Abstract Classes and Interfaces

CPT204 Advanced Object-Oriented Programming

Lecture 3 Abstract Classes and Interfaces

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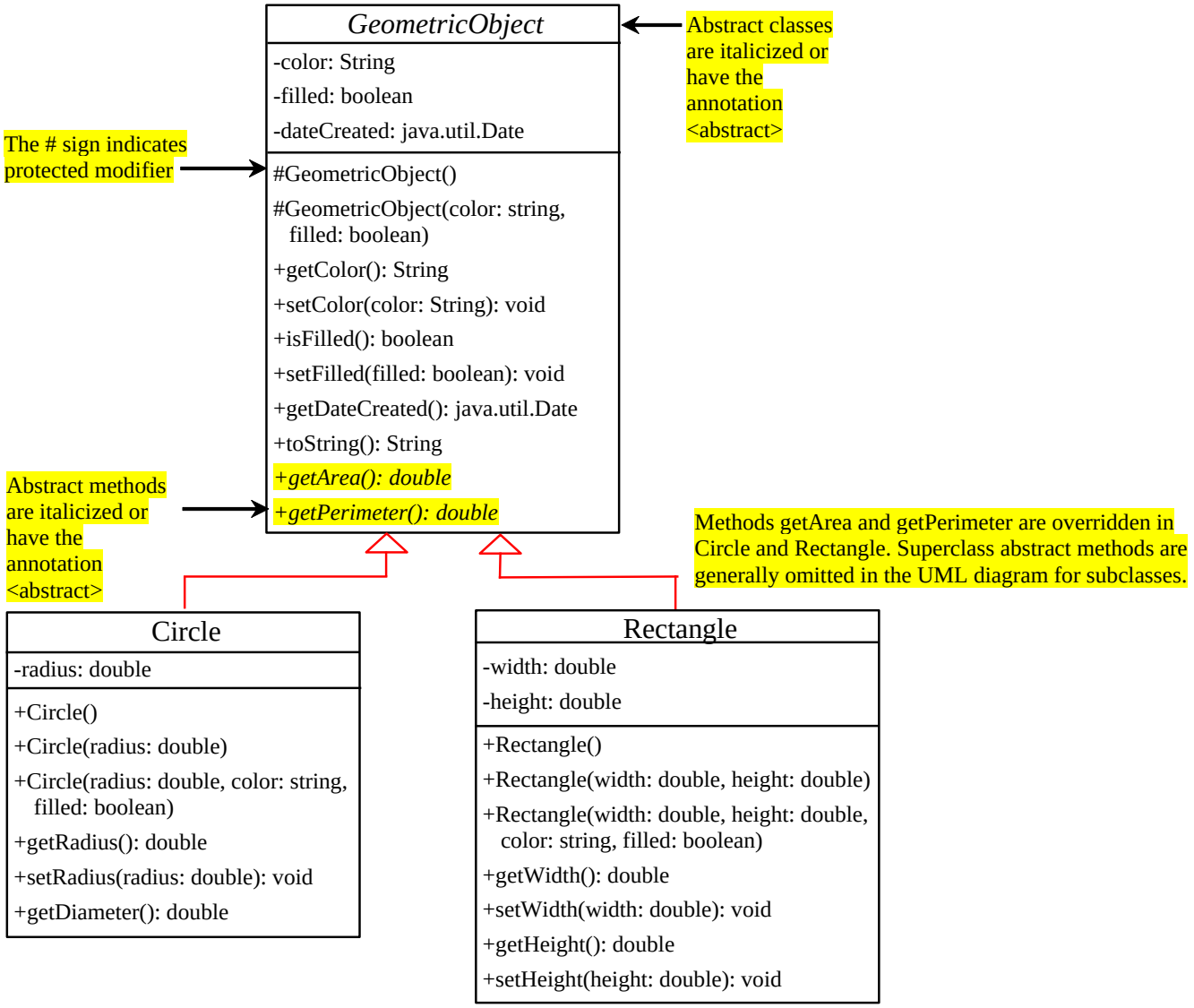
Abstract Classes and Abstract Methods



