COMPUTER SCIENCE DEPARTMENT FACULTY OF ENGINEERING AND TECHNOLOGY

ADVANCED PROGRAMMING COMP231

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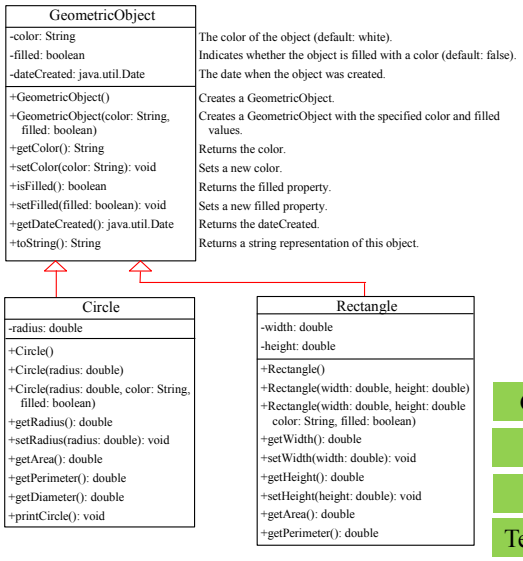
Chapter 11 Inheritance and Polymorphism

Motivations

Suppose you will define classes to model circles, rectangles, and triangles. These classes have many common features. What is the best way to design these classes so to avoid redundancy?

The answer is to use inheritance.

