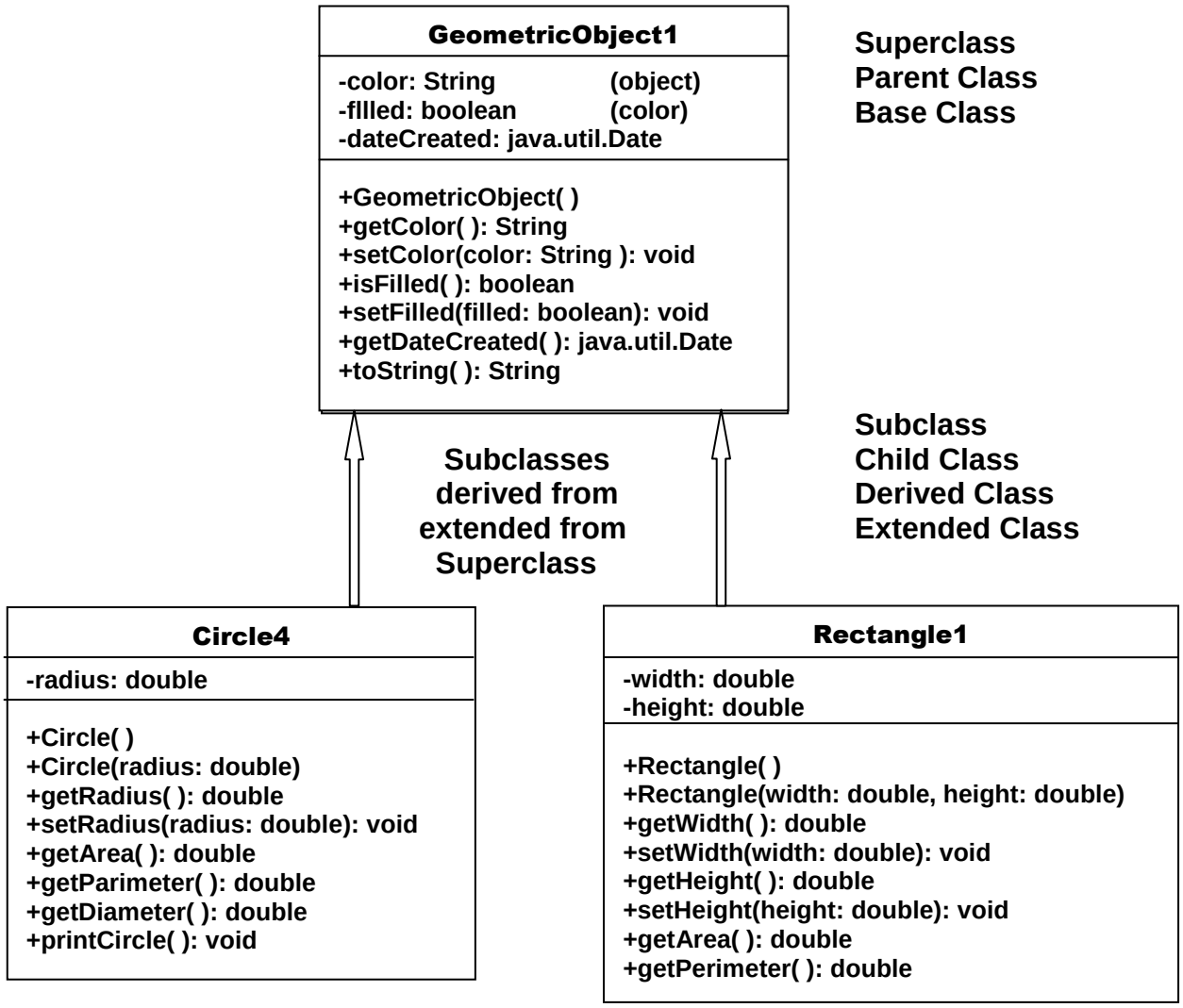
Lecture Notes
Chapter #10
Inheritance & Polymorphism

- **Inheritance – results from deriving new classes from existing classes**
- **Root Class – all java classes are derived from the java.lang.Object class**



- **A child class inherits all accessible data fields and methods from its parent class!**
- **A child class does not inherit the constructors of the parent class!**
- **The child class may also add uniquely new data fields and methods!**

