Object Oriented Programming

1. Packages
2. Inheritance
3. Polymorphism

Organizing Related Classes Into Packages

- Package: Set of related classes
- To put classes in a package, you must place a line

```
package packageName;
```

  as the first instruction in the source file containing the classes
- Package name consists of one or more identifiers separated by periods

Organizing Related Classes Into Packages

- For example, to put the `Database` class introduced into a package named `oop.examples`, the `Database.java` file must start as follows:

```
package oop.examples;
public class Database
{
    . . .
}
```

- Default package has no name, no `package` statement
- BlueJ demo

Organizing Related Classes Into Packages

Package	Purpose	Sample Class
java.lang	Language Support	Math
java.util	Utilities	Random
java.io	Input and Output	PrintScreen
java.awt	Abstract Windowing Toolkit	Color
java.applet	Applets	Applet
java.net	Networking	Socket
java.sql	Database Access	ResultSet
java.swing	Swing user interface	JButton
org.omg.CORBA	Common Object Request Broker Architecture	IntHolder

Importing Packages

- Can always use class without importing

```
java.util.Scanner in = new
   java.util.Scanner(System.in);
```

- Tedious to use fully qualified name
- Import lets you use shorter class name

```
import java.util.Scanner;
. . .
Scanner in = new Scanner(System.in)
```

- Can import all classes in a package

```
import java.util.*;
```

- Never need to import `java.lang`
- You don't need to import other classes in the same package

Package Names and Locating Classes

- Use packages to avoid name clashes

  `java.util.Timer vs. javax.swing.Timer`

- Package names should be unambiguous
- Recommendation: start with reversed domain name, e.g.

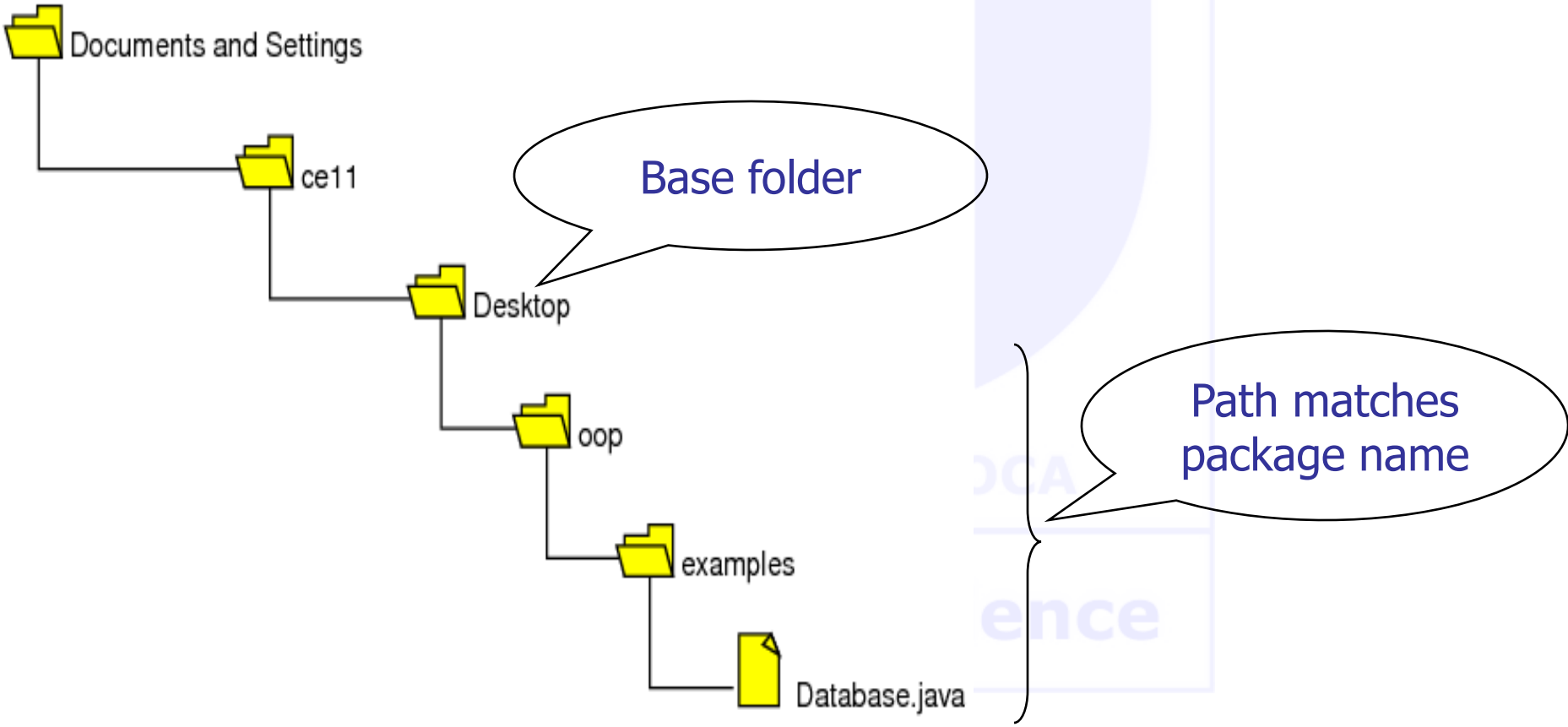
  `ro.utcluj.cs.jim`: for jim's classes (jim@cs.utcluj.ro)

Package Names and Locating Classes

- Path name should match package name
  `oop/examples/Dababase.java`
- Path name starts with class path
  ```
  export CLASSPATH=/home/jim/lib:.
  set CLASSPATH=D:\Students\dsa11\Desktop;.
  ```
- Class path contains the base directories that may contain package directories

Base Directories and Subdirectories for Packages

```
set CLASSPATH=D:\Documents and Settings\ce11\Desktop;.
```



How to build a package

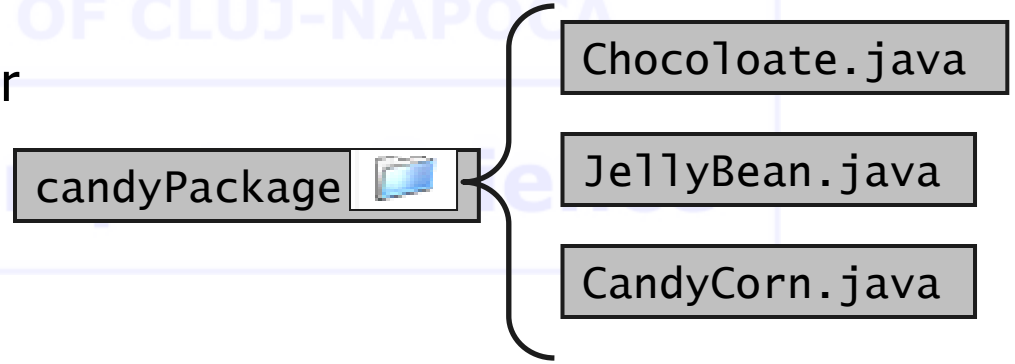
1) Place a line with the name of the package at the beginning of every class.

```
package candyPackage;
public class Chocolate {
   . . .
}
```

```
package candyPackage;
public class JellyBean {
   . . .
}
```