Superclasses and Subclasses

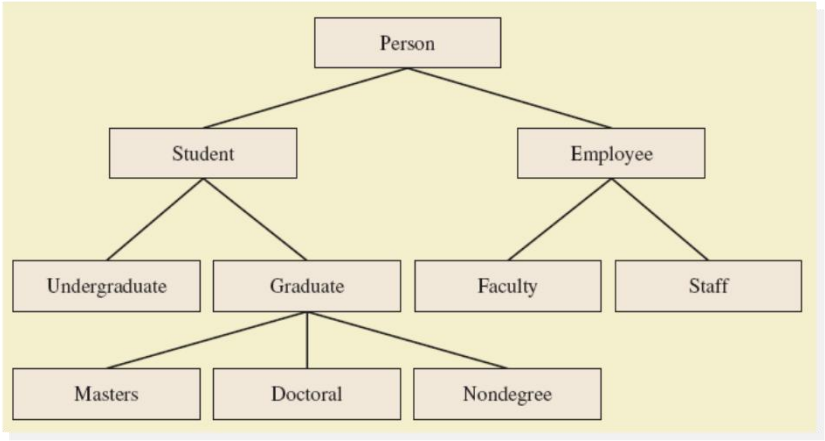


GeometricObject

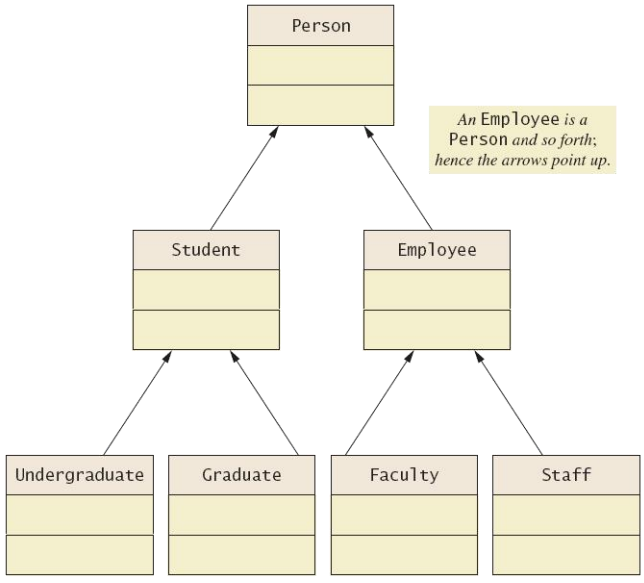
Circle

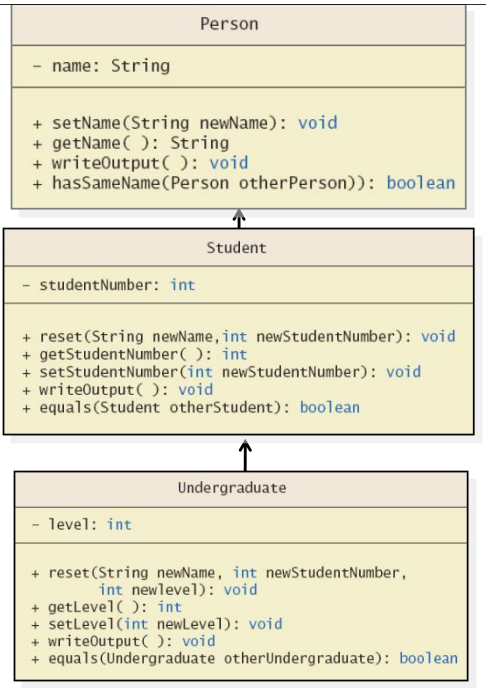
Rectangle

TestCircleRectangle Run



superclass and subclass





Are superclass's Constructor Inherited?

- No. They are not inherited.
- They are invoked explicitly or implicitly.
- Explicitly using the **super keyword.**
- A constructor is used to construct **an instance of a class**. Unlike properties and methods, **a superclass's constructors** are not inherited in the subclass.
- They can only be invoked from the subclasses' constructors, using the keyword **super**.
- If the keyword **super is not explicitly used**, the superclass's no-arg constructor is **automatically invoked**.

Superclass's Constructor Is Always Invoked

A constructor may invoke an overloaded constructor or its superclass's constructor. If none of them is invoked **explicitly**, the compiler puts super() as the first statement in the constructor. For example,

```
public A() {
}
```

is equivalent to

```
public A() {
  super();
}
```

```
public A(double d) {
  // some statements
}
```

is equivalent to

```
public A(double d) {
  super();
  // some statements
}
```

Using the Keyword `super`

The keyword **`super`** refers to the **superclass** of the class in which **`super`** appears. This keyword can be used in two ways:

- ❑To call a superclass constructor
- ❑To call a superclass method

CAUTION

- ❖ You must use the keyword super to call the superclass constructor.
- ❖ Invoking a superclass constructor's name in a subclass causes **a syntax error**.
- ❖ Java requires that the statement that uses the keyword **super** appear **first** in the constructor.

Example (using super with constructor, methods, variables)

```
class  A{
int a,b;
 A(int x, int y)
   {a=x; b=y;}

 int multi( ){
   return a*b;
   }
}
```

```
class  B extends A{
int c;
 B(int x, int y, int z)
   {super(x,y);//first
       c=z;}
  int multi( ){
   return a*b*c;
   }
}
```

Cont..

```
class  A{
void hello( ){
 System.out.println("Hello 1");
  }
}
class  B extend A{
 void hello( ){
     System.out.println("Hello 2");}
void display( )
  {hello( ); super.hello( );
  }
}
```

Cont..

```
class  A{
int a=8;


}
class  B extend A{
 int a =7;
void display( )
  {  System.out.println(a);
     System.out.println(super.a);
  }
}
```


```
class A {
int a, b;
  A(int x, int y) {
       a = x;
       b = y;
     }
int multi() {
      return a * b;
     }}
class B extends A {
int c;

   B(int x, int y, int z) {
    super(x, y);// first
     c = z;}

public int methodX() {
int d = super.multi();
return d;}

@Override
int multi() {
return a * b * c;}
}
```

```
public class testmethodoverload {
public static void main(String[] args) {
A a = new A(5, 5);
System.out.println(a.multi());

B b = new B(5, 10, 15);
System.out.println(b.multi());
System.out.println(b.methodX());
   }

}
```

```
25
750
50
```

Constructor Chaining

Constructing an instance of a class invokes all the superclasses' constructors along the inheritance chain. This is known as constructor chaining.

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println('(4) Faculty's no-arg constructor is invoked');
  }
}

class Employee extends Person {
  public Employee() {
    this('(2) Invoke Employee's overloaded constructor');
    System.out.println('(3) Employee's no-arg constructor is invoked');
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println('(1) Person's no-arg constructor is invoked');
  }
}
```

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

1. Start from the main method

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

2. Invoke Faculty constructor

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

3. Invoke Employee's no-arg constructor

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

4. Invoke Employee(String) constructor

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

5. Invoke Person() constructor

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

6. Execute println

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

7. Execute println

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

8. Execute println

animation

Trace Execution

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

9. Execute println