1. Implementation

a. GeometricObject1.java

```
public class GeometricObject1
{
   private String color = "white";
   private boolean filled;
   private java.util.Date  dateCreated;

   public GeometricObject1( ) { dateCreated = new java.util.Date( ); }

  public String getColor( )  { return color; }

  public void setColor(String color)  { this.color = color;}

  public boolean isFilled( )  { return filled; }

  public void setFilled(boolean filled)  { this.filled = filled; }

  public java.util.Date getDateCreated( ) { return dateCreated; }

  public String toString( )  { return "created on " + dateCreated
                              + "\ncolor: " + color + " and filled: " + filled; }
}
```

b. Circle4.java

```
public class Circle4 extends GeometricObject1
{
    private double radius;

    public Circle4( ) { }
    public Circle4(double radius ) { this.radius = radius; }

   public double getRadius( ) { return radius; }
   public void setRadius( double radius) { this.radius = radius; }

   public double getArea( ) { return radius * radius * Math.PI; }
   public double getDiameter( ) { return 2 * radius; }
   public double getPerimeter( ) { return 2 * radius * Math.PI; }

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

c. Rectangle1.java

```
public class Retangle1 extends GeometricObject1
{
  private double width;
  private double height;

  public Rectangle1( ) { }
  public Rectangle1(double width, double height )
  {
     this width = width;
     this height = height;
  }

  public double getWidth( ) { return width; }
  public void setWidth(double width) { this width = width; }

  public double getHeight( ) { return height; }
  public void setHeigth(double height) { this height = height; }

  public double getArea( ) {  return width * height: }
  public double getPerimeter( ) { return 2 * (width + height); }
}
```

d. TestCircleRectangle.java

```
public class TestCircleRetangle
{
  public static void main(String[ ] args)
  {
     Circle4 circle = new Circle4(1);
     System.out.println( circle.toString( ));
     System.out.println( circle.getRadius( ));
     System.out.println(circle.getArea( ) );
     System.out.println( circle.getDiameter( ));