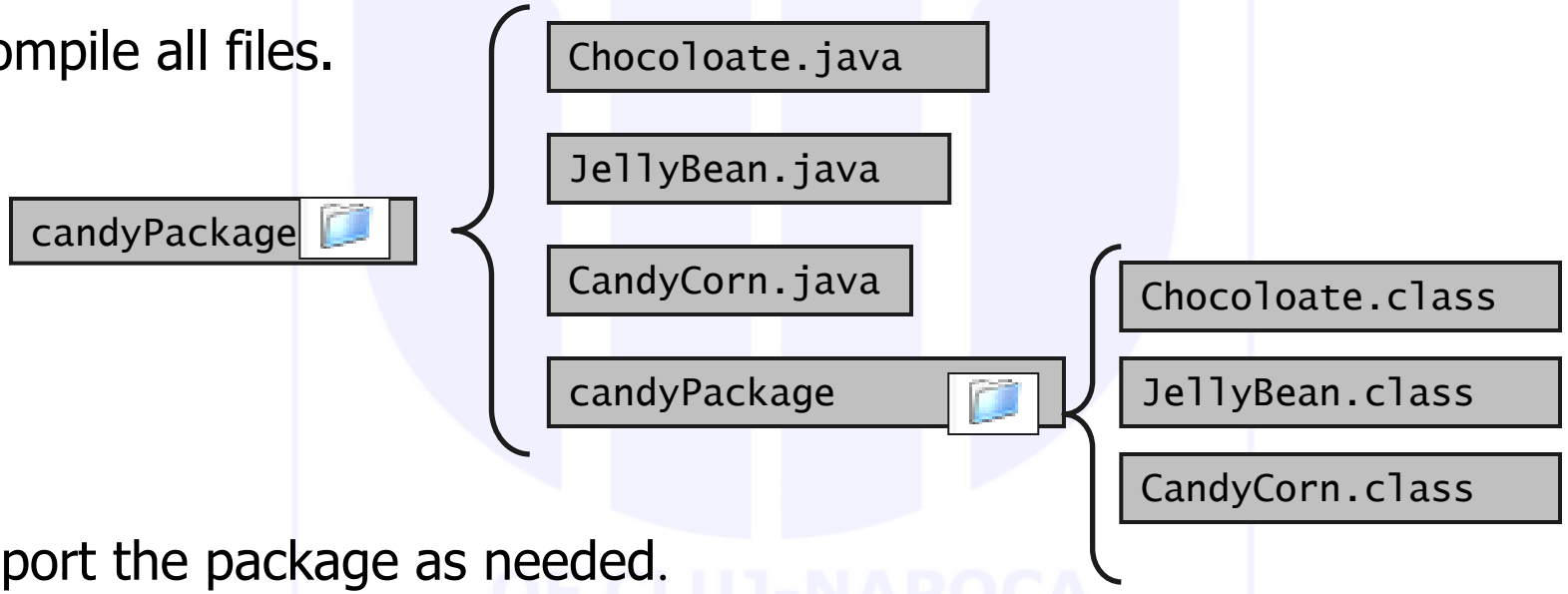
```
package candyPackage;
public class CandyCorn {
   . . .
}
```

2) Store the Java files for the package in the common directory.



How to build a package

3) Compile all files.



4) Import the package as needed.

```
import sweets.candyPackage.*;
public class SweetEater { . . .
```

How to Reuse Code?

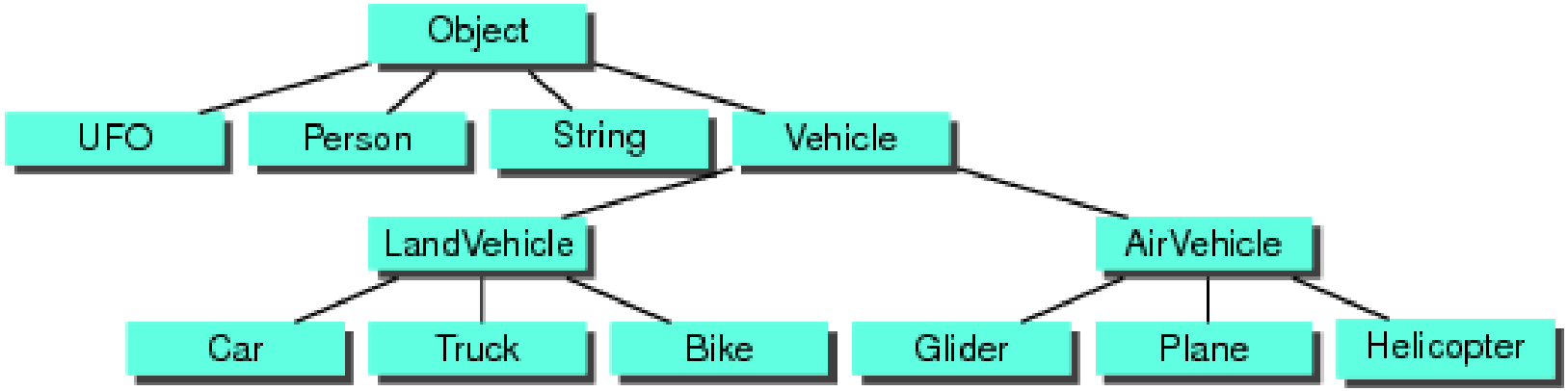
- Write the class completely from scratch (one extreme).
  - What some programmers always want to do!
- Find an existing class that exactly match your requirements (another extreme).
  - The easiest for the programmer!
- Built it from well-tested, well-documented existing classes.
  - A very typical reuse, called composition reuse!
- Reuse an existing class with inheritance
  - Requires more knowledge than composition reuse.

Introduction to Inheritance

- *Inheritance* is one of the main techniques of object-oriented programming
- Using this technique:
  - a very general form of a class is first defined and compiled, and then
  - more specialized versions of the class are defined by adding instance variables and methods
- The specialized classes are said to *inherit* the methods and instance variables of the general class

Introduction to Inheritance

- Inheritance models "*is a*" relationships
  - Object "is an" other object if it can behave in the same way
  - Inheritance uses *similarities and differences* to model groups of related objects
- Where there's Inheritance, there's an *Inheritance Hierarchy* of classes