```
class A {
  A(){
    System.out.println("Print A constructor");
    }
  }

class B extends A {
   B(){
     System.out.println("Print B constructor");
     }
  }

class C extends B {
  C(){
   System.out.println("Print C constructor");
   }
 }

public class superClass {

  public static void main(String[] args) {
    new C();
  }
}
```

```
class A {
  A(){
    System.out.println("Print A constructor");
   }
}

class B extends A {
 B(){
   super();
   System.out.println("Print B constructor");
   }
}

class C extends B {
C(){
  super();
  System.out.println("Print C constructor");
   }
}
public class superClass {
 public static void main(String[] args) {
 new C();
  }
}
```


❖Example on the Impact of a Superclass without no-arg Constructor They can only be invoked from the subclasses' constructors, using the keyword **super**.

Find out the errors in the program:

```
public class Apple extends Fruit {
      Apple(){
      super("Hi:");}
}

class Fruit {
  public Fruit(String name) {
    System.out.print(name);
    System.out.println("Fruit's constructor is invoked");
  }
}
```

Fruit class doesn't contains default constructor
i.e , Fruit(){} doesn't exists

Hi:Fruit's constructor is invoked

❖If the keyword **super is not explicitly used**, the superclass's no-arg constructor is **automatically invoked**.

Find out the errors in the program:

```
public class Apple extends Fruit {
     Apple(){}
}

class Fruit {
  public Fruit(){
  System.out.println("C1: Fruit's constructor is invoked");
}
  public Fruit(String name) {
    System.out.println("C2 :Fruit's constructor is invoked");
  }
}
```

Fruit class is defined , default constructor
Super is implicitly created

C1 :Fruit's constructor is invoked

Defining a Subclass

A subclass inherits from a superclass. You can also:

- Add new properties
- Add new methods
- Override the methods of the superclass

Calling Superclass Methods

You could rewrite the printCircle() method in the Circle class as follows:

```
public void printCircle( ) {
  System.out.println(‘The circle is created ‘ +
    super.getDateCreated( ) + ‘ and the radius is ‘ + radius);
}
```

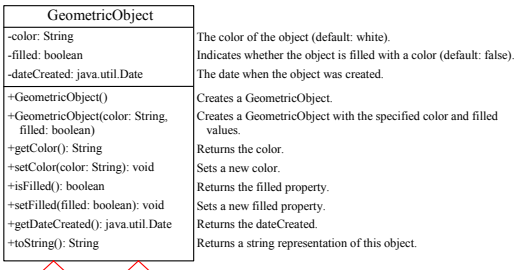
Overriding Methods in the Superclass

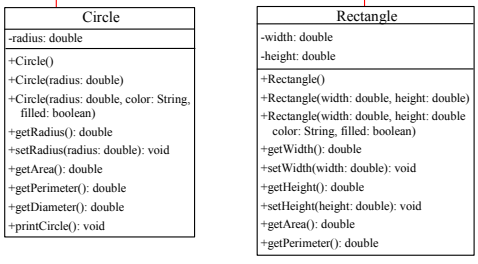
A subclass inherits methods from a superclass. Sometimes it is necessary for the subclass to modify the implementation of a method defined in the superclass. This is referred to as **method overriding**.

```
public class Circle extends GeometricObject {
  // Other methods are omitted

  /** Override the toString method defined in GeometricObject */
  public String toString() {
    return super.toString() + "\nradius is " + radius;
  }
}
```

Superclasses and Subclasses





GeometricObject

Circle

Rectangle

TestCircleRectangle Run

NOTE

An instance method can be overridden only **if it is accessible**. **Thus a private method cannot be overridden**, because it is not accessible outside its own class. If a method defined in a subclass is **private in its superclass**, the two methods are **completely unrelated.**

Both methods are private, not related to each other.

(hidden from out side of superclass and subclass)

Example

```
public class superClass {

public static void main(String[] args) {
 C c=new C();
  c.printMesg("Hi");
    }
}
```

Syntax error ? Why ?

Because private method print Message in super class is only for Class A

```
package project;

class A {
A(){
System.out.println("Print A constructor");
  }
  private void printMesg(String str) {
 System.out.print(str);
}
}

class B extends A {
B(){
super();
System.out.println("Print B constructor");
}
}

class C extends B {
C(){
super();
System.out.println("Print C constructor");
}
void printMesg(String str){
super.printMesg(str);
  }
}
```

NOTE

Like an **instance method**, a static method can be **inherited**. However, a **static method cannot be overridden**. If a static method defined in the superclass is redefined in a subclass, the method defined in the **superclass is hidden**.

→Both methods in superclass and subclass defined as static, then you cannot view in related object.

Example