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

```
public class Rectangle extends GeometricObject {
  private double width;
  private double height;
  public Rectangle() {
    // super();
  }
  public Rectangle(double width, double height) {
    this();
    this.width = width;
    this.height = height;
  }
  public Rectangle(double width, double height, String color,
      boolean filled) {
    super(color,filled);
    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 TestGeometricObject1 {
  public static void main(String[] args) {
    // Declare and initialize two geometric objects
    GeometricObject geoObject1 = new Circle(5);
    GeometricObject geoObject2 = new Rectangle(5, 3);
    // Display circle
    displayGeometricObject(geoObject1);
    // Display rectangle
    displayGeometricObject(geoObject2);
    System.out.println("The two objects have the same area? " +
       equalArea(geoObject1, geoObject2));
  }

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

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

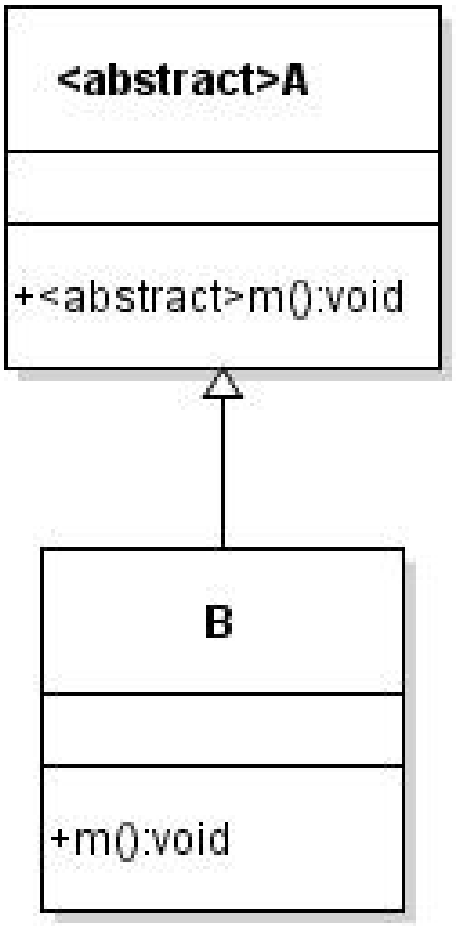
abstract methods in *abstract* classes

- An abstract method can only be contained in an abstract class.

subclasses of abstract classes

- In a nonabstract (a.k.a., concrete) subclass extended from an abstract super-class, all the abstract methods MUST be implemented.