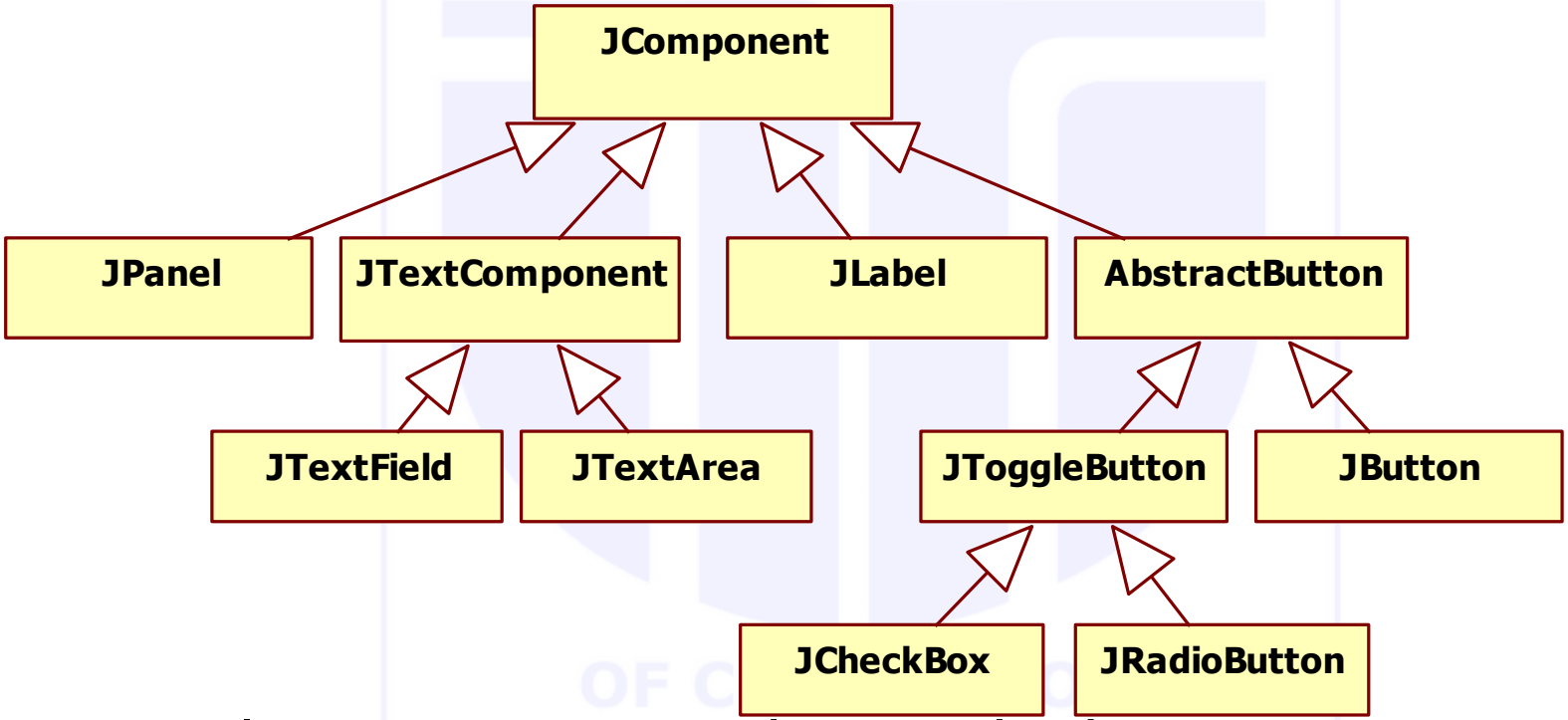
Introduction to Inheritance

- Inheritance is a way of:
  - organizing information
  - grouping similar classes
  - modeling similarities between classes
  - creating a taxonomy of objects
- **`Vehicle`** is called *superclass*
  - or *base class* or *parent class*
- **`LandVehicle`** is called *subclass*
  - or *derived class* or *child class*
- Any class can be both at same time
  - E.g., **`LandVehicle`** is superclass of **`Truck`** and subclass of **`Vehicle`**

Introduction to Inheritance

- Can only inherit from *one* superclass in Java
  - otherwise, no limit to depth or breadth of class hierarchy
  - C++ allows a subclass to inherit from multiple superclasses (error-prone)
- Note that, in Java, *every class* extends the `Object` class either directly or indirectly
- A derived class automatically has all the instance variables and methods that the base class has, and it can have additional methods and/or instance variables as well
- Inheritance is especially advantageous because it allows code to be *reused*, without having to copy it into the definitions of the derived classes

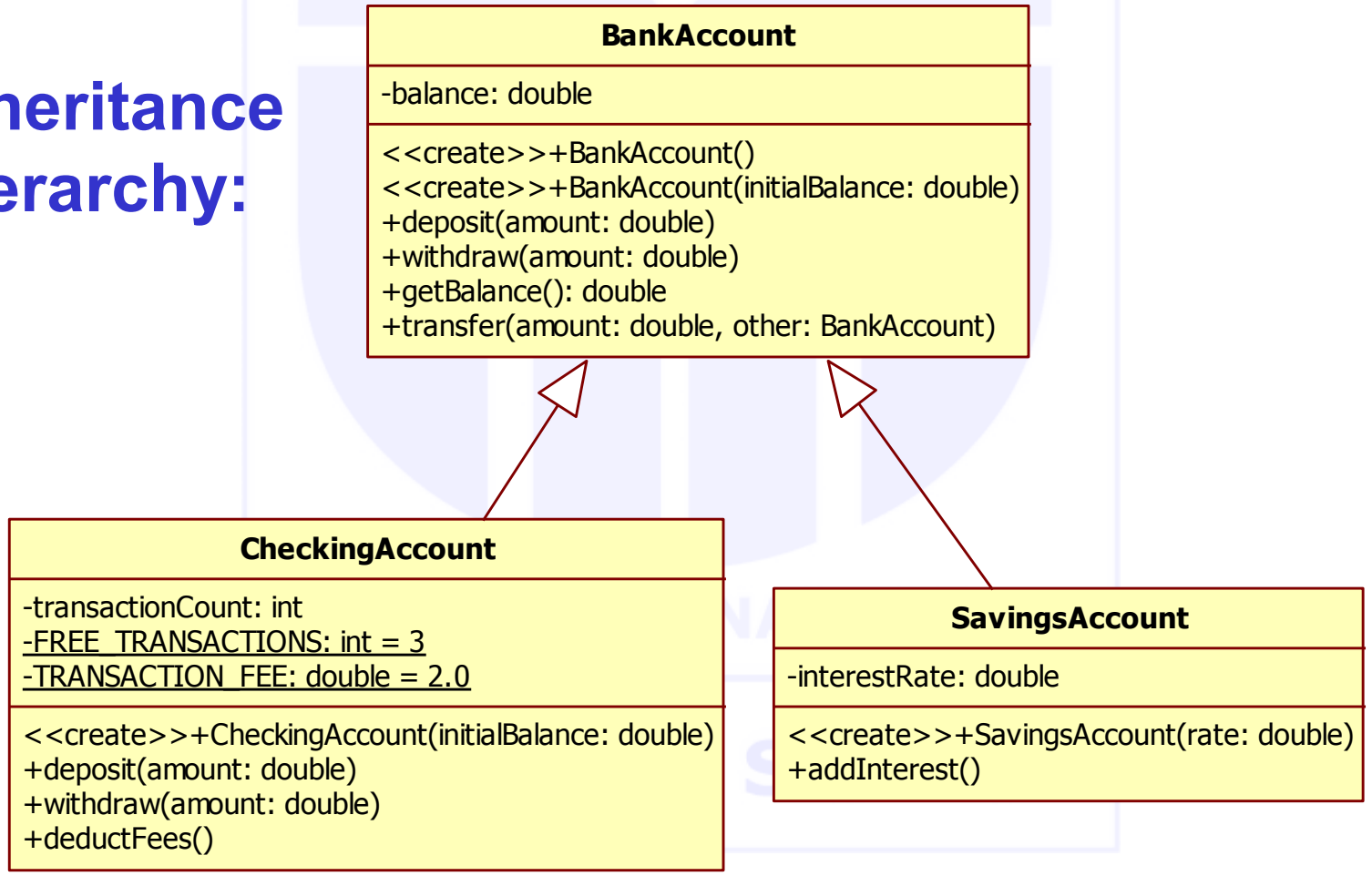
Example. A Part of the Hierarchy of Swing User Interface Components



- Superclass `JComponent` has methods `getWidth`, `getHeight`
- `AbstractButton` class has methods to set/get button text and icon

A Simpler Hierarchy: Hierarchy of Bank Accounts

- **Inheritance hierarchy:**



A Simpler Hierarchy: Hierarchy of Bank Accounts

- Brief specification
  - All bank accounts support the `getBalance` method
  - All bank accounts support the `deposit` and `withdraw` methods, but the implementations differ
  - Checking account needs a method `deductFees`; savings account needs a method `addInterest`