```
public class staticExample {

        public static void main(String[] args)
            {
            Three three = new Three( );
            three.printMesg('Hi' );
        }

    }
```

Syntax error ? Why ?

Because static method print Message in super class cannot override and super.printMesg(str), super can't use with static

```
package chapter11;

class One {
    One( ) {
        System.out.println('Print A constructor' );
    }

    public static void printMesg(String str) {
        System.out.print(str+ ' from A' );
    }
}

class Two extends One {
    Two( ) {
        super( );
        System.out.println('Print B constructor' );
    }
}

class Three extends Two {
    Three( ) {
        super( );
        System.out.println('Print C constructor' );
    }

    public  void  printMesg(String str) {
        super.printMesg(str);
        System.out.println(str + ' from B' );
    }
}
```

Overriding تجاوز vs. Overloading الزائد التحميل

```
public class Test {
  public static void main(String[] args) {
    A a = new A();
    a.p(10);
    a.p(10.0);
  }
}

class B {
  public void p(double i) {
    System.out.println(i * 2);
  }
}

class A extends B {
  // This method overrides the method in B
  public void p(double i) {
    System.out.println(i);
  }
}
```

```
public class Test {
  public static void main(String[] args) {
    A a = new A();
    a.p(10);
    a.p(10.0);
  }
}

class B {
  public void p(double i) {
    System.out.println(i * 2);
  }
}

class A extends B {
  // This method overloads the method in B
  public void p(int i) {
    System.out.println(i);
  }
}
```

Note: methods are Overriding for superclass in subclass (in inheritance) While method Overloading at same class for different passed parameters to methods in class.

The Object Class and Its Methods

Every class in Java is descended from the java.lang.Object class. If no inheritance is specified when a class is defined, the superclass of the class is Object.

```
public class Circle {
  ...
}
```

Equivalent

```
public class Circle extends Object {
  ...
}
```

The toString() method in Object

The toString() method returns a string representation of the object. The default implementation returns a string consisting of a **class name** of which the object is an instance, the at sign (@), and a number representing this object.

```
Loan loan = new Loan();
System.out.println(loan.toString());
```

The code displays something like Loan@15037e5 . This message is not very **helpful or informative**. Usually you should **override the toString** method so that it returns a **digestible** string representation of the object.

Polymorphism (many behavior)

Polymorphism means that a variable of a supertype can refer to a subtype object.

A class defines a type. A type defined by a subclass is called a **subtype**, and a type defined by its superclass is called a **supertype**. Therefore, you can say that **Circle** is a subtype of **GeometricObject** and **GeometricObject** is a supertype for **Circle**.

Static polymorphism in Java is achieved by method **overloading**

Dynamic polymorphism in Java is achieved by method **overriding**

PolymorphismDemo Run

Polymorphism, Dynamic Binding and Generic Programming

```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
  public String toString() {
    return "Student";
  }
}

class Person extends Object {
  public String toString() {
    return "Person"; }}
```

Method m takes a parameter of the Object type. You can invoke it with any object.

An object of a subtype can be used wherever its supertype value is required. This feature is known as **polymorphism.**

When the method m(Object x) is executed, the argument x's toString method is invoked. x may be an instance of GraduateStudent, Student, Person, or Object. Classes GraduateStudent, Student, Person, and Object have their own implementation of the toString method. Which implementation is used will be determined **dynamically by the Java Virtual Machine** at runtime. This capability is known as **dynamic binding**.

