int depth);
6:     protected abstract double depth();
7:     public final void surface(); }
```


Abstract Classes and Interaces

- How many abstract methods does the concrete Swan / abstract Swan class inherit/implement?



Interfaces (3 of 3)

- If a class implements an interface, it uses the `implements` keyword in the class header.

```
public class FinalExam3 extends
  GradedActivity implements Relatable
```

- Example:
  - GradedActivity.java
  - Relatable.java
  - FinalExam3.java
  - InterfaceDemo.java

Fields in Interfaces

- An interface can contain field declarations:
  - all fields in an interface are treated as `final` and `static`.
- Because they automatically become `final`, you must provide an initialization value.

```
public interface Doable
{
  int FIELD1 = 1, FIELD2 = 2;
  (Method headers...)
}
```

- In this interface, `FIELD1` and `FIELD2` are `final static int` variables.
- Any class that implements this interface has access to these variables.

Implementing Multiple Interfaces

- A class can be derived from only one superclass.
- Java allows a class to implement multiple interfaces.
- When a class implements multiple interfaces, it must provide the methods specified by all of them.
- To specify multiple interfaces in a class definition, simply list the names of the interfaces, separated by commas, after the implements key word.

```
public class MyClass implements Interface1,
                                Interface2,
                                Interface3
```


Duplicate Interface Method Declarations

- A class that inherits from two interfaces that contain the same abstract method.
- A class that inherits from two interfaces, if the method name is the same but the input parameters are different
- A class that inherits from two interfaces, if the duplicate methods have the same signature but different return types
  - If return types are covariant
  - If return types are NOT covariant

Duplicate Interface Method Declarations

- A class that inherits from two interfaces that contain the same abstract method.

```
public interface Herbivore {
   public void eatPlants();
}
```

```
public interface Omnivore {
   public void eatPlants();
   public void eatMeat();
}
```

```
public class Bear implements Herbivore, Omnivore {
   public void eatMeat() {
      System.out.println("Eating meat");
   }
   public void eatPlants() {
      System.out.println("Eating plants");
   }
}
```


Duplicate Interface Method Declarations

- A class that inherits from two interfaces, if the method name is the same but the input parameters are different

```
public interface Herbivore {
   public int eatPlants(int quantity);
}
```

```
public interface Omnivore {
   public void eatPlants();
}
```

```
public class Bear implements Herbivore, Omnivore {
   public int eatPlants(int quantity) {
      System.out.println("Eating plants: "+quantity);
      return quantity;
   }
   public void eatPlants() {
      System.out.println("Eating plants");
   }
}
```


Duplicate Interface Method Declarations

- A class that inherits from two interfaces, if the duplicate methods have the same signature but different return types
  - If return types are covariant
- Since Java5 in overriding, it is not mandatory for the methods in the superclass and subclass to have the same return type. These two methods can have different return types but, the method in the subclass should return the subtype of the return type of the method in the superclass. Thus overriding methods become variant with respect to return types and, these are known as co-variant return types.

```
interface Dances {
   String swingArms();
}
```

```
interface EatsFish {
   Object swingArms();
}
```

```
public class Penguin implements Dances, EatsFish {
   public String swingArms() {
      return "swing!";
   }
}
```


Duplicate Interface Method Declarations

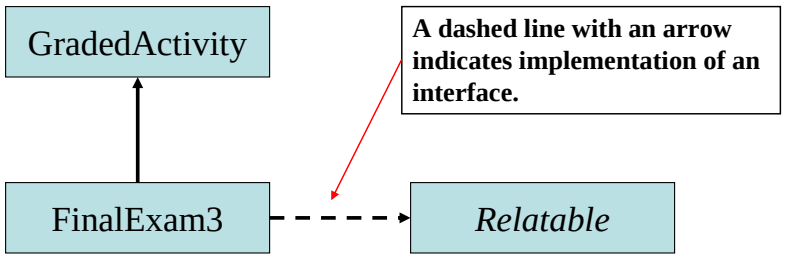
- A class that inherits from two interfaces, if the duplicate methods have the same signature but different return types
  - If return types are NOT covariant

```
interface Dances {
   int countMoves();
}
```

```
interface EatsFish {
   boolean countMoves();
}
```

```
public class Penguin implements Dances, EatsFish { // DOES NOT COMPILE
   ...
}
```

Interfaces in UML



Polymorphism with Interfaces (1 of 3)

- Java allows you to create reference variables of an interface type.
- An interface reference variable can reference any object that implements that interface, regardless of its class type.
- This is another example of polymorphism.
- Example:
  - RetailItem.java
  - CompactDisc.java
  - DvdMovie.java
  - PolymorphicInterfaceDemo.java

Polymorphism with Interfaces (2 of 3)

- In the example code, two `RetailItem` reference variables, `item1` and `item2`, are declared.
- The `item1` variable references a `CompactDisc` object and the `item2` variable references a `DvdMovie` object.
- When a class implements an interface, an inheritance relationship known as *interface inheritance* is established.
  - a `CompactDisc` object *is a* `RetailItem`, and
  - a `DvdMovie` object *is a* `RetailItem`.

Polymorphism with Interfaces (3 of 3)

- A reference to an interface can point to any class that implements that interface.
- You cannot create an instance of an interface.