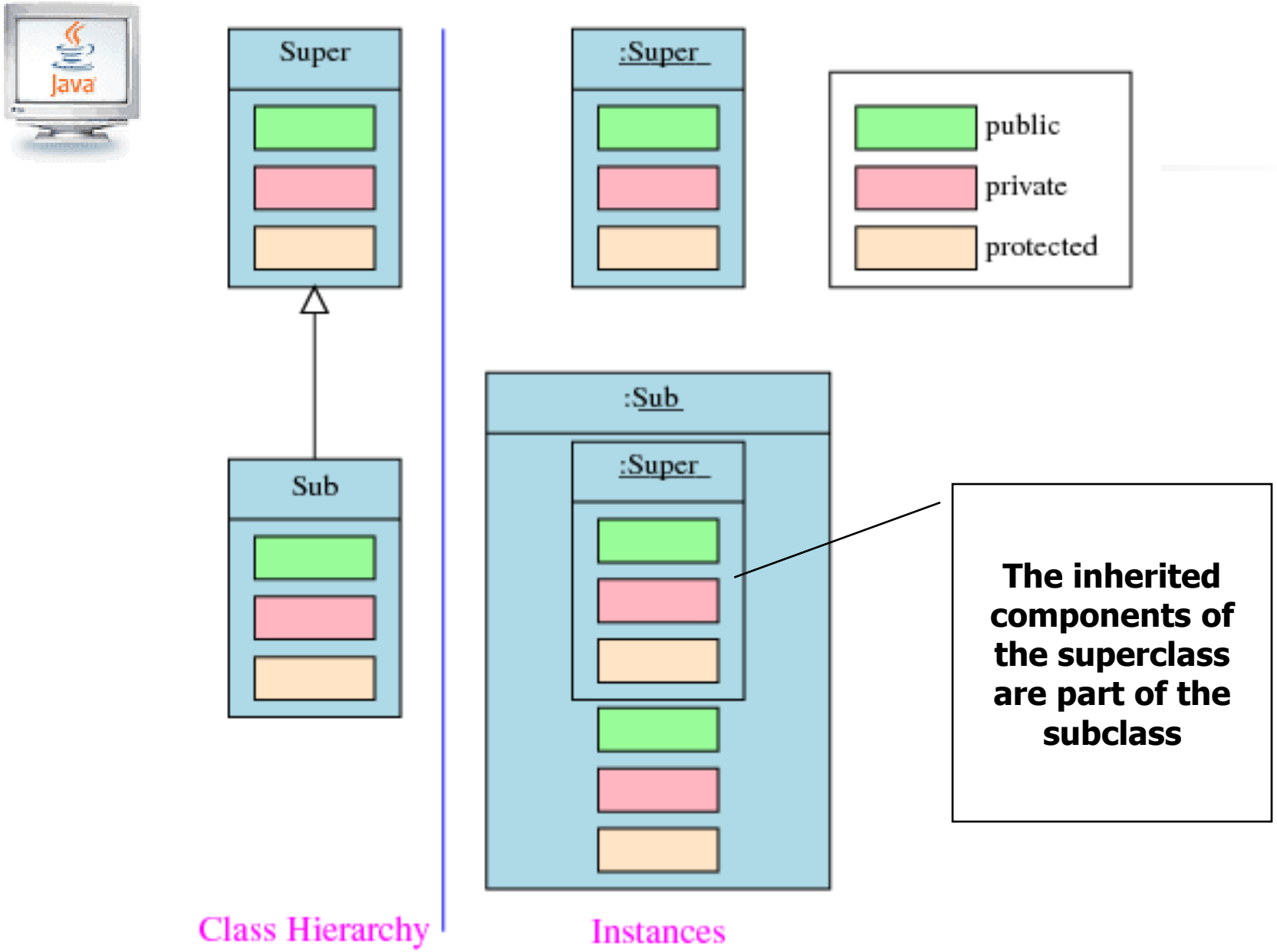
Derived Classes

- Since an savings account is a bank account, it is defined as a *derived* class of the class **`BankAccount`**
  - A *derived class* is defined by adding instance variables and/or methods to an existing class
  - The phrase **`extends BaseClass`** must be added to the derived class definition:

```
public class SavingsAccount extends BankAccount
```

- Syntax for inheritance:

```
class SubclassName extends SuperclassName
{
      methods
      instance fields
}
```


Super
Sub
:Super
public
private
protected
:Sub
:Super
The inherited components of the superclass are part of the subclass
Class Hierarchy
Instances

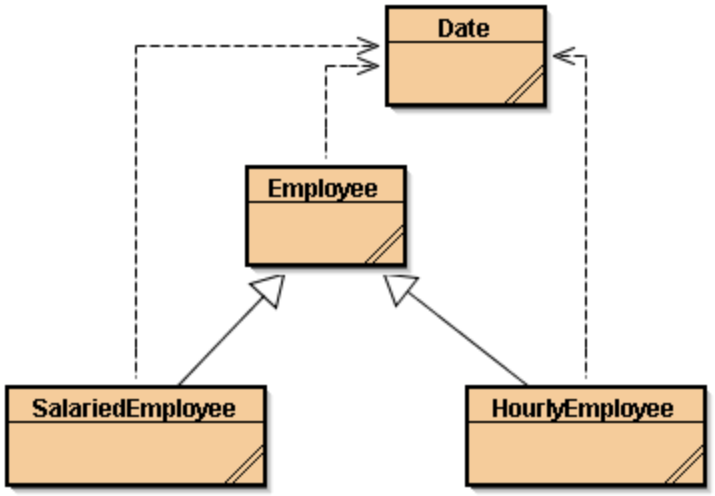
An Example: Employees

Date

+ Date(int, int, int)
+ Date(String, int, int)
+ Date(int)
+ Date(Date)
+ Date()
+ equals(Date): boolean
+ toString(): String
+ getMonth(): int
+ getYear(): int
+ getDay(): int
+ setDate(int): void
+ setDate(String, int, int): void
+ setDate(int, int, int): void
+ setMonth(int): void
+ setYear(int): void
+ setDay(int): void
+ precedes(Date): boolean
+ readInput(): void

Employee

+ Employee(String, Date)
+ Employee(Employee)
+ Employee()
+ equals(Employee): boolean
+ toString(): String
+ getName(): String
+ setName(String): void
+ getHireDate(): Date
+ setHireDate(Date): void



SalariedEmployee

+ SalariedEmployee(String, Date, double)
+ SalariedEmployee(SalariedEmployee)
+ SalariedEmployee()
+ equals(SalariedEmployee): boolean
+ toString(): String
+ getSalary(): double
+ getPay(): double
+ setSalary(double): void

HourlyEmployee

+ HourlyEmployee(String, Date, double, double)
+ HourlyEmployee(HourlyEmployee)
+ HourlyEmployee()
+ equals(HourlyEmployee): boolean
+ toString(): String
+ getHours(): double
+ setHours(double): void
+ getPay(): double
+ getRate(): double
+ setRate(double): void

- See with BlueJ

Derived Classes

- When a derived class is defined, it is said to inherit the instance variables and methods of the base class that it extends
  - Class **`Employee`** defines the instance variables **`name`** and **`hireDate`** in its class definition
  - Class **`HourlyEmployee`** also has these instance variables, but they are not specified in its class definition
  - Class **`HourlyEmployee`** has additional instance variables **`wageRate`** and **`hours`** that are specified in its class definition