      Rectangle1 rectangle = new Rectangle1(2,4);
     System.out.println( rectangle.toString( ));
     System.out.println(rectangle.getArea( ) );
     System.out.println( rectangle.getPerimeter( ));
  }
}
```

See Liang page 334 for output of TestCircleRectangle.java

Remark: A subclass is NOT a subset of its superclass; in fact, since the subclass has access to more items than the superclass, an instance of the superclass can be thought of as a subset of an instance of the subclass!

Remark: Inheritance is used to model *is-a* relationships; e.g., an apple is a fruit! For a class B to extend a class A, class B should contain more detailed information than class A.
A subclass and a superclass must have an *is-a* relationship

Remark: C++ allows inheritance from multiple classes; i.e., it supports multiple inheritance.

Remark: Java does not allow inheritance from multiple classes; a Java class may inherit directly only from one superclass, i.e., the restriction is known as single inheritance. If the *extends* keyword is used to define a subclass, it allows only one parent class. Multiple inheritance in java is achieved by the use of *interfaces*.

2. Constructor Chaining

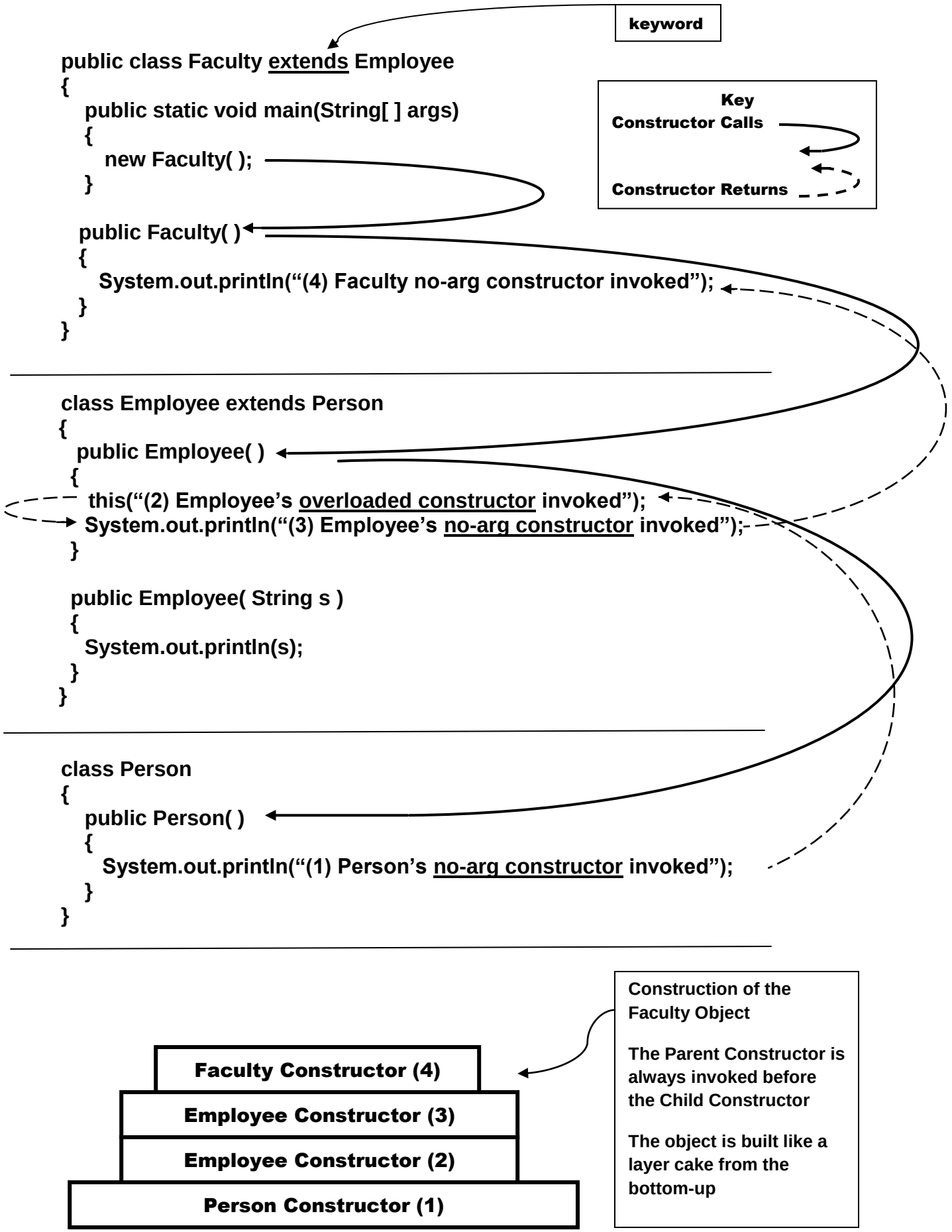
- **A child class inherits all accessible data fields and methods from its parent class, BUT the child class does not inherit the constructors of the parent class!**

- **"*this*" keyword – refers to the calling object – *self-referential***

- **"*super*" keyword – refers to the parent of the calling object – used to**

  - **call a superclass constructor**
    - **super( ) invokes the no-arg constructor of its superclass**
    - **super(argument list) invokes the superclass constructor that matches the argument list**
    - **the call for a superclass constructor must be the first statement in the subclass constructor**
    - **invoking a superclass constructor name in a subclass causes a syntax error**
    - **if a subclass does not explicitly invoke its superclass constructor, the compiler places the "super( )" statement as the first line in the subclass constructor, i.e.,**

      public A( ){ } ⟹ **public A( ){ super( ); }**


keyword
public class Faculty extends Employee
{
public static void main(String[ ] args)
{
new Faculty( );
}
public Faculty( )
{
System.out.println("(4) Faculty no-arg constructor invoked");
}
}
Key
Constructor Calls
Constructor Returns
class Employee extends Person
{
public Employee( )
{
this("(2) Employee's overloaded constructor invoked");
System.out.println("(3) Employee's no-arg constructor invoked");
}
public Employee(String s)
{
System.out.println(s);
}
}
class Person
{
public Person( )
{
System.out.println("(1) Person's no-arg constructor invoked");
}
}
Faculty Constructor (4)
Employee Constructor (3)
Employee Constructor (2)
Person Constructor (1)
Construction of the Faculty Object
The Parent Constructor is always invoked before the Child Constructor
The object is built like a layer cake from the bottom-up