```
abstract class A {
  abstract void m();
}
class B extends A {
  void m(){
  }
}
```



In-Class Quiz 1: Abstract Classes

- What will happen when executing this program?

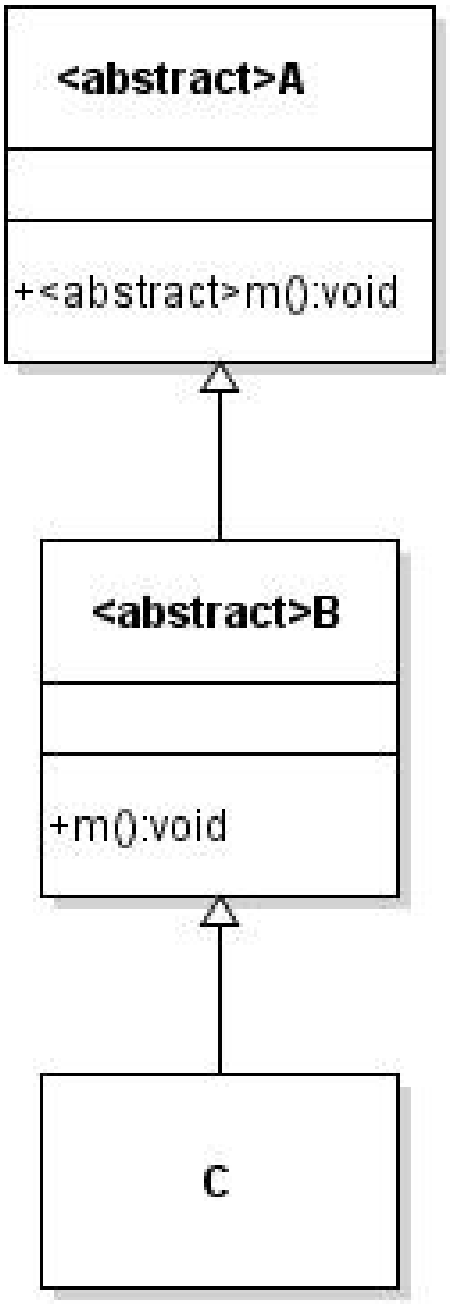
```
1  abstract class X {
2      abstract void methodX();
3  }
4
5  class Y extends X {
6  }
7
8  class Z extends Y {
9      void methodX() {
10     }
11 }
12
13 public class Test {
14     public static void main(String[] args) {
15         Z obj = new Z();
16     }
17 }
```

- compile error because Y is not abstract
- compile error because Z is not abstract
- runtime error because an abstract class is instantiated
- object `obj` is created

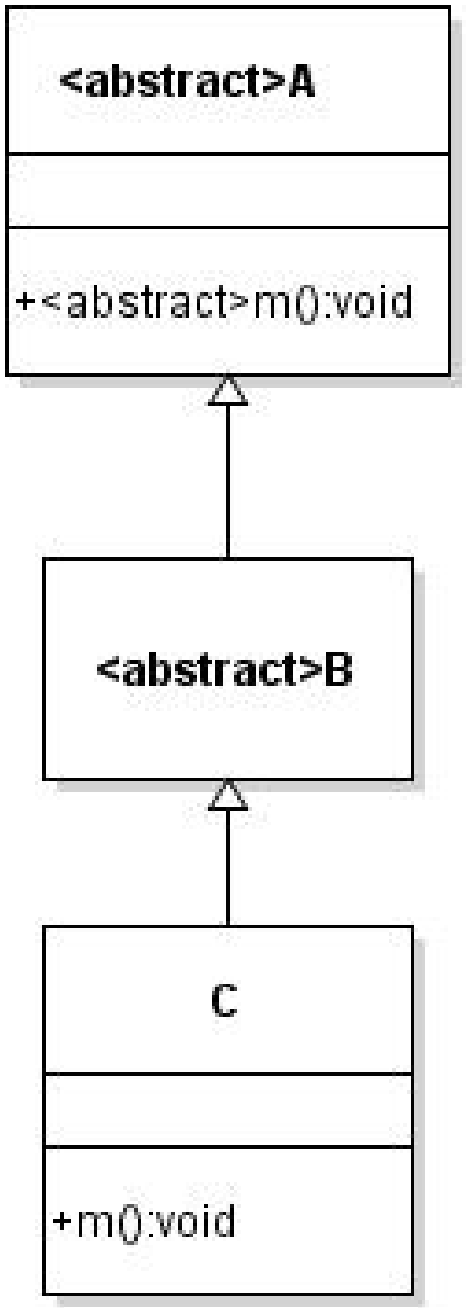
subclasses of abstract classes

- In an abstract subclass extended from an abstract super-class, we can choose:
  - to implement the inherited abstract methods OR
  - to postpone the constraint to implement the abstract methods to its nonabstract subclasses.