Derived Classes

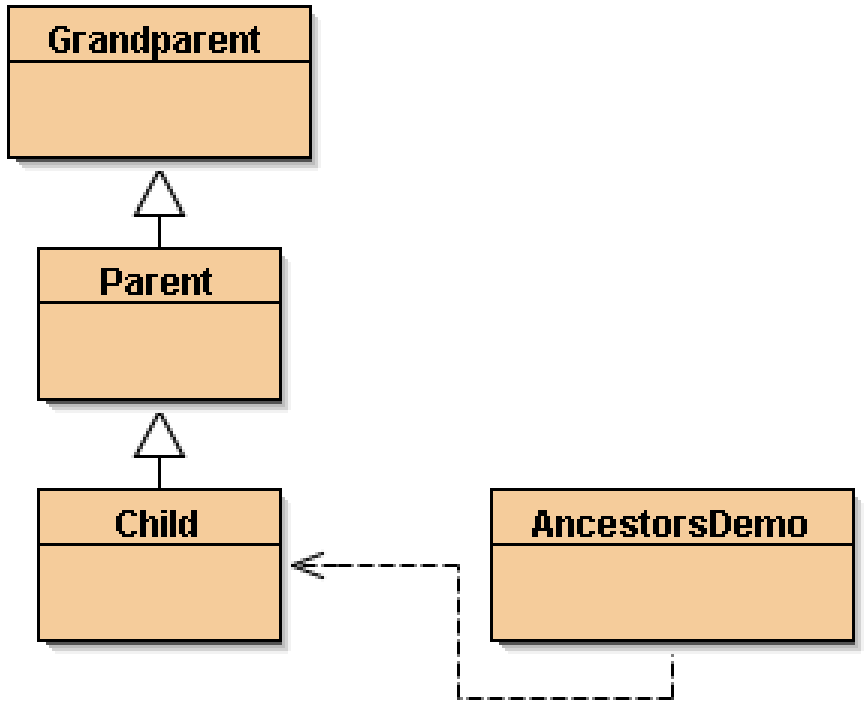
- Just as it inherits the instance variables of the class **`Employee`**, the class **`HourlyEmployee`** inherits all of its methods as well
  - The class **`HourlyEmployee`** inherits the methods **`getName`**, **`getHireDate`**, **`setName`**, and **`setHireDate`** from the class **`Employee`**
  - Any object of the class **`HourlyEmployee`** can invoke one of these methods, just like any other method

Derived Class (Subclass)

- A derived class, also called a *subclass*, is defined by starting with another already defined class, called a *base class* or *superclass*, and adding (and/or changing) methods, instance variables, and static variables
  - The derived class *inherits* all the *public methods*, all the *public and private instance variables*, and all the *public and private static variables* from the base class
  - The derived class *can add more* instance variables, static variables, and/or methods
- *Definitions* for the inherited variables and methods *do not appear* in the derived class
  - The code is reused without having to explicitly copy it, unless the creator of the derived class *redefines* one or more of the base class *methods*

Parent and Child Classes

- A base class is often called the *parent class*
  - A derived class is then called a *child class*
- These relationships are often extended such that a class that is a parent of a parent . . . of another class is called an *ancestor class*
  - If class **`A`** is an ancestor of class **`B`**, then class **`B`** can be called a *descendent* of class **`A`**



Abstract Classes

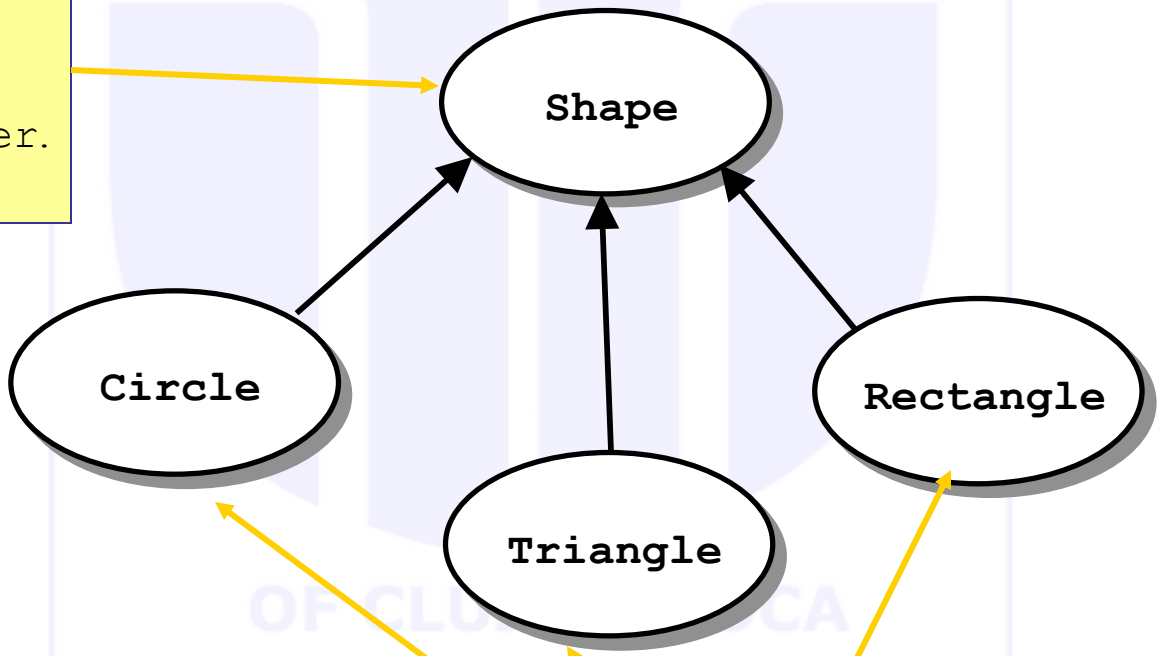
- An abstract method or class is declared with the **`abstract`** keyword. E.g.

```
public abstract double calcPay(
double hours );
```

- No object can be instantiated from an abstract class
- Every subclass of an abstract class that will be used to instantiate objects must provide implementations for all abstract methods in the superclass.
- Abstract classes save time, since we do not have to write "useless" code that would never be executed.
- An abstract class can inherit *abstract* methods
  - From an interface, or
  - From a class.

Example: A `Shape` Class

Superclass: contains abstract methods `calculateArea` and `calculatePerimeter`.



Subclasses: implement concrete methods `calculateArea` and `calculatePerimeter`.

Example: A `Shape` Class

```
/**
 * Abstract class Shape - base for inheritance for shapes
 */
public abstract class Shape {
    private static int counter;
    // Constructor
    public Shape()      {
        counter++;
    }
    // calculate area
    public abstract double calculateArea();
    // calculate perimeter
    public abstract double calculatePerimeter();
    // get number of shapes
    public int getCount() {
        return counter;
    }
    protected void finalize() throws Throwable {
        counter--;
    }
}
```

Superclass definition. Note class is declared `abstract`.

Abstract method definitions. Note only header is declared. These methods **must be overridden** in all concrete subclasses.

Example: the `Circle` Subclass

```
/**
 * Concrete class Circle - inherits from Shape
 */
public class Circle extends Shape {
    private double r; // radius of circle
    // Constructor
    public Circle(double r)     {
        super();
        this.r = r;
    }
    // calculate area
    public double calculateArea()     {
        return  Math.PI * r * r;
    }
    // calculate perimeter
    public double calculatePerimeter()     {
        return 2.0 * Math.PI * r ;
    }
     protected void finalize() throws Throwable     {
        super.finalize();
    }
}
```

Concrete class. Class *must not* contain or inherit abstract methods. Inherited abstract methods must be overridden.

Concrete method definitions. Note that the method body is declared here.

Example: the `Triangle` Subclass

```
/**
 * Concrete class Triangle - inherits from Shape
 */
public class Triangle extends Shape {
    private double s; // side of Triangle
    // Constructor
    public Triangle(double s)      {
        super();
        this.s = s;
    }
    // calculate area
    public double calculateArea()     {
        return ( Math.sqrt(3.)/4 * s *s );
    }
    // calculate perimeter
    public double calculatePerimeter()     {
        return 3.0 * s ;
    }
     protected void finalize() throws Throwable {
        super.finalize();
    }
}
```

Concrete class. Class *must not* contain or inherit abstract methods. Inherited abstract methods must be overridden.

Concrete method definitions. Note that the method bodies are different from those in `Circle`, but the method signatures are *identical*.

