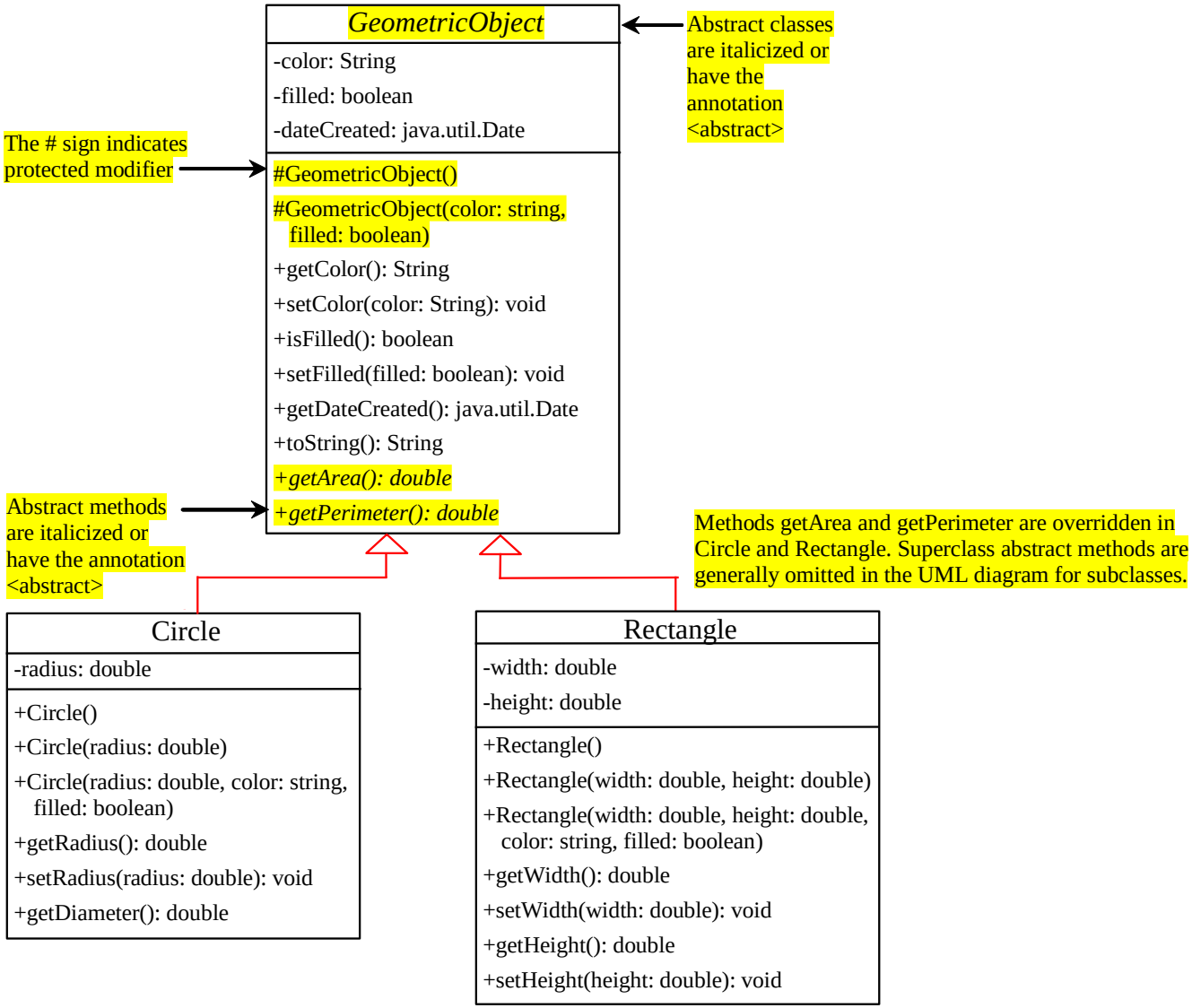
Abstract Classes and Interfaces

CSE 114, Computer Science 1

Stony Brook University

http://www.cs.stonybrook.edu/~cse114

Abstract Classes and Abstract Methods



```
public abstract class GeometricObject {
  private String color = "white";
  private boolean filled;
  private java.util.Date dateCreated;
  protected GeometricObject() {
    dateCreated = new java.util.Date();
  }
  protected GeometricObject(String color, boolean filled) {
    dateCreated = new java.util.Date();
    this.color = color;
    this.filled = filled;
  }
  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;
  }
  /** Abstract method getArea */
  public abstract double getArea();
  /** Abstract method getPerimeter */
  public abstract double getPerimeter();
}
```

```
public class Circle extends GeometricObject {
  private double radius;
  public Circle() {   }
  public Circle(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;
  }
  /* Print the circle info */
  public void printCircle() {
    System.out.println("The circle is created " + getDateCreated() +
      " and the radius is " + radius);
  }
}
```

```
public class Rectangle extends GeometricObject {
  private double width;
  private double height;
  public Rectangle() {  }
  public Rectangle(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 setHeight(double height) {    this.height = height;  }

  public double getArea() {
    return width * height;
  }

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

```
public class TestGeometricObject {
  public static void main(String[] args) {
    // Declare and initialize two geometric objects
    GeometricObject geoObject1 = new Circle(5);
    GeometricObject geoObject2 = new Rectangle(5, 3);
    System.out.println("The two objects have the same area? " +
      equalArea(geoObject1, geoObject2));
    // Display circle
    displayGeometricObject(geoObject1);
    // Display rectangle
    displayGeometricObject(geoObject2);
  }

  /** A method for comparing the areas of two geometric objects */
  public static boolean equalArea(GeometricObject object1,
      GeometricObject object2) {
    return object1.getArea() == object2.getArea();
  }

  /** A method for displaying a geometric object */
  public static void displayGeometricObject(GeometricObject object) {
    System.out.println();
    System.out.println("The area is " + object.getArea());
    System.out.println("The perimeter is " + object.getPerimeter());
  }
}
```

abstract method in *abstract* class

- An abstract method cannot be contained in a nonabstract class.
- In a nonabstract subclass extended from an abstract class, all the abstract methods must be implemented, even if they are not used in the subclass.
- If a subclass of an abstract superclass does not implement all the abstract methods, the subclass must be defined abstract.

abstract classes

- An object cannot be created from abstract class
  - An abstract class cannot be instantiated using the new operator
  - We can still define its constructors, which are invoked in the constructors of its subclasses.
    - For instance, the constructors of GeometricObject are invoked in the Circle class and the Rectangle class.

abstract classes

- A class that contains abstract methods must be abstract
- An abstract class without abstract method:
  - It is possible to define an abstract class that contains no abstract methods.
  - We cannot create instances of the class using the new operator.
  - **This class is used as a base class for defining new subclasses**

abstract classes

- A subclass can be abstract even if its superclass is concrete.
  - For example, the Object class is concrete, but a subclass, GeometricObject, is abstract

abstract classes

- A subclass can override a method from its superclass to define it abstract
  - rare, but useful when the implementation of the method in the superclass becomes invalid in the subclass.
  - the subclass must be defined abstract

abstract classes as types

- You cannot create an instance from an abstract class using the new operator, but an abstract class can be used as a data type:

```
GeometricObject c = new Circle(2);
```

  - The following statement, which creates an array whose elements are of GeometricObject type, is correct

```
GeometricObject[] geo=new GeometricObject[10];
```

    - There are only **null** elements in the array!!!

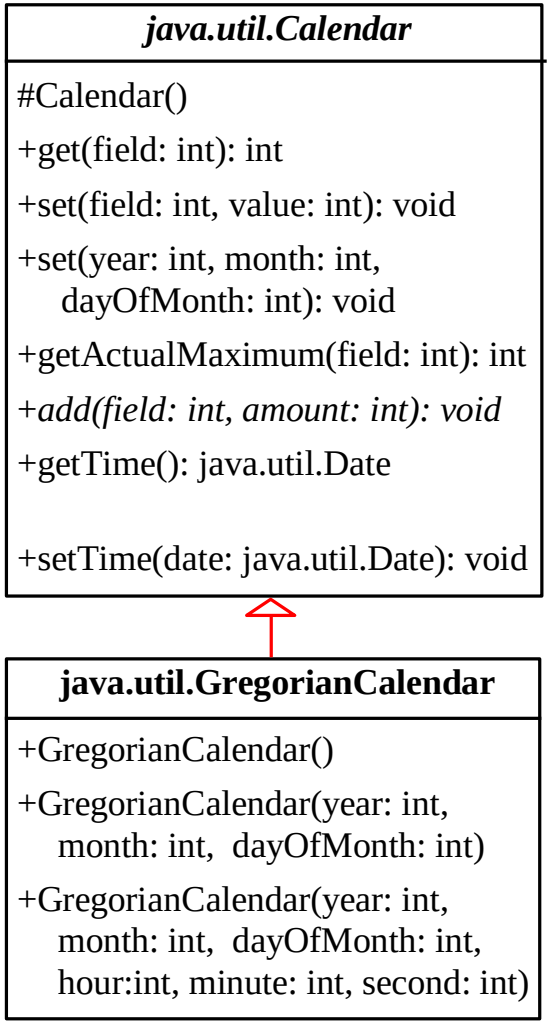
The *abstract* Calendar class and its GregorianCalendar subclass

- An instance of java.util.Date represents a specific instant in time with millisecond precision
- java.util.Calendar is an abstract base class for extracting detailed information such as year, month, date, hour, minute and second from a Date object for a specific calendar
  - Subclasses of Calendar can implement specific calendar systems such as Gregorian calendar, Lunar Calendar and Jewish calendar.
    - java.util.GregorianCalendar is for the Gregorian calendar

The GregorianCalendar Class

- Java API for the GregorianCalendar class: http://docs.oracle.com/javase/8/docs/api/java/util/GregorianCalendar.html
- new GregorianCalendar() constructs a default GregorianCalendar with the current time
- new GregorianCalendar(year, month, date) constructs a GregorianCalendar with the specified year, month, and date
  - The month parameter is 0-based, i.e., 0 is for January.

The *abstract* Calendar class and its GregorianCalendar subclass



Constructs a default calendar.

Returns the value of the given calendar field.

Sets the given calendar to the specified value.

Sets the calendar with the specified year, month, and date. The month parameter is 0-based, that is, 0 is for January.

Returns the maximum value that the specified calendar field could have.

Adds or subtracts the specified amount of time to the given calendar field.

Returns a Date object representing this calendar's time value (million second offset from the Unix epoch).

Sets this calendar's time with the given Date object.

Constructs a GregorianCalendar for the current time.

Constructs a GregorianCalendar for the specified year, month, and day of month.

Constructs a GregorianCalendar for the specified year, month, day of month, hour, minute, and second. The month parameter is 0-based, that is, 0 is for January.

The get Method in Calendar Class

- The get(int field) method defined in the Calendar class is useful to extract the date and time information from a Calendar object.
- The fields are defined as constants, as shown in the following.

Constant	Description
YEAR	The year of the calendar.
MONTH	The month of the calendar with 0 for January.
DATE	The day of the calendar.
HOUR	The hour of the calendar (12-hour notation).
HOUR_OF_DAY	The hour of the calendar (24-hour notation).
MINUTE	The minute of the calendar.
SECOND	The second of the calendar.
DAY_OF_WEEK	The day number within the week with 1 for Sunday.
DAY_OF_MONTH	Same as DATE.
DAY_OF_YEAR	The day number in the year with 1 for the first day of the year.
WEEK_OF_MONTH	The week number within the month.
WEEK_OF_YEAR	The week number within the year.
AM_PM	Indicator for AM or PM (0 for AM and 1 for PM).

```
import java.util.*;
public class TestCalendar {
  public static void main(String[] args) {
    // Construct a Gregorian calendar for the current date and time
    Calendar calendar = new GregorianCalendar();
    System.out.println("Current time is " + new Date());
    System.out.println("YEAR:\t" + calendar.get(Calendar.YEAR));
    System.out.println("MONTH:\t" + calendar.get(Calendar.MONTH));
    System.out.println("DATE:\t" + calendar.get(Calendar.DATE));
    System.out.println("HOUR:\t" + calendar.get(Calendar.HOUR));
    System.out.println("HOUR_OF_DAY:\t" + calendar.get(Calendar.HOUR_OF_DAY));
    System.out.println("MINUTE:\t" + calendar.get(Calendar.MINUTE));
    System.out.println("SECOND:\t" + calendar.get(Calendar.SECOND));
    System.out.println("DAY_OF_WEEK:\t" + calendar.get(Calendar.DAY_OF_WEEK));
    System.out.println("DAY_OF_MONTH:\t" + calendar.get(Calendar.DAY_OF_MONTH));
    System.out.println("DAY_OF_YEAR: " + calendar.get(Calendar.DAY_OF_YEAR));
    System.out.println("WEEK_OF_MONTH: " + calendar.get(Calendar.WEEK_OF_MONTH));
    System.out.println("WEEK_OF_YEAR: " + calendar.get(Calendar.WEEK_OF_YEAR));
    System.out.println("AM_PM: " + calendar.get(Calendar.AM_PM));
    // Construct a calendar for January 1, 2020
    Calendar calendar1 = new GregorianCalendar(2020, 0, 1);
    System.out.println("January 1, 2020 is a " +
        dayNameOfWeek(calendar1.get(Calendar.DAY_OF_WEEK)) );
  }
  public static String dayNameOfWeek(int dayOfWeek) {
    switch (dayOfWeek) {
      case 1: return "Sunday"; case 2: return "Monday"; case 3: return "Tuesday";
      ... case 7: return "Saturday";
      default: return null;
    }}}
```

Interfaces

- What is an interface?
  - An interface is a class-like construct that contains only constants and abstract methods.
- Why is an interface useful?
  - An interface is similar to an abstract class, but the intent of an interface is to specify behavior for objects.
    - For example: specify that the objects are comparable, edible, cloneable, …
  - Allows multiple inheritance.

Define an Interface

- Declaration:

```
public interface InterfaceName {
   // constant declarations;
   // method signatures;
}
```

- Example:

```
public interface Edible {
   /** Describe how to eat */
   public abstract String howToEat();
}
```

Interface is a Special Class

- An interface is treated like a special class in Java:
  - Each interface is compiled into a separate bytecode file, just like a regular class.
  - Like an abstract class, you cannot create an instance from an interface using the new operator
  - Uses:
    - as a data type for a variable
    - as the result of casting

Interface Example

- The Edible interface specifies whether an object is edible

```
public interface Edible {
      public abstract String howToEat();
}
```

- The class Chicken implements the Edible interface:

```
class Chicken extends Animal implements Edible {
  public String howToEat() {
    return "Chicken: Fry it";
  }
}
```

```
interface Edible {
  public abstract String howToEat(); /** Describe how to eat */
}
class Animal { }
class Chicken extends Animal implements Edible {
  public String howToEat() {
    return "Chicken: Fry it";
  }
}
class Tiger extends Animal {  /** Does not implement Edible */
}
abstract class Fruit implements Edible { }
class Apple extends Fruit {
  public String howToEat() {
    return "Apple: Make apple cider";
  }
}
class Orange extends Fruit {
  public String howToEat() {
    return "Orange: Make orange juice";
  }
}
public class TestEdible {
  public static void main(String[] args) {
    Object[] objects = {new Tiger(), new Chicken(), new Apple()};
    for (int i = 0; i < objects.length; i++)
      if (objects[i] instanceof Edible)
        System.out.println(((Edible)objects[i]).howToEat());
  }
}
```

Omitting Modifiers in Interfaces

- All data fields are *public static final* in an interface
- All methods are *public abstract* in an interface
- These modifiers can be omitted:

```
public interface T1 {
  public static final int K = 1;

  public abstract void p();
}
```

Equivalent

```
public interface T1 {
  int K = 1;

  void p();
}
```

- A constant defined in an interface can be accessed using InterfaceName.CONSTANT_NAME, for example: T1.K

Example: The Comparable Interface

```
// This interface is defined in
// the java.lang package

package java.lang;
public interface Comparable {
      int compareTo(Object o);
}
```

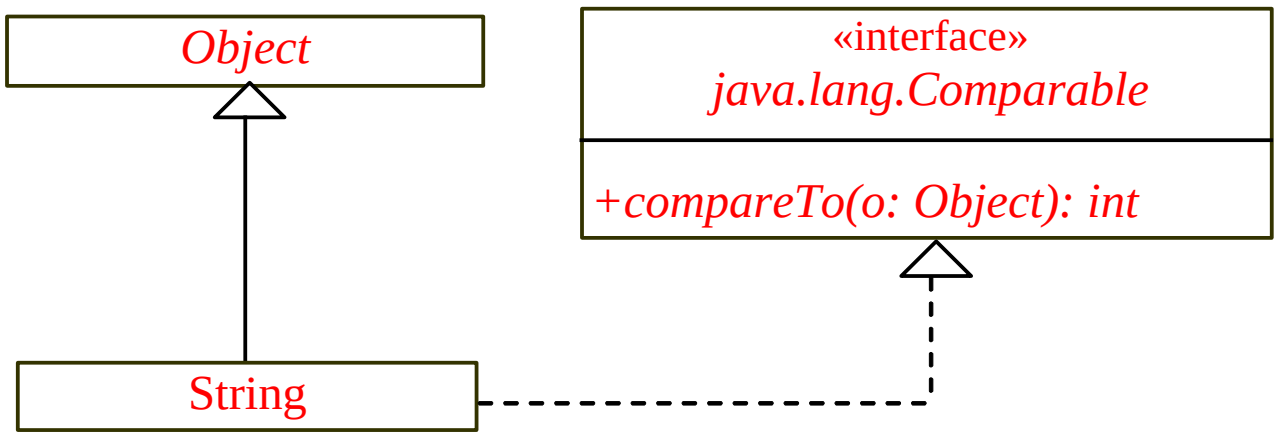
String and Date Classes

- Many classes (e.g., String and Date) in the Java library implement Comparable to define a natural order for the objects

```
public class String extends Object
    implements Comparable {
  // class body omitted
}
```

```
public class Date extends Object
    implements Comparable {
  // class body omitted
}
```

```
new String() instanceof String                    true
new String() instanceof Comparable                true
new java.util.Date() instanceof java.util.Date    true
new java.util.Date() instanceof Comparable        true
```



In UML, the interface and the methods are italicized

dashed lines and triangles are used to point to the interface

Generic `max` Method

```
// Max.java: Find a maximum object
public class Max {
  /** Return the maximum of two objects */
  public static Comparable max
      (Comparable o1, Comparable o2) {
    if (o1.compareTo(o2) > 0)
      return o1;
    else
      return o2;
  }
}
```

(a)