```
public class Apple extends Fruit
{

}
```

```
public Apple( ){ }
```

Since the Apple class does not have any constructors, a no-arg constructor is implicitly declared.

The Apple no-arg constructor automatically invokes the Fruit no-arg constructor; but Fruit does not have a no-arg constructor. But since Fruit has an explicitly declared constructor with a parameter, i.e., **public Fruit(String name),** then the complier cannot implicitly invoke a no-arg constructor.

Hence, an Apple object cannot be created and the program cannot be compiled!

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

Best Practices

PROVIDE EVERY CLASS WITH A NO-ARG CONSTRUCTOR

SUCH A POLICY AIDS THE EXTENSION OF THE CLASS, I.E.,

IT AVOIDS THE ERROR DELINEATED ABOVE

3. Overriding Methods

- **"*super*" keyword is also used to call a superclass method**
- **subclasses inherit methods from their superclasses**
- **a subclass may modify the definition of an inherited method for use in that subclass – method overriding**

```
public class GeometricObject1
{
    private String color = "white";
    private boolean filled;
    private java.util.Date  dateCreated;
    public GeometricObject1( ) { dateCreated = new java.util.Date( ); }
    public String getColor( )  { return color; }
    public void setColor(String color)  { this.color = color;}
    public boolean isFilled( )  { return filled; }
    public void setFilled(boolean filled)  { this.filled = filled; }
    public java.util.Date getDateCreated( ) { return dateCreated; }
    public String toString( )
    {
       return "created on " + dateCreated
                        + "\ncolor: " + color + " and filled: " + filled;
    }
 }
```

The Circle4 toString( ) method overrides the GeometricObject1 toString( ) method ; it invokes the GeometricObject1 toString( ) method and then modifies it to specify information specific to the circle4 object.

```
public class Circle4 extends GeometricObject1
{
   private double radius;
   public Circle4( ) { }
   public Circle4(double radius ) { this.radius = radius; }
   public double getRadius( ) { return radius; }
   public void setRadius( double radius) { this.radius = radius; }

   public double getArea( ) { return radius * radius * Math.PI; }
   public double getDiameter( ) { return 2 * radius; }
   public double getPerimeter( ) { return 2 * radius * Math.PI; }

   public void printCircle( )
   {
     System.out.println("The circle is created " + getDateCreated( ) +
                    " and the radius is " + radius);
   }
   public String toString( )
   {
      return super.toString( ) + "\nradius is " + radius;
   }

}
```

a. **Rules for Overridding Inherited Methods**

- **private data fields in a superclass are not accessible outside of that class, hence they cannot be used directly by a subclass; they can be accessed &/or mutated by public accessor &/or mutators defined in the superclass**
- **an instance method can be overridden only if it is accessible; private methods cannot be overridden**
- **if a method defined in a subclass is private in its superclass, the two methods are completely unrelated**
- **a static method can be inherited, but a static method cannot be overridden remember that static methods are class methods**
- **if a static method defined in a superclass is redefined in a subclass, the method defined in the superclass is hidden; the hidden static method can be invoked by using the syntax "SuperClassName.staticMethodName( );"**

b. **Overriding versus Overloading**

i. **Overloading – same name, different signitures**

ii. **Overriding – method defined in the superclass, overridden in a subclass using the same name, same signature, and same return type as defined in the superclass**

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

class B
{
  public void p(int i){ }
}

class A extends B
{
  public void p(int i)
  {
    System.out.println(i);
  }
}
```