Other subclasses of **`Shape`** will also override the abstract methods **`calculateArea`** and **`calculatePerimeter`**

Example: Class `TestShape`

```
/**
 * Write a description of class TestShape here.
 *
 * @author (your name)
 * @version (a version number or a date)
 */
public class TestShape
{
    public static void main(String[] args)
    {
        // Create an array of Shapes
        Shape s[] = new Shape[2];
        // create objects
        s[0] = new Circle(2);
        s[1] = new Triangle(2);
        // Print out the number of Shapes
        System.out.println(s[0].getCount() + " shapes created");
        for (int i = 0; i < s.length; i++ ) {
            System.out.print(s[i].toString() + " ");
            System.out.print("Area = " + s[i].calculateArea());
            System.out.println(" Perimeter = " + s[i].calculatePerimeter());
        }
    }
}
```

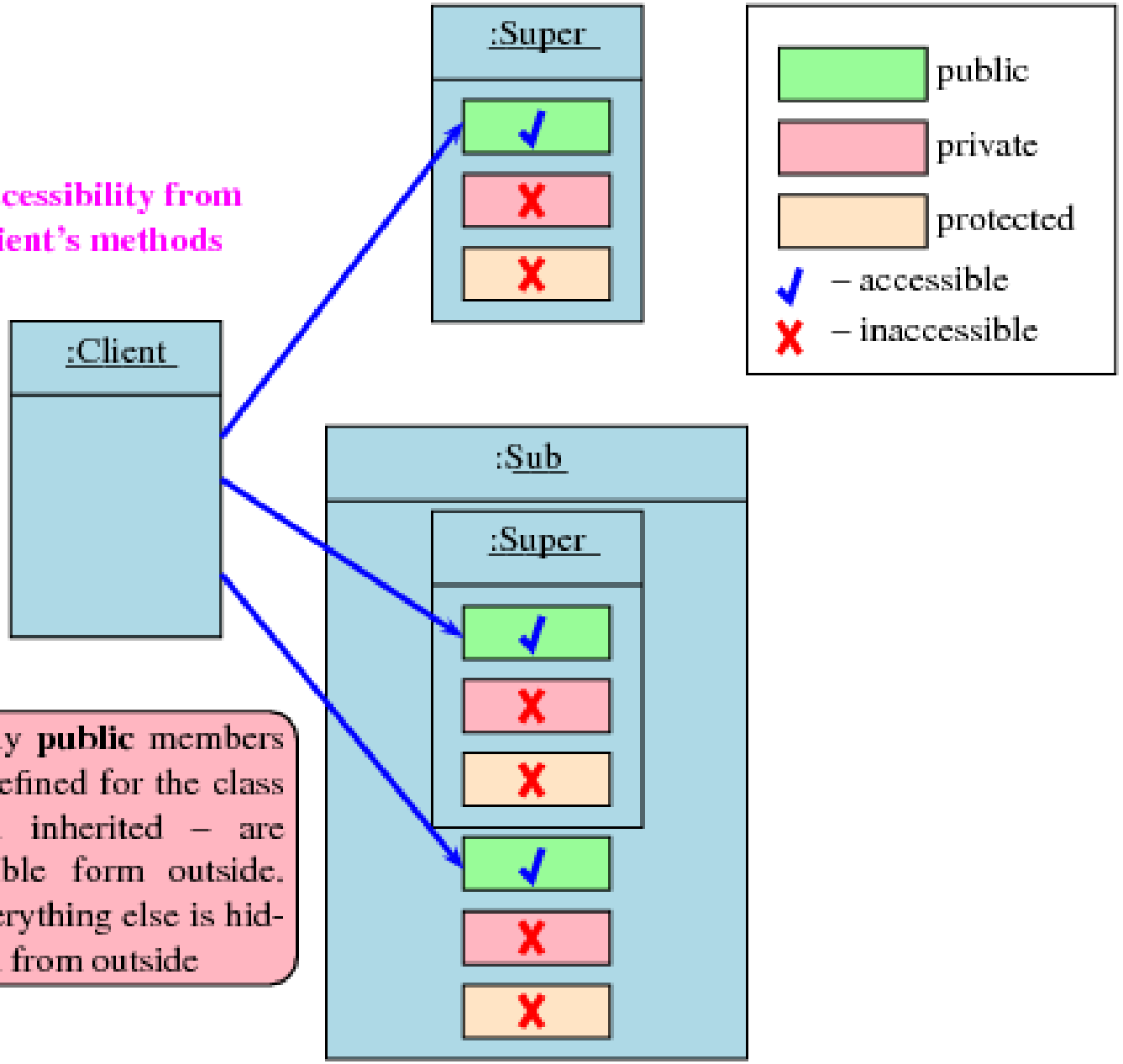
Create objects of subclasses using superclass references.

Call calculteArea and calculatePerimeter methods. The proper version of each method will be automatically called for each object.

`protected` Instance Variables

- As a general pattern, subclasses:
  - Inherit `public` capabilities (methods)
  - Inherit `private` properties (instance variables) but do not have access
  - Inherit `protected` variables and can access them
- A variable that is declared `protected` by a superclass becomes *part of the inheritance*
  - variable becomes available for subclasses to access *as if it were their own*
  - in contrast, if an instance variable is declared `private` by a superclass, its subclasses won't have access to it
    - superclass could still provide protected access to its private instance variables via *accessor* and *mutator* methods

- **Accessibility from Client's methods**

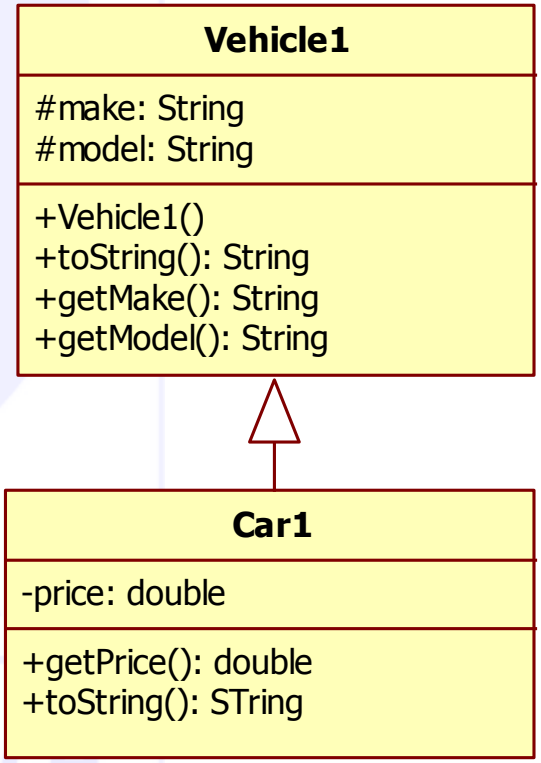


`protected` vs `private` Instance Variables

- How can I decide between **`private`** and **`protected`**?
  - use **`private`** if you want an instance variable to be *encapsulated* by superclass
    - e.g., doors, windows, spark plugs of a car
  - use **`protected`** if you want an instance variable to be available for subclasses to change (and you don't want to make the variable more generally accessible via accessor/mutator methods)
    - e.g., engine of a car

protected, Example

```
public class Vehicle1 {
  protected String make;
  protected String model;
  public Vehicle1() { make = ""; model = "";}
  public String toString() {
    return "Make: " + make + " Model: " + model;
  }
  public String getMake(){ return make;}
  public String getModel() { return model;}
}
public class Car1 extends Vehicle1 {
  private double price;
  public Car1() { price = 0.0; }
  public String toString() {
    return "Make: " + make + " Model: " + model
      + " Price: " + price;
  }
  public double getPrice(){ return price; }
}
```



Overriding a Method Definition

- Although a derived class inherits methods from the base class, it can change or *override* an inherited method if necessary
  - In order to override a method definition, a new definition of the method is simply placed in the class definition, just like any other method that is added to the derived class
- Ordinarily, the type returned may not be changed when overriding a method
- However, if it is a *class type*, then the returned type may be changed to that of any *descendent class* of the returned type
- This is known as a *covariant return type*
  - *Covariant return types* are new in Java 5.0; they are not allowed in earlier versions of Java