```
// Max.java: Find a maximum object
public class Max {
  /** Return the maximum of two objects */
  public static Object max
      (Object o1, Object o2) {
    if ((Comparable)o1).compareTo(o2) > 0)
      return o1;
    else
      return o2;
  }
}
```

(b)

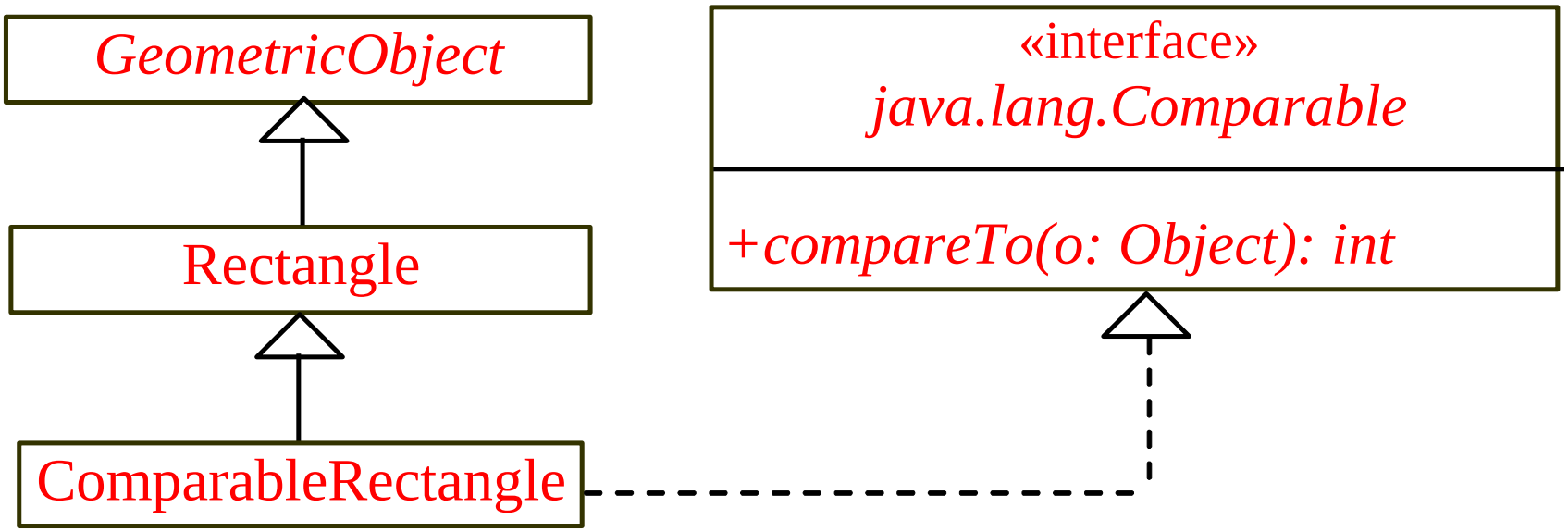
```
String s1 = "abcdef";
String s2 = "abcdee";
String s3 = (String)Max.max(s1, s2);
```

```
Date d1 = new Date();
Date d2 = new Date();
Date d3 = (Date)Max.max(d1, d2);
```

The return value from the max method is of the Comparable type. So, we need to cast it to String or Date explicitly.

Defining Classes to Implement Comparable

- We cannot use the max method to find the larger of two instances of Rectangle, because Rectangle does not implement Comparable
- We can define a new rectangle class ComparableRectangle that implements Comparable: the instances of this new class are comparable



```
public class ComparableRectangle extends Rectangle
    implements Comparable {
  /** Construct a ComparableRectangle with specified properties */
  public ComparableRectangle(double width, double height) {
    super(width, height);
  }

  /** Implement the compareTo method defined in Comparable */
  public int compareTo(Object o) {
    if (getArea() > ((ComparableRectangle)o).getArea())
      return 1;
    else if (getArea() < ((ComparableRectangle)o).getArea())
      return -1;
    else
      return 0;
  }

  public static void main(String[] args) {
    ComparableRectangle rectangle1 = new ComparableRectangle(4, 5);
    ComparableRectangle rectangle2 = new ComparableRectangle(3, 6);
    System.out.println(Max.max(rectangle1, rectangle2));
  }
}
```

The `Cloneable` Interface

- Marker Interface: an empty interface
  - Does not contain constants or methods
  - It is used to denote that a class possesses certain desirable properties
- A class that implements the Cloneable interface is marked cloneable: its objects can be cloned using the clone() method defined in the Object class

```
package java.lang;
public interface Cloneable {
}
```

The `Cloneable` Interface

- Calendar (in the Java library) implements Cloneable:

```
Calendar calendar = new GregorianCalendar(2020, 1, 1);
Calendar calendarCopy = (Calendar)(calendar.clone());
System.out.println("calendar == calendarCopy is "
  +(calendar == calendarCopy));
```

Displays:

```
calendar == calendarCopy is false
```

```
System.out.println("calendar.equals(calendarCopy) is "
  + calendar.equals(calendarCopy));
```

Displays:

```
calendar.equals(calendarCopy) is true
```

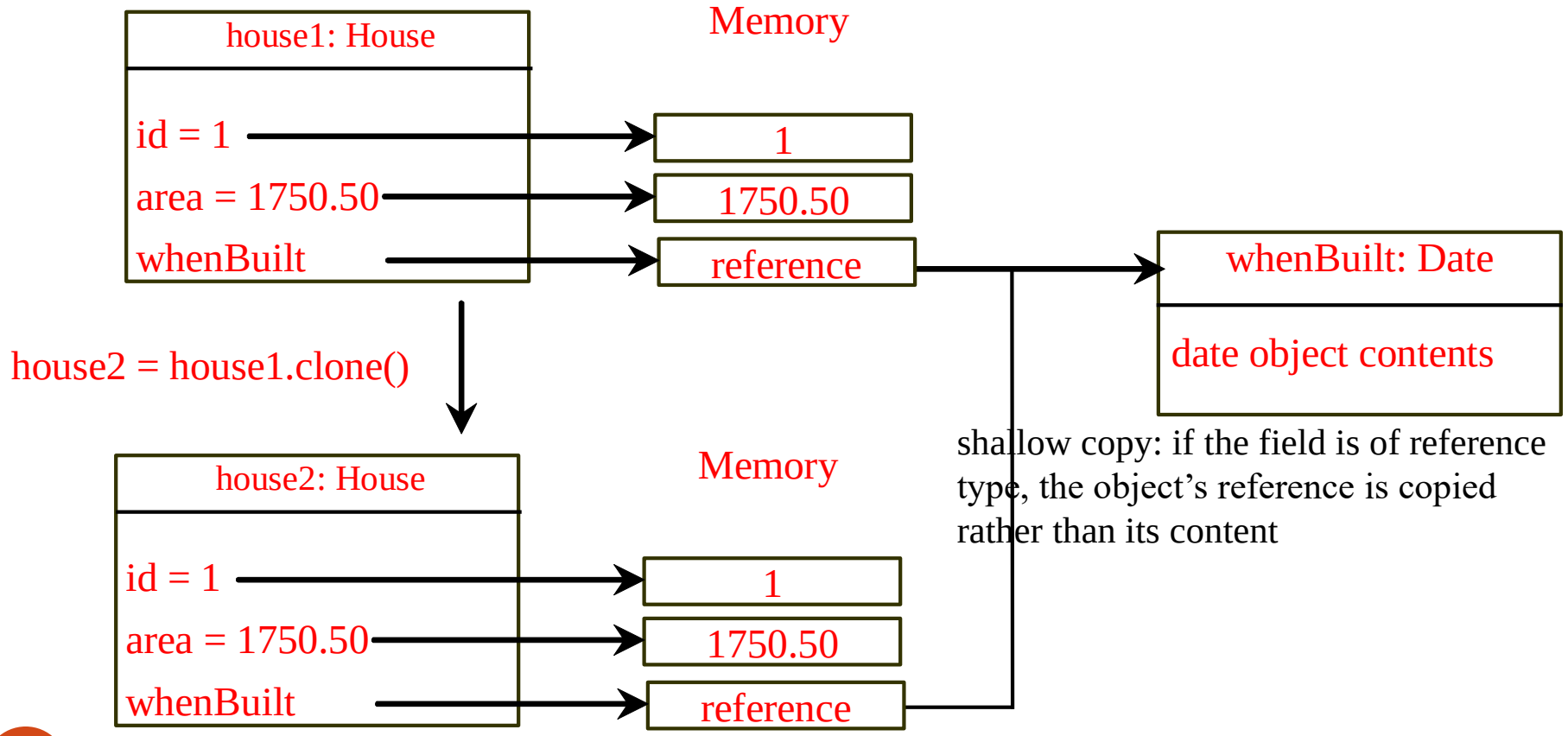
Implementing the `Cloneable` Interface

- If we try to create a clone of an object instance of a class that does not implement the **`Cloneable`** interface, it throws **`CloneNotSupportedException`**
- We can override the **`clone`**() method from the **`Object`** class to create custom clones
  - The **`clone`** method in the **`Object`** class creates a new instance of the class of this object and initializes all its fields with exactly the contents of the corresponding fields of this object, as if by assignment; the contents of the fields are not themselves cloned.
- The **`clone`**() method returns an **`Object`** that needs to be casted