a.p(10) invokes class A method; hence prints 10

overrides

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

class B
{
  public void p(int i){ }
}

class A extends B
{
  public void p(double i)
  {
    System.out.println(i);
  }
}
```

a.p(10) invokes class B method; hence prints nothing

overloads

4. **Object** Class & Methods

- **Every class in Java is descended from java.lang.Object**

- **If no inheritance is declared when a class is defined, the class is a subclass of Object by default**

- **public String toString( );**
  returns a string consisting of the objects name, the @ sign, and the objects memory address in hexadecimal, e.g., student@B7F9A1

  - **Override the toString( ) method to produce relevant information concerning the subclass objects**

  - **System.out.println(student); ➔ System.out.println(student.toString( ));**

- **public boolean equals(Object obj) { return (this == obj); }**
  default implementation tests whether two reference variables point to the same object

  Invoked by the statement object1.equals(object2);

  - **Override the equals( ) method to test whether two distinct objects have the same content, e.g.,**

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

INSTANCEOF OPERATOR

o instanceof Circle
returns true if o is an instance of Circle

Do not use (Circle o) as the argument when overriding the equals( ) method, i.e., do not use the signature
public boolean equals(Circle o)
see page 355 #10.12

- **Comparison Operators/Methods**

  - **"==" operator is used to compare primitive data type values**

  - **"==" operator is also used to compare whether two reference variables refer to the same object (where arrays may be considered to be objects)**

  - **The modified "equals( )" method can be used to determine whether two objects have the same contents**

  - **The "equals( )" method can be modified to test the contents of all or a selected subset of the data fields in the class**

5. Polymorphism, Dynamic & Genetic Programming

- **a class defines a type**
- **a type defined by a subclass is a subtype**
- **a type defined by a superclass is a supertype**

- **a variable must be declared to be of a specific type**
- **the type of a variable called it's declared type**
- **a variable of a reference type can hold a null value or a reference to an object**

- **an object is an instance of a class**
- **a subclass is a specialization of its superclass**

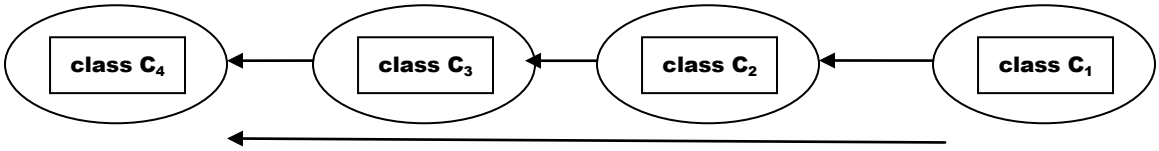
- **every instance of a subclass is an instance of its superclass**
  - **every circle is an object**

- **an instance of a superclass is not an instance of a subclass**
  - **not every object is a circle**

- **an instance of a subclass can be passed to a parameter of its superclass, i.e., a Circle object can be passed to a GeometricObject class prarameter**

- **polymorphism – an object of a subtype can be used whenever its superclass object is required; i.e., a variable of a supertype can refer to a subtype object**

- **dynamic binding – given an inheritance chain as follows,**



and the object C_1 **o** = new C_1( );

if the object o were to invoke a method, i.e., o.p( ); then the JVM searches for the method p( ) in the classes in the order C_1, C_2, C_3, C_4, java.lang.Object

once an implementation of p( ) is found, the search stops and that implementation of p( ) is invoked

```
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"; }
```

The call for the execution of the method **m(new GraduateStudent( ));** results in a the invocation of the **toString( )** method; the JVM starts a search of the inheritance chain starting with the GraduateStudent class for an implementation of the toString( ) method.

The Student class yields such an implementation which results in the output of the string "Student".

The call for the execution of the method **m(new Student( ));** results in the invocation of its **toString( )** method and the output of the second string "Student".

The call for the execution of the method **m(new Person( ));** results in the invocation of its **toString( )** method and the output of the string "Person".

The call for the execution of the method **m(new Object( ));** results in the invocation of the java.lang.Object's **toString( )** method and the output of a string similar to "java.lang.object@AD23F5".

A reference variable's declared type determines which method is matched at compile time; i.e., the compiler uses the parameter type, the number & order of parameters to determine the matching method.

For a method defined in several subclasses, the JVM dynamically binds the implementation of a method at runtime decided by the actual class of the object referenced by the variable.

Recall that polymorphism refers to the use a variable of a supertype to refer to an object of a subtype; the implementation is known as generic programming.

If a methods parameter type is a superclass, then an object of any of the subclasses may be passed to the method via that parameter type.

6. Casting Objects & the instanceof Operator

a. Implicit Casting

```
Object o = new Student( );        equivalent statements        m( new Student( ));
m( o );
```

An instance of Student is automatically an instance of Object

b. Explicit Casting

Student b = o; ➔ compilation error !

An instance of Object is not necessarily an instance of Student

```
Student b = (Student) o;
```

c. Up Casting

Casting an instance of a subclass to a variable of a superclass is always possible; implicit casting may be used.

d. Down Casting

Casting an instance of a superclass to a variable of a subclass: must use explicit casting & object cast must be an instance of the subclass

error message ClassCastException

e. instanceof Operator