Covariant Return Type

- Given the following base class:

```
public class BaseClass
{ . . .
  public Employee getSomeone(int someKey)
  . . .
```

- The following is allowed in Java 5.0:

```
public class DerivedClass extends BaseClass
{ . . .
  public HourlyEmployee getSomeone(int someKey)
  . . .
```

Changing the Access Permission of an Overridden Method

- The access permission of an overridden method can be changed *from private* in the *base class* to *public* (or some other *more permissive access*) in the *derived class*
- However, the access permission of an overridden method *can not be changed* from public in the base class *to a more restricted access* permission in the derived class
  - I.e. we can relax access permission in a derived class

Changing the Access Permission of an Overridden Method

- Given the following method header in a base class:

```
private void doSomething()
```

- The following method header is valid in a derived class:

```
public void doSomething()
```

- However, the opposite is not valid
- Given the following method header in a base class:

```
public void doSomething()
```

- The following method header is not valid in a derived class:

```
private void doSomething()
```

Pitfall: Overriding Versus Overloading

- Do not confuse *overriding* a method in a derived class with *overloading* a method name
  - When a method is *overridden*, the new method definition given in the derived class has the *exact same number and types of parameters as in the base class*
  - When a method in a derived class has a *different signature* from the method in the base class, that is *overloading*
  - Note that when the *derived class overrides* the original method, *it still inherits the original method* from the base class as well

The `final` Modifier

- If the modifier **`final`** is placed before the definition of a *method*, then that method *may not be redefined* in a derived class

- It the modifier **`final`** is placed before the definition of a *class*, then that *class may not be used as a base class* to derive other classes

The `super` Constructor

- A derived class uses a constructor from the base class to initialize all the data inherited from the base class
  - In order to invoke a constructor from the base class, it uses a special syntax:

```
public DerivedClass(int p1, int p2, double p3)
{
  super(p1, p2);
  instanceVariable = p3;
}
```

  - In the above example, `super(p1, p2);` is a call to the base class constructor

The `super` Constructor

- A call to the base class constructor can never use the name of the base class, but uses the keyword `super` instead
- A call to `super` must always be the first action taken in a constructor definition
- An instance variable cannot be used as an argument to `super`
  - Why this is not allowed?

The `super` Constructor

- If a derived class constructor does not include an invocation of `super`, then the no-argument constructor of the base class will automatically be invoked
  - This can result in an error if the base class has not defined a no-argument constructor
- Since the inherited instance variables should be initialized, and the base class constructor is designed to do that, then *an explicit call to* `super` *should always be used*

Constructors and Subclasses

- The keyword **this** is used in a constructor to invoke another constructor of the same class. Example:

```
public class Circle extends ClosedFigure
{
  private int radius;
  public Circle(int radius)
  {
    super();
    this.radius = radius;
  }
  public Circle()
  {
    this(1); // invoke above constructor with argument 1
  }
…
}
```

Access to a Redefined Base Method

- Within the definition of a method of a derived class, the base class version of an overridden method of the base class can still be invoked
  - Simply preface the method name with super and a dot

```
public String toString()
{
   return (super.toString() + "$" + wageRate);
}
```

- However, using an object of the derived class outside of its class definition, there is no way to invoke the base class version of an overridden method

You Cannot Use Multiple `supers`

- It is only valid to use `super` to invoke a method from a *direct* parent
  - Repeating `super` will not invoke a method from some other ancestor class
- For example, if the `Employee` class were derived from the class `Person`, and the `HourlyEmployee` class were derived from the class `Employee` , it would not be possible to invoke the `toString` method of the `Person` class within a method of the `HourlyEmployee` class

```
super.super.toString() // ILLEGAL!
```

The `this` Constructor

- Within the definition of a constructor for a class, **`this`** can be used as a name for invoking another constructor in the same class
  - The same restrictions on how to use a call to **`super`** apply to the **`this`** constructor

- If it is necessary to include a call to both **`super`** and **`this`**, the call using **`this`** must be made first, and then the constructor that is called must call **`super`** as its first action

The `this` Constructor

- Often, a no-argument constructor uses `this` to invoke an explicit-value constructor
  - No-argument constructor (invokes explicit-value constructor using `this` and default arguments):

```
public ClassName()
{
   this(argument1, argument2);
}
```

  - Explicit-value constructor (receives default values):

```
public ClassName(type1 param1, type2 param2)
{
   . . .
}
```

The `this` Constructor

```
public HourlyEmployee()
{
   this("No name", new Date(), 0, 0);
}
```

- The above constructor will cause the constructor with the following heading to be invoked:

```
public HourlyEmployee(String theName, Date
  theDate, double theWageRate, double
  theHours)
```

Tip: An Object of a Derived Class Has More than One Type

- An object of a derived class has the type of the derived class, and it also has the type of the base class
- More generally, an object of a *derived class* has the *type of every one of its ancestor classes*
  - Therefore, an object of a derived class can be assigned to a variable of any ancestor type

Tip: An Object of a Derived Class Has More than One Type

- An object of a derived class can be plugged in as a parameter in place of any of its ancestor classes
- In fact, a derived class object can be used anyplace that an object of any of its ancestor types can be used
- Note, however, that this relationship does not go the other way
  - An ancestor type can never be used in place of one of its derived types

Pitfall: The Terms "Subclass" and "Superclass"

- The terms *subclass* and *superclass* are sometimes mistakenly reversed
  - A *superclass* or base class is *more general* and inclusive, but *less complex*
  - A *subclass* or derived class is *more specialized*, less inclusive, and *more complex*
    - As more instance variables and methods are added, the number of objects that can satisfy the class definition becomes more restricted

Abstract Class Use

- An abstract class factors out implementation of its concrete subclasses.
- Used to exploit polymorphism.
  - Functionality specified in parent class can be given implementations appropriate to each concrete subclass.
- Abstract class must be stable.
  - any change in an abstract class propagates to subclasses and their clients.
- A concrete class can only extend one (abstract) class

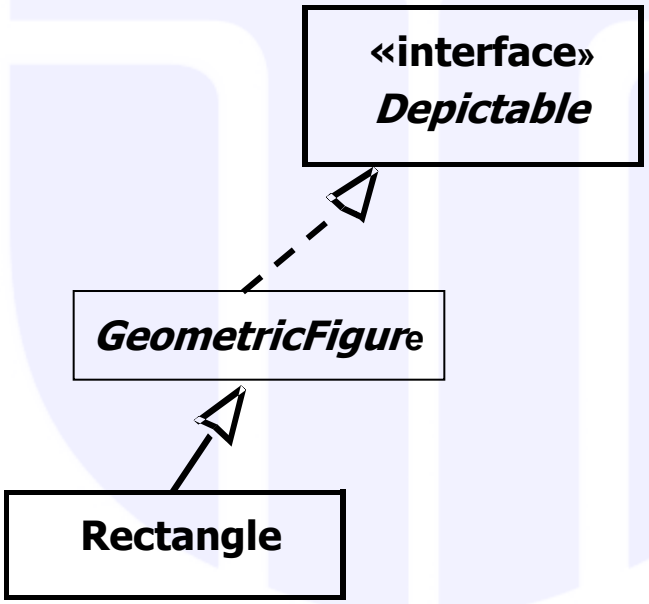
Interfaces, Abstract classes and Concrete Classes

- An ***interface***
  - used to specify functionality required by a client.
- An ***abstract class***
  - provides a basis on which to build concrete servers.
- A ***concrete class***
  - completes server implementation specified by an interface;
  - furnish run-time objects;
  - not generally suited to serve as a basis for extension.