```
RetailItem item = new RetailItem(); // ERROR!
```

- When an interface variable references an object:
  - only the methods declared in the interface are available,
  - explicit type casting is required to access the other methods of an object referenced by an interface reference.

Interface Definition Rules

- Interfaces cannot be instantiated.
- All top-level types, including interfaces, cannot be marked protected or private.
- Interfaces are assumed to be abstract and cannot be marked final.
- Interfaces may include zero or more abstract methods.
- An interface can extend any number of interfaces.
- An interface reference may be cast to any reference that inherits the interface, although this may produce an exception at runtime if the classes aren't related.
- The compiler will only report an unrelated type error for an instanceof operation with an interface on the right side if the reference on the left side is a final class that does not inherit the interface.
- An interface method with a body must be marked default, private, static, or private static

Abstract Interface Method Rules

- Abstract methods can be defined only in abstract classes or interfaces.
- Abstract methods cannot be declared private or final.
- Abstract methods must not provide a method body/implementation in the abstract class in which is it declared.
- Implementing an abstract method in a subclass follows the same rules for overriding a method, including covariant return types, exception declarations, etc.
- Interface methods without a body are assumed to be abstract and public.

Interface Variables Rules

- Interface variables are assumed to be public, static, and final.
- Because interface variables are marked final, they must be initialized with a value when they are declared.

The Class `Object`

- In Java, every class is a descendent of the class ***`Object`***
  - Every class has `Object` as its ancestor
  - Every object of every class is of type `Object`, as well as being of the type of its own class
- If a class is defined that is not explicitly a derived class of another class, it is still automatically a derived class of the class `Object`

The Class `Object`

- The class `Object` is in the package `java.lang` which is always imported automatically
- Having an `Object` class enables methods to be written with a parameter of type `Object`
  - A parameter of type `Object` can be replaced by an object of any class whatsoever
  - For example, some library methods accept an argument of type `Object` so they can be used with an argument that is an object of any class

The Class `Object`

- The class `Object` has some methods that every Java class inherits
  - For example, the `equals` and `toString` methods
- Every object inherits these methods from some ancestor class
  - Either the class `Object` itself, or a class that itself inherited these methods (ultimately) from the class `Object`
- However, these inherited methods should be overridden with definitions more appropriate to a given class
  - Some Java library classes assume that every class has its own version of such methods

The Right Way to Define `equals`

- Since the `equals` method is always inherited from the class `Object`, methods like the following simply overload it:

```
public boolean equals(Employee otherEmployee)
{ . . . }
```

- However, this method should be overridden, not just overloaded:

```
public boolean equals(Object otherObject)
{ . . . }
```


The Right Way to Define `equals`

- The overridden version of `equals` must meet the following conditions
  - The parameter `otherObject` of type `Object` must be type cast to the given class (e.g., `Employee)`
  - However, the new method should only do this if `otherObject` really is an object of that class, and if `otherObject` is not equal to `null`
  - Finally, it should compare each of the instance variables of both objects

A Better `equals` Method for the Class `Employee`

```
public boolean equals(Object otherObject)
{
  if(otherObject == null)
    return false;
  else if(getClass( ) != otherObject.getClass( ))
    return false;
  else
  {
    Employee otherEmployee = (Employee)otherObject;
    return (name.equals(otherEmployee.name) &&
      hireDate.equals(otherEmployee.hireDate));
  }
}
```


Default Methods

- Beginning in Java 8, interfaces may have *default methods*.
- A default method is an interface method that has a body.
- You can add new methods to an existing interface without causing errors in the classes that already implement the interface.
- Example:
  - Displayable.java
  - Person.java
  - InterfaceDemoDefaultMethod.java

Anonymous Inner Classes

- An inner class is a class that is defined inside another class.
- An anonymous inner class is an inner class that has no name.
- An anonymous inner class must implement an interface, or extend another class.
- Useful when you need a class that is simple, and to be instantiated only once in your code.
- Example:
  - IntCalculator.java
  - AnonymousClassDemo.java

The LORD will fulfill his purpose for me;
your steadfast love, O LORD, endures forever.
Do not forsake the work of your hands.

Psalm 138:8

Being confident of this, that he who began a good work in you will carry it on to completion until the day of Christ Jesus.

Philippians 1:6

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