```
Student
Student
Person
java.lang.Object@15db9742
```

Run

DynamicBindingDemo

Dynamic Binding

Dynamic binding works as follows: Suppose an object **o** is an instance of classes C_1, C_2, ..., C_{n-1}, and C_n, where C_1 is a subclass of C_2, C_2 is a subclass of C_3, ..., and C_{n-1} is a subclass of C_n. That is, C_n is the most general class, and C_1 is the most specific class. In Java, C_n is the Object class. If **o** invokes a **method p**, the **JVM searches the implementation for the method p in C_1, C_2, ..., C_{n-1} and C_n, in this order, until it is found.** Once an implementation is found, the search stops and the first-found implementation is invoked.

Since o is an instance of C_1, o is also an instance of $C_2, C_3, \ldots, C_{n-1}$, and C_n

Method Matching vs. Binding (link, connect)

Matching a method signature and binding a method implementation are two issues. **The compiler finds a matching method according to parameter type, number of parameters, and order of the parameters at compilation time**. A method may be implemented in several subclasses. **The Java Virtual Machine dynamically binds the implementation of the method at runtime**.

Generic Programming

```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
  public String toString() {
    return "Student";
  }
}

class Person extends Object {
  public String toString() {
    return "Person";
  }
}
```

Polymorphism allows methods to be used generically for a wide range of object arguments. This is known as **generic programming**. If a method's parameter type is a superclass (e.g., Object), you may pass an object to this method of any of the parameter's subclasses (e.g., Student or String).

When an object (e.g., a Student object or a String object) is used in the method, the particular implementation of the method of the object that is invoked (e.g., toString) is determined dynamically.

Casting Objects

You have already used the casting operator to convert variables of one primitive type to another. **Casting** can also be used to convert an object of one class type to another **within an inheritance hierarchy**. In the preceding section, the statement

```
m(new Student());
```

assigns the object new Student() to a parameter of the Object type. This statement is equivalent to:

```
Object o = new Student(); // Implicit casting
m(o);
```

The statement Object o = new Student(), known as **implicit** casting, is **legal because an instance** of Student is automatically an instance of Object.

Why Casting Is Necessary?

Suppose you want to assign the object reference o to a variable of the Student type using the following statement:

```
Student b = o;
```

A compile error would occur. Why does the statement **Object o = new Student()** work and the statement **Student b = o** doesn't? **This is because a Student object is always an instance of Object, but an Object is not necessarily an instance of Student.** Even though **you can see that o is really a Student object**, the compiler is not so clever to know it. To tell the compiler that o is a Student object, use an explicit casting. The syntax is similar to the one used for casting among primitive data types. Enclose the target object type in parentheses and place it before the object to be cast, as follows:

```
Student b = (Student)o; // Explicit casting
```

Casting from Superclass to Subclass

Explicit casting must be used when casting an object from a **superclass to a subclass**. This type of casting may **not always succeed.**

```
Apple x = (Apple)fruit;
```

Fruit f = new Apple();

```
Orange x = (Orange)fruit;
```

Fruit o = new Orange();

The `instanceof` Operator

Use the **`instanceof`** operator to test whether an object is an instance of a class:

```
Object myObject = new Circle();
... // Some lines of code
/** Perform casting if myObject is an instance of
  Circle */
if (myObject instanceof Circle) {
  System.out.println("The circle diameter is " +
    ((Circle)myObject).getDiameter());
  ...
}
```

TIP

- To help understand casting, you may also consider the analogy of fruit, apple, and orange with the Fruit class as the superclass for Apple and Orange.
- An apple is a fruit, so you can always safely assign an instance of Apple to a variable for Fruit.
- However, a fruit is not necessarily an apple, so you have to use explicit casting to assign an instance of Fruit to a variable of Apple.

Example: Demonstrating Polymorphism and Casting

This example creates two geometric objects: a circle, and a rectangle, invokes the displayGeometricObject method to display the objects. The displayGeometricObject displays the area and diameter if the object is a circle, and displays area if the object is a rectangle.

CastingDemo Run


```
public class CastingDemo {
  /** Main method */
  public static void main(String[] args) {
    // Create and initialize two objects
    Object object1 = new Circle(1);
    Object object2 = new Rectangle(1, 1);

    // Display circle and rectangle
    displayObject(object1);
    displayObject(object2);
  }

  /** A method for displaying an object */
  public static void displayObject(Object myobject) {
    if (myobject instanceof Circle) {
      System.out.println("The circle area is " +   ((Circle)myobject).getArea());
      System.out.println("The circle diameter is " +     ((Circle)myobject).getDiameter());
    }
 else if (myobject instanceof  Rectangle) {
      System.out.println("The rectangle area is " +((Rectangle)myobject).getArea());
        }
      }
}
```

The `equals` Method

The `equals()` method compares the contents of two objects. The default implementation of the equals method in the **Object class** is as follows:

```
public boolean equals(Object obj) {
  return this == obj;
}
```

For example, the equals method is overridden in the Circle class.