Interface Use

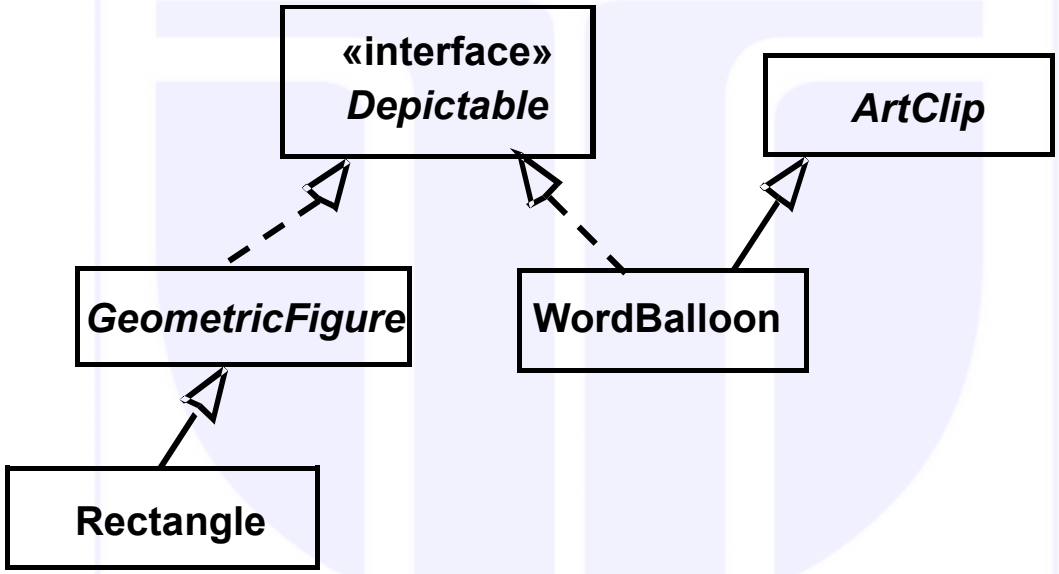
- Interfaces are by definition abstract.
  - separate an object's implementation from its specification.
  - they do not fix any aspect of an implementation.
- A class can implement more than one interface.
- Interfaces allow a more generalized use of polymorphism; instances of relatively unrelated classes can be treated as identical for some specific purpose.
- In your program designs, remember to use the Java *interface to share common behavior*. Use *inheritance to share common code*.

Interfaces, Abstract Classes, and Concrete Classes




```
public boolean isIn (Location point, Depictable figure)
{
        Location l = figure.getLocation();
        Dimension d = figure.getDimension();
        …
}
```

Interfaces, Abstract Classes, and Concrete Classes




```
public boolean isIn (Location point, Depictable figure)
{
        Location l = figure.getLocation();
        Dimension d = figure.getDimension();
        …
}
```

- Can pass instances of WordBalloon to **`isIn`**.

Polymorphism Example

```
public class Base {
   protected int theInt = 100;

   ...
   public void printTheInt() {
      System.out.println( theInt );
   }
```

```
public class Doubler extends Base {
   ...
   public void printTheInt() {
      System.out.println( theInt*2 );
   }
```

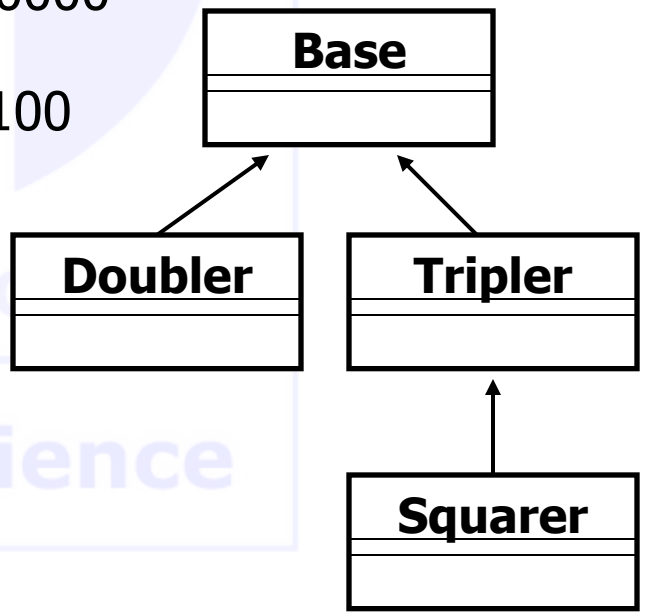
```
public class Tripler extends Base {
   ...
   public void printTheInt() {
      System.out.println( theInt*3 );
   }
```

```
public class Squarer extends Tripler {
   ...
   public void printTheInt() {
            System.out.println( theInt*theInt );
   }
}
```

Polymorphism Example

```
Base theBase;
theBase = new Base();
theBase.printTheInt();
theBase = new Doubler();
theBase.printTheInt();
theBase = new Tripler();
theBase.printTheInt();
theBase = new Squarer();
theBase.printTheInt();
theBase = new Base();
theBase.printTheInt();
…
```

100
200
300
10000
100



subtype polymorphism

As dynamic binding occurs the behavior (i.e., methods) follow the objects.

Polymorphism

- A polymorphic variable can appear to change its type through dynamic binding.
- The compiler always understands a variable's type according to its declaration.
- The compiler permits some flexibility by way of type conformance.
- At run-time the behavior of a method call depends upon the type of the *object* and not the variable.
- Example:

```
Base theBase;
theBase = new Doubler();
theBase = new Squarer();
theBase.printTheInt();
```

Why is Polymorphism Useful?

- Polymorphism permits a superclass to capture commonality, leaving the specifics to subclasses.

Suppose that AView included an calcArea method, as shown.

```
public class AView {
   ...
   public double calcArea() {
            return 0.0;
   }
```

Then ARectangle should be written as ...

```
public class ARectangle extends AView {
   ...
   public double calcArea() {
            return getWidth() * getHeight();
   }
}
```

and AOval should be written as ...

```
public class AOval extends AView {
   ...
   public double calcArea() {
            return getWidth()/2. * getHeight()/2. * Math.PI;
   }
}
```

now consider

```
public double coverageCost( AView v, double costPerSqUnit) {
            return v.calcArea() * costPerSqUnit;
}
```

Inheriting from `Object`

- *Every class in Java extends some other class*.
- If you don't explicitly specify the class that your new class extends, it will automatically extend the class named ***Object***.
- All classes in Java are in a class hierarchy where the class named *Object* is the root of the hierarchy.
- Some classes extend *Object* directly, while other classes are subclasses of *Object* further down the hierarchy.
- Class *Object* is defined in `java.lang`

How a decision is made about which method to run

1. If there is a concrete method for the operation in the current class, run that method.
2. Otherwise, check in the immediate superclass to see if there is a method there; if so, run it.
3. Repeat step 2, looking in successively higher superclasses until a concrete method is found and run.
4. If no method is found, then there is an error
   - In Java and C++ the program would not have compiled

Dynamic binding

- Occurs when decision about which method to run can only be made at run time
  - Needed when:
    - A variable is declared to have a superclass as its type, and
    - There is more than one possible polymorphic method that could be run among the type of the variable and its subclasses

Reading

- Eckel: chapters 8, 9
- Barnes: chapters 8, 9
- Deitel: chapters 9, 10

Summary

- Java packages
  - organizing related classes
  - Java APIs
- Inheritance
  - base class, superclass
  - derived class, subclass
  - hierarchy
  - **`super`** and **`this`** constructors
  - access to instance variables
  - method overriding vs overloading
- Interfaces, abstract classes, concrete classes
- Polymorphism