```
Object o = new Circle( );
if( o instanceof Circle )
{
    double d = ((Circle) o ).getDiameter( ));
}
```

The declared type determines which method to match at compile time; "o.getDiameter( );" would cause a compile error since Object does not contain a "getDiameter( )" method.

To enable Generic Programming, declare variables with their supertype; thus they can accept a value of any type.

f. TestPolymorphismCasting.java

```
public class TestPolymorphismCasting
{
   public static void main(String [ ] args)
   {
      Object o1 = new Circle4( 1 );
      Object o2 = new Rectangle1(1, 1);
      displayObject(o1);
      displayObject(o2);
   }
   public static void displayObject(Object o)
   {
      if (o instanceof Circle4)
      {
         System.out.println(((Circle4) o ).getArea( ));
         System.out.println(((Circle4) o ).getDiameter( ));
      }
      else if (o instanceof Rectangle1)
         System.out.println(((Rectangle1) o ).getArea( ));
    }
}
```

Generic Programming

7. ArrayList Class JDK 1.2

Java.util.ArrayList
+ArrayList( )
+add(o:Object): void
+add(index: int, o: Object): void
+clear( ): void
+contains(o: Object): boolean
+get(index: int): Object
+indexOf(o: Object): int
+isEmpty( ): boolean
+lastIndexOf(o: Object): int
+remove(o: Object): boolean
+remove(index: int): boolean
+size( ): int
+set(index: int, o: Object): Object

See Liang page 347-348 for

- **program using ArrayList**
- **list of differences & similarities between ArrayList operations and Array operations**
- **Arrays are fixed in size at creation**
- **ArrayLists are extensible at any time**

8. Vector Class JDK 1.1

Similar to Arraylist; it is used to store objects.
Deprecated by Arraylist in JDK 1.2

9. Composition Construction

a. Inheritance models is-a relationships

b. Composition models has-a relationships

```
public class MyStack
{
   private java.util.ArrayList list = new java.util.ArrayList( );

   public boolean isEmpty( )
   {
      return list.isEmpty( );
   }

   public int getSize( )
   {
      return list.size( );
   }

   public Object peek( )
   {
      return list.get(getSize( ) – 1);
   }

   public Object pop( )
   {
      Object o = list.get(getSize( ) – 1);
      list.remove(getSize( ) - 1);
     return o;
   }

   public Object push( Object o )
   {
     list.add( o );
      return o;
   }

   public int Search( Object o )
   {
      return list.lastIndexOf(o);
   }

  public String toString( )
  {
     Return “Stack: “ + list.toString( );
  }
}
```

MyStack
-- list: ArrayList
+ isEmpty( ): boolean +getSize( ): int +peek( ): Object + pop( ): Object + push(o: Object): Object +search(o: Object): int

Returns the index of the first-matching element in the stack by invoking the list.lastIndexOf(o) method since the top of the stack is the last element in the list; i.e., the end of the list is the top of the stack.

The **(String)toString method** returns a string representation of all of the elements in the ArrayList object

10. **protected** Data & Methods

a. **A protected data item or protected method in a public class can be accessed by any class in the same package or by its subclasses even if the subclasses are in different packages.**

b. **Visibility / Accessibility Modifiers**

Private None Protected Public

Visibility Increases

Modifiers 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	☒	☒	☒	
None (default)	☒	☒		
Private	☒			

Private Modifier

Hide members so that they cannot be accessed outside of the class
i.e., the members are not intended for use outside of the class
Used only for members of the class

No Modifier

Allow members of the class to be accessed directly from any class within the same package but not from other packages
Can be used on the class as well as the members of the class

Protected Modifier

Enable members to be accessed by the subclasses in any package or classes in the same package, i.e., members of the class are intended for extenders of the class but not for users of the class
Used only for members of the class

Public Modifier

Enable members of the class to be accessed by any class, i.e., members of the class are intended for users of the class
Can be used on the class as well as the members of the class

A subclass may override a method from a superclass and increase its visibility in the subclass; but it may not restrict the methods visibility, e.g., if a method is defined to be public in the superclass, it cannot be changed to protected, none (default) nor private in the subclass!

Preventing Extending & Overriding

```
public final class C
{
    …
}
```

Class C cannot be extended

```
public class Test
{
   public final void m( )
   {
      …
   }
}
```

Method m( ) cannot be extended