```
public class House implements Cloneable, Comparable {
  private int id;
  private double area;
  private java.util.Date whenBuilt;
  public House(int id, double area) {this.id = id; this.area = area;
    whenBuilt = new java.util.Date();}
  public double getId() { return id;}
  public double getArea() { return area;}
  public java.util.Date getWhenBuilt() { return whenBuilt;}
  /** Override the protected clone method defined in the Object
    class, and strengthen its accessibility */
  public Object clone() {
    try {
      return super.clone();
    }catch (CloneNotSupportedException ex) {
      return null;
    }
  }
  /** Implement the compareTo method defined in Comparable */
  public int compareTo(Object o) {
    if (area > ((House)o).area)
      return 1;
    else if (area < ((House)o).area)
      return -1;
    else
      return 0;
  }}
```

Shallow vs. Deep Copy

- House house1 = new House(1, 1750.50);
- House house2 = (House)(house1.clone());



For deep copying, we can override the clone method with custom object creation

```
public class House implements Cloneable {
   ...
   public Object clone() { // deep copy
     try {
       House h =  (House)(super.clone());
       h.whenBuilt = (Date)(whenBuilt.clone());
       return h;
     }catch (CloneNotSupportedException ex) {
       return null;
     }
   }
   ...
}
```

Interfaces vs. Abstract Classes

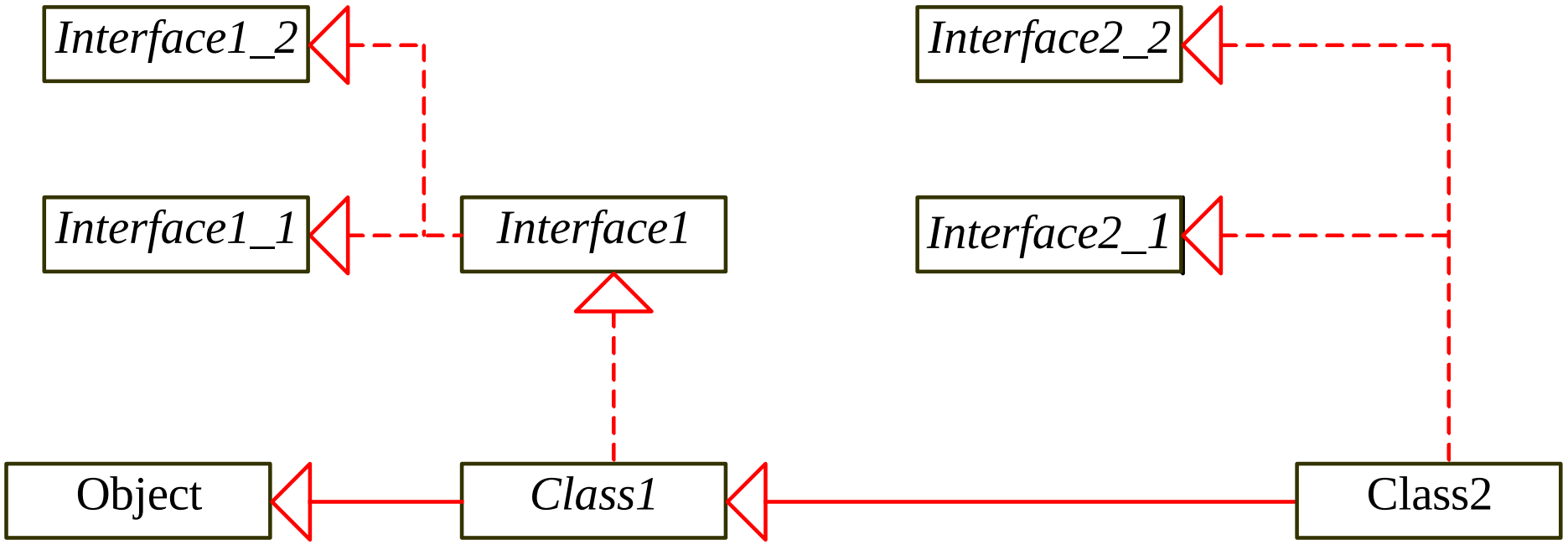
- In an interface, the data must be constants; an abstract class can have all types of data

- Each method in an interface has only a signature without implementation; an abstract class can have concrete methods

	Variables	Constructors	Methods
Abstract class	**No restrictions**	**Constructors are invoked by subclasses through constructor chaining. An abstract class cannot be instantiated using the new operator.**	**No restrictions.**
Interface	**All variables must be public static final**	**No constructors. An interface cannot be instantiated using the new operator.**	**All methods must be public abstract methods**

Interfaces vs. Abstract Classes

- A class can implement any number of interfaces
- An interface can extend another interface
- There is no root for interfaces



Caution: conflicting interfaces