```
public boolean equals(Object o) {
  if (o instanceof Circle) {
    return radius == ((Circle)o).radius;
  }
  else
    return false;
}
```

NOTE

- The == comparison operator is used for comparing two primitive data type values or for determining whether two objects have the same references.
- The **equals method** is intended to test whether **two objects** have the same contents, provided that the method is modified in the defining class of the objects.
- The == operator is stronger than the equals method, in that the == operator checks whether the two reference variables refer to the same object.

The ArrayList Class

You can create an array to store objects. But the array's size is fixed once the array is created. Java provides the ArrayList class that can be used to store an unlimited number of objects.

java.util.ArrayList<E>	
+ArrayList()	Creates an empty list.
+add(o: E) : void	Appends a new element o at the end of this list.
+add(index: int, o: E) : void	Adds a new element o at the specified index in this list.
+clear(): void	Removes all the elements from this list.
+contains(o: Object): boolean	Returns true if this list contains the element o.
+get(index: int) : E	Returns the element from this list at the specified index.
+indexOf(o: Object) : int	Returns the index of the first matching element in this list.
+isEmpty(): boolean	Returns true if this list contains no elements.
+lastIndexOf(o: Object) : int	Returns the index of the last matching element in this list.
+remove(o: Object): boolean	Removes the element o from this list.
+size(): int	Returns the number of elements in this list.
+remove(index: int) : boolean	Removes the element at the specified index.
+set(index: int, o: E) : E	Sets the element at the specified index.

Generic Type

ArrayList is known as a **generic class** with a generic type E. You can specify a concrete type to replace E when creating an ArrayList. For example, the following statement creates an ArrayList and assigns its reference to variable cities. This ArrayList object can be used to store strings.

```
ArrayList<String> cities = new ArrayList<String>();
ArrayList<String> cities = new ArrayList<>();
```

TestArrayList Run

```java
import java.util.ArrayList;

public class TestArrayList {
  public static void main(String[] args) {
    // Create a list to store cities
    ArrayList<String> cityList = new ArrayList<>();

    // Add some cities in the list
    cityList.add("Ramallah");
    // cityList now contains [Ramallah]
    cityList.add("Jericho");
    // cityList now contains [Ramllah, Jericho]
    cityList.add("Jerusalem");
    // cityList now contains [Ramallah,Jericho,Jerusalem]
    cityList.add("Nablus");
    // contains [Ramallah,Jericho,Jerusalem,Nablus]
    cityList.add("Jinen");
    // contains [Ramallah,Jericho,Jerusalem,Nablus,Jinen]
    cityList.add("Hebron");
   //contains[Ramallah,Jericho,Jerusalem,Nablus,Jinen,
       Hebron]

    System.out.println("List size? " + cityList.size());
    System.out.println("Is Ramllah in the list? " +
      cityList.contains("Ramllah"));
    System.out.println("The location of Hebron in the list? "
      + cityList.indexOf("Hebron"));
    System.out.println("Is the list empty? " +
      cityList.isEmpty()); // Print false
// Insert a new city at index 2
cityList.add(1, "Salfet");
   // contains [Ramallah,Salfet,Jerusalem,Nablus,Jinen,Hebron]

   // Remove a city from the list
   cityList.remove(" Nablus ");
   // contains[Ramallah,Salfet,Jerusalem,Jinen,Hebron]

   // Remove a city at index 1
   cityList.remove(4);
   // contains [Ramallah,Salfet,Jerusalem,Jinen]

   // Display the contents in the list
   System.out.println(cityList.toString());

   // Display the contents in the list in reverse order
   for (int i = cityList.size() - 1; i >= 0; i--)
     System.out.print(cityList.get(i) + " ");
   System.out.println();

   // Create a list to store two circles
   ArrayList<Circle> list = new ArrayList<>();

   // Add two circles
   list.add(new Circle(2));
   list.add(new Circle(3));

   // Display the area of the first circle in the list
   System.out.println("The area of the circle? " +
     list.get(0).getArea());
 }}
```

Differences and Similarities between Arrays and ArrayList

Operation	*Array*	*ArrayList*
Creating an array/ArrayList	`String[] a = new String[10]`	`ArrayList<String> list = new ArrayList<>();`
Accessing an element	`a[index]`	`list.get(index);`
Updating an element	`a[index] = "London";`	`list.set(index, "London");`
Returning size	`a.length`	`list.size();`
Adding a new element		`list.add("London");`
Inserting a new element		`list.add(index, "London");`
Removing an element		`list.remove(index);`
Removing an element		`list.remove(Object);`
Removing all elements		`list.clear();`

DistinctNumbers Run

Array Lists from/to Arrays

Creating an ArrayList from an array of objects:

```
String[] array = {"red", "green", "blue"};
ArrayList<String> list = new ArrayList<String>(Arrays.asList(array));
```

Creating an array of objects from an ArrayList:

```
String[] array1 = new String[list.size()];
list.toArray(array1);
```

max and min in an Array List

- String[] array = {"red", "green", "blue"};
- System.*out*.println(java.util.Collections.max(*new* ArrayList<String>(Arrays.asList(array))));

```
String[] array = {"red", "green", "blue"};
System.out.println(java.util.Collections.min(new
ArrayList<String>(Arrays.asList(array) )));
```

Shuffling an Array List

```
Integer[] array = {3, 5, 95, 4, 15, 34, 3, 6, 5};
ArrayList<Integer> list = new   ArrayList<Integer>(Arrays.asList(array));
java.util.Collections.shuffle(list); //randomize the list
System.out.println(list);
```

The `protected` Modifier

- The `protected` modifier can be applied on data and methods in a class. **A protected data or a protected method** in a public class can be accessed by any class in the same package or its **subclasses**, even if the **subclasses are in a different package.**
- private, default, protected, public

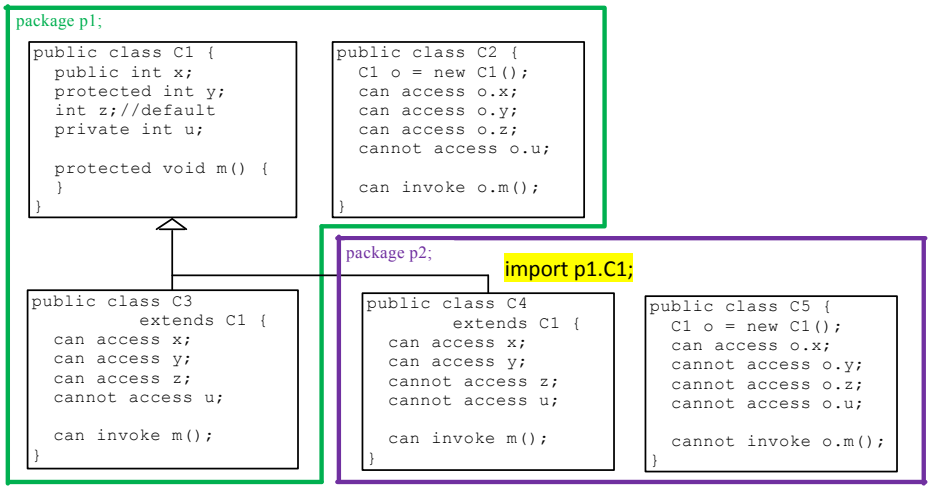
Visibility increases →

private, none (if no modifier is used), protected, public

Accessibility Summary

Modifier on members in a class	Accessed from the same class	Accessed from the same package	Accessed from a subclass	Accessed from a different package
public	✓	✓	✓	✓
protected	✓	✓	✓	–
default	✓	✓	–	–
private	✓	–	–	–

Visibility Modifiers



A Subclass Cannot Weaken the Accessibility

- A subclass may **override a protected** method in its superclass and **change its visibility (رؤيتها وليس الوصول لها) to public**.
- However, a subclass **cannot weaken the accessibility** of a method defined in the superclass.
- For example, if a method is defined as public in the superclass, it must be defined as public in the subclass.

NOTE

The modifiers (defualt,public, abstarct,final) are used on class

The modifiers (defualt,public,protected,private, abstarct,final) classes and class members (data and methods), except that the final modifier can also be used **on local variables** in a method. A final local variable is a constant inside a method.

The `final` Modifier

- The `final` class cannot be extended:

```
final class Math {
   ...
 }
```

- The `final` variable is a constant:

```
final static double PI = 3.14159;
```

- The `final` method cannot be overridden by its subclasses.