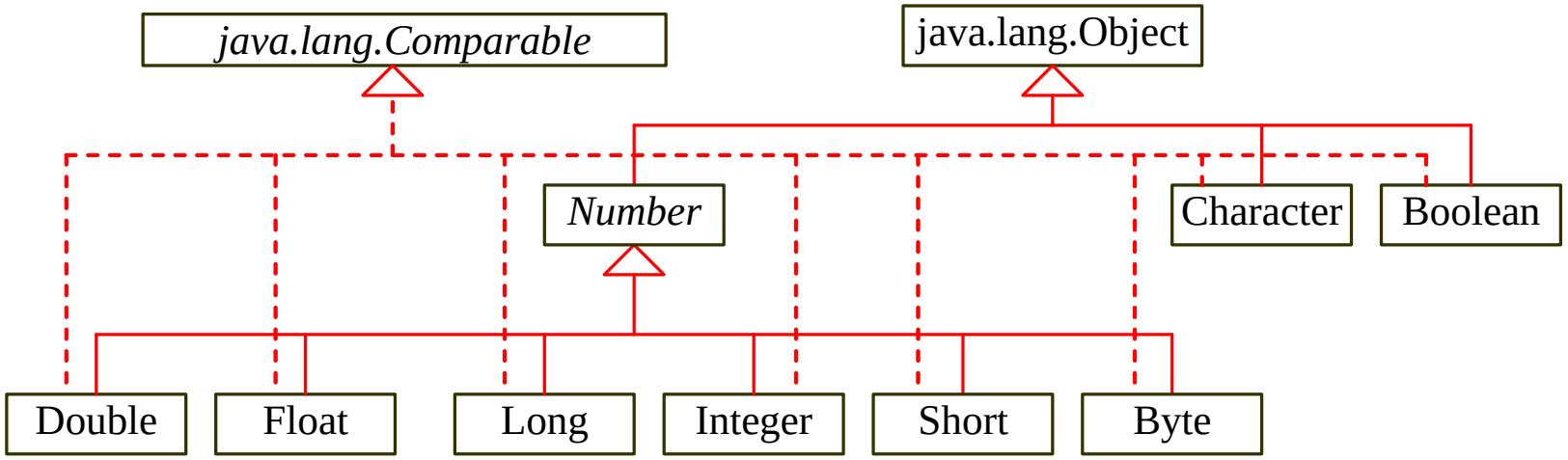
- Errors detected by the compiler:
  - If a class implements two interfaces with conflict information:
    - two same constants with different values, or
    - two methods with same signature but different return type

Whether to use an interface or a class?

- Strong is-a: a relationship that clearly describes a parent-child relationship - should be modeled using classes and class inheritance
  - For example: a staff member is a person
- Weak is-a (is-kind-of): indicates that an object possesses a certain property - should be modeled using interfaces
  - For example: all strings are comparable, so the String class implements the Comparable interface
- You can also use interfaces to circumvent single inheritance restriction if multiple inheritance is desired

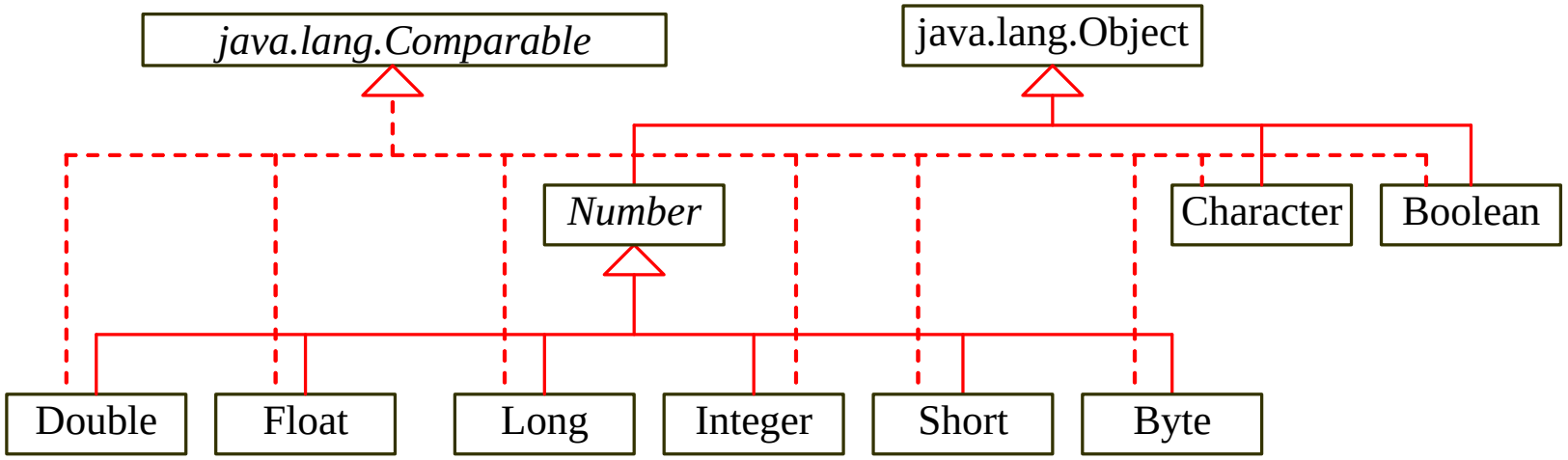
Wrapper Classes

- Primitive data types in Java ➔ **Better performance**
- Each primitive has a wrapper class: Boolean, Character, Short, Byte, Integer, Long, Float, Double
  - The wrapper classes do not have no-arg constructors
  - The instances of all wrapper classes are immutable: their internal values cannot be changed once the objects are created



Wrapper Classes

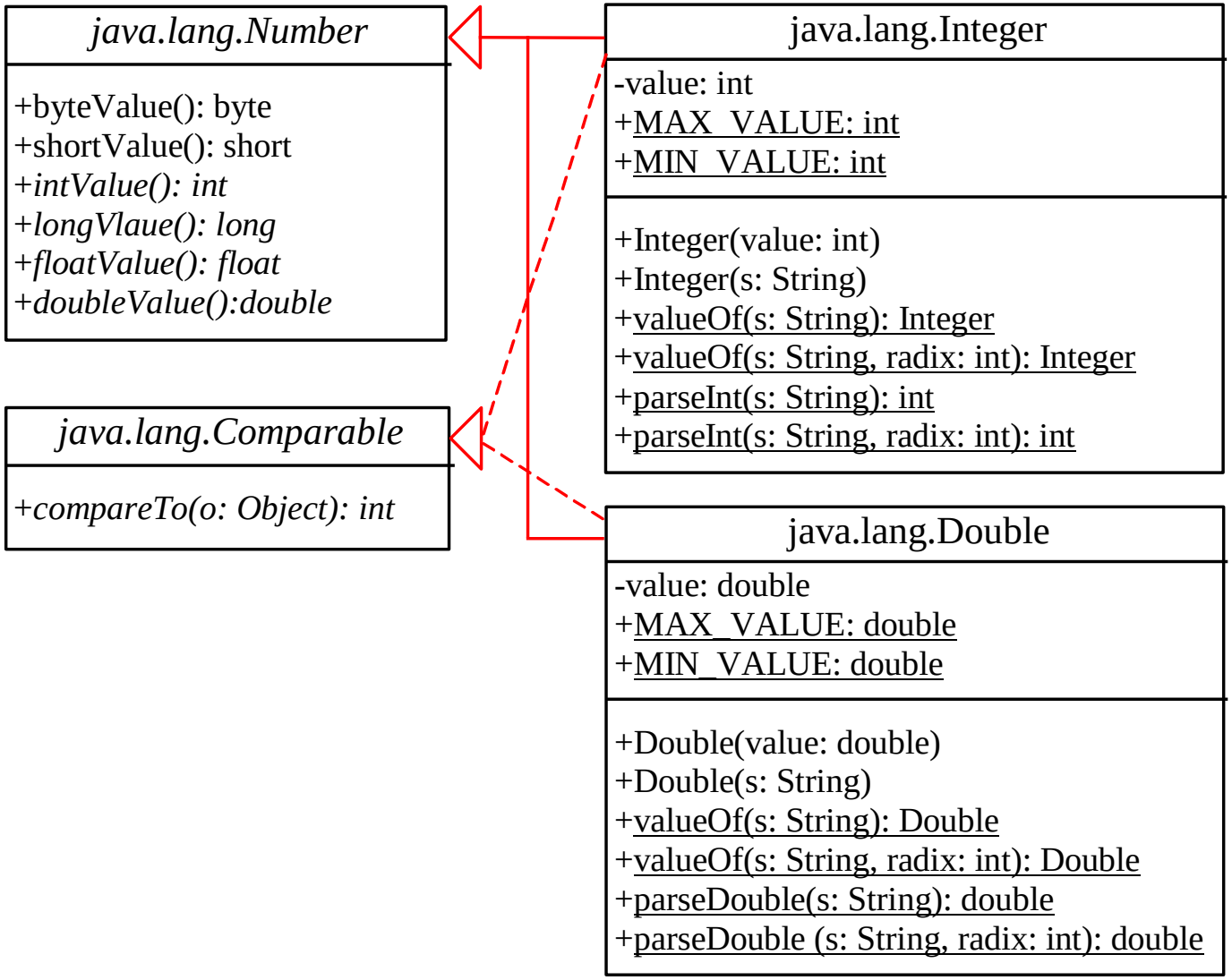
- Each wrapper class overrides the toString, equals, and hashCode methods defined in the Object class
- Since these classes implement the Comparable interface, the compareTo method is implemented in these classes



The Number Class

- Each numeric wrapper class extends the abstract Number class:
  - The abstract Number class contains the methods doubleValue, floatValue, intValue, longValue, shortValue, and byteValue to "convert" objects into primitive type values
  - The methods doubleValue, floatValue, intValue, longValue are abstract
  - The methods byteValue and shortValue are not abstract, which simply return (byte)intValue() and (short)intValue(), respectively
  - Each numeric wrapper class implements the abstract methods doubleValue, floatValue, intValue and longValue

The Integer and Double Classes



Wrapper Classes

- You can construct a wrapper object either from a primitive data type value or from a string representing the numeric value

- The constructors for Integer and Double are:

```
public Integer(int value)

public Integer(String s)

public Double(double value)

public Double(String s)
```

Numeric Wrapper Class Constants

- Each numerical wrapper class has the constants MAX_VALUE and MIN_VALUE:
  - MAX_VALUE represents the maximum value of the corresponding primitive data type
  - For Float and Double, MIN_VALUE represents the minimum *positive* float and double values
  - The maximum integer: 2,147,483,647
  - The minimum positive float: 1.4E-45
  - The maximum double floating-point number: 1.79769313486231570e+308d

The Static valueOf Methods

- The numeric wrapper classes have a static method valueOf(String s) to create a new object initialized to the value represented by the specified string:

```
Double doubleObject = Double.valueOf("12.4");

Integer integerObject = Integer.valueOf("12");
```

- Each numeric wrapper class has overloaded parsing methods to parse a numeric string into an appropriate numeric value:

```
double d = Double.parseDouble("12.4");

int i = Integer.parseInt("12");
```

Sorting an Array of Objects

```
public class GenericSort {
  public static void main(String[] args) {
    Integer[] intArray={new Integer(2),new Integer(4),new Integer(3)};
    sort(intArray);
    printList(intArray);
  }
  public static void sort(Object[] list) {
    Object currentMax;
    int currentMaxIndex;
    for (int i = list.length - 1; i >= 1; i--) {
      currentMax = list[i];
      currentMaxIndex = i; // Find the maximum in the list[0..i]
      for (int j = i - 1; j >= 0; j--) {
        if (((Comparable)currentMax).compareTo(list[j]) < 0) {
          currentMax = list[j];
          currentMaxIndex = j;
        }
      }
      list[currentMaxIndex] = list[i];
      list[i] = currentMax;
    }
  }
  public static void printList(Object[] list) {
    for (int i=0;i<list.length;i++) System.out.print(list[i]+" ");}}
```

The objects are instances of the Comparable interface and they are compared using the compareTo method.

Sorting an Array of Objects

- Java provides a static sort method for sorting an array of Object in the java.util.Arrays class:

```
java.util.Arrays.sort(intArray);
```

Arrays of Objects

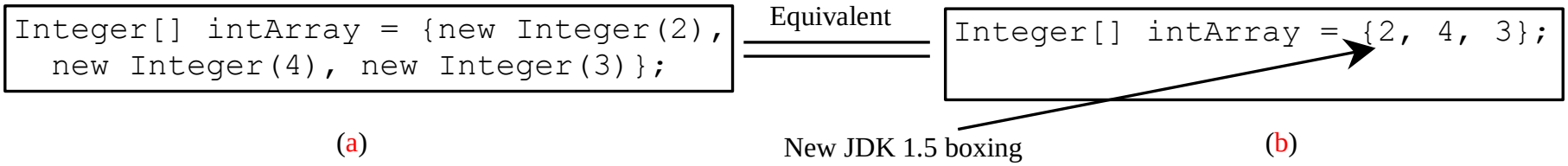
- Arrays are objects:
  - An array is an instance of the Object class
  - If A is a subclass of B, every instance of A[] is an instance of B[]

```
new int[10] instanceof Object                          true
new GregorianCalendar[10] instanceof Calendar[];true
new Calendar[10] instanceof Object[]                   true
new Calendar[10] instanceof Object                     true
```

- Although an int value can be assigned to a double type variable, int[] and double[] are two incompatible types:
  - We cannot assign an int[] array to a variable of double[] array

Wrapper Classes

- Automatic Conversion Between Primitive Types and Wrapper Class Types:
  - JDK 1.5 allows primitive type and wrapper classes to be converted automatically = boxing




```
Integer[] intArray = {1, 2, 3};
System.out.println(intArray[0] + intArray[1] + intArray[2]);
```

Unboxing

BigInteger and BigDecimal

- BigInteger and BigDecimal classes in the java.math package:
  - For computing with very large integers or high precision floating-point values
    - BigInteger can represent an integer of any size
    - BigDecimal has no limit for the precision (as long as it's finite=terminates)
  - Both are *immutable*
  - Both extend the Number class and implement the Comparable interface.

BigInteger and BigDecimal

```
BigInteger a = new BigInteger("92233720368547758O7");
BigInteger b = new BigInteger("2");
BigInteger c = a.multiply(b); // 92233720368547758O7 * 2
System.out.println(c);
```

```
                    18446744073709551614
```

```
BigDecimal a = new BigDecimal(1.0);
BigDecimal b = new BigDecimal(3);
BigDecimal c = a.divide(b, 20, BigDecimal.ROUND_UP);
System.out.println(c);
```

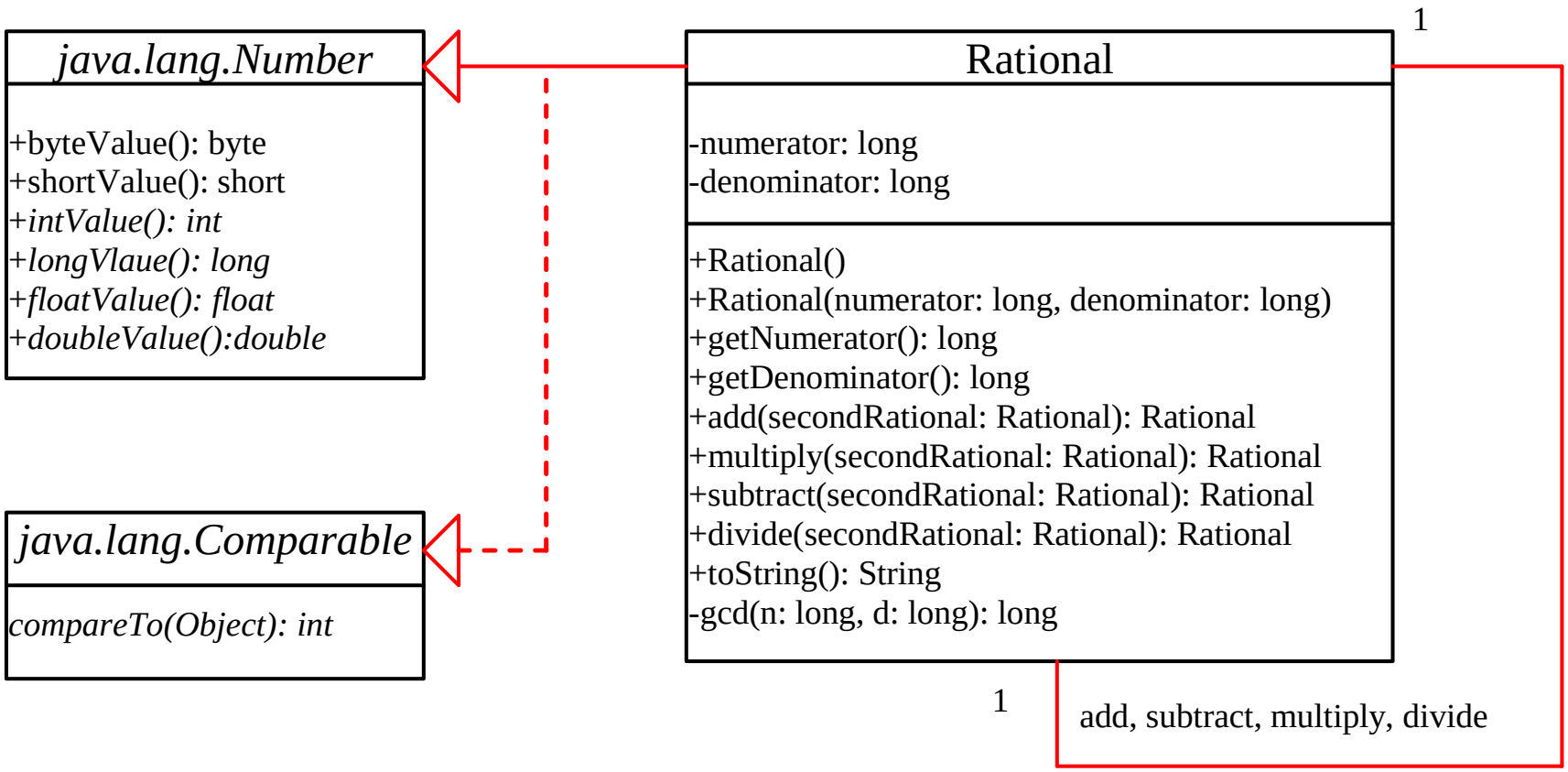
```
                    0.33333333333333333334
```

BigInteger and BigDecimal

```
import java.math.*;
public class LargeFactorial {
  public static void main(String[] args) {
    System.out.println("50! is \n" + factorial(50));
  }
  public static BigInteger factorial(long n) {
    BigInteger result = BigInteger.ONE;
    for (int i = 1; i <= n; i++)
      result = result.multiply(new BigInteger(i+""));
    return result;
  }
}
```

```
30414093201713378043612608166064768844377641
568960512000000000000
```

Case Study: The `Rational` Class



```
public class Rational extends Number implements Comparable {
  private long numerator = 0;
  private long denominator = 1;
  public Rational() { this(0, 1); }
  public Rational(long numerator, long denominator) {
    long gcd = gcd(numerator, denominator);
    this.numerator = ((denominator > 0) ? 1 : -1) * numerator / gcd;
    this.denominator = Math.abs(denominator) / gcd;
  }
  public Rational add(Rational secondRational) {
    long n = numerator * secondRational.getDenominator() +
      denominator * secondRational.getNumerator();
    long d = denominator * secondRational.getDenominator();
    return new Rational(n, d);
  }
  private static long gcd(long n, long d) {
    long n1 = Math.abs(n);
    long n2 = Math.abs(d);
    int gcd = 1;
    for (int k = 1; k <= n1 && k <= n2; k++) {
      if (n1 % k == 0 && n2 % k == 0)
        gcd = k;
    }
    return gcd;
  }
```

```
  /** Override the abstract intValue method in java.lang.Number */
  public int intValue() {   return (int)doubleValue();  }
  // ... Override all the abstract *Value methods in java.lang.Number

  /** Override the compareTo method in java.lang.Comparable */
  public int compareTo(Object o) {
    if ((this.subtract((Rational)o)).getNumerator() > 0) return 1;
    else if ((this.subtract((Rational)o)).getNumerator()<0) return -1;
    else return 0;
  }
  public static void main(String[] args) {
    Rational r1 = new Rational(4, 2);
    Rational r2 = new Rational(2, 3);
    System.out.println(r1 + " + " + r2 + " = " + r1.add(r2));
  }
}
```