```
abstract class A {
     abstract void m();
}

abstract class B extends A {
     void m(){
     }
}

class C extends B {

}
```

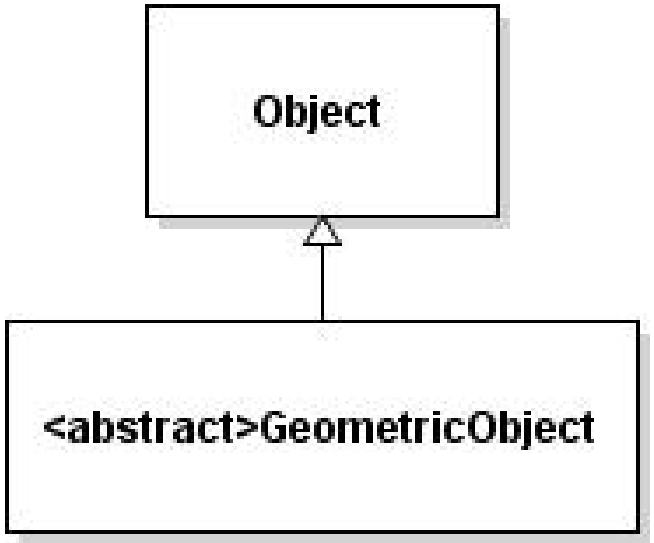


```
abstract class A{
     abstract void m();
}

abstract class B extends A{

}

public class C extends B {
     void m(){
     }
}
```



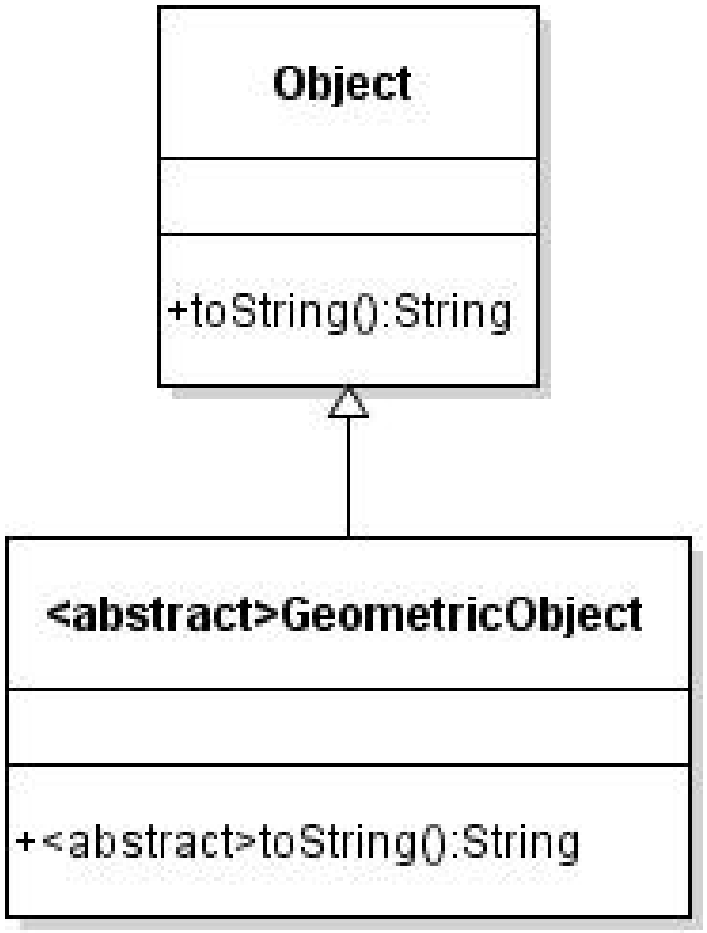
abstract classes

- 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 concrete superclass to define it ***abstract***
  - useful when we want to **force** its subclasses to implement that method, or
  - the implementation of the method in the superclass is invalid in the subclass



abstract classes

- It is possible to define an abstract class that contains no abstract methods.
  - **This class is used as a base class for defining new subclasses.**

abstract classes

- An object **cannot** be created from abstract class:
  - An abstract class cannot be instantiated using the **`new`** operator:

```
GeometricObject o =
    new GeometricObject();
```

  - We still define its constructors, which are invoked in the constructors of its subclasses through **constructor chaining**.
    - For instance, the constructors of **`GeometricObject`** are invoked by the constructors in the **`Circle`** and the **`Rectangle`** classes.

abstract classes as types

- An abstract class can be used as a data type:

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

- We can create an array whose elements are of **GeometricObject** type:

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

  - There are only **null** elements in the array until they are initialized with concrete objects:

```
geo[0] = new Circle();
geo[1] = new Rectangle();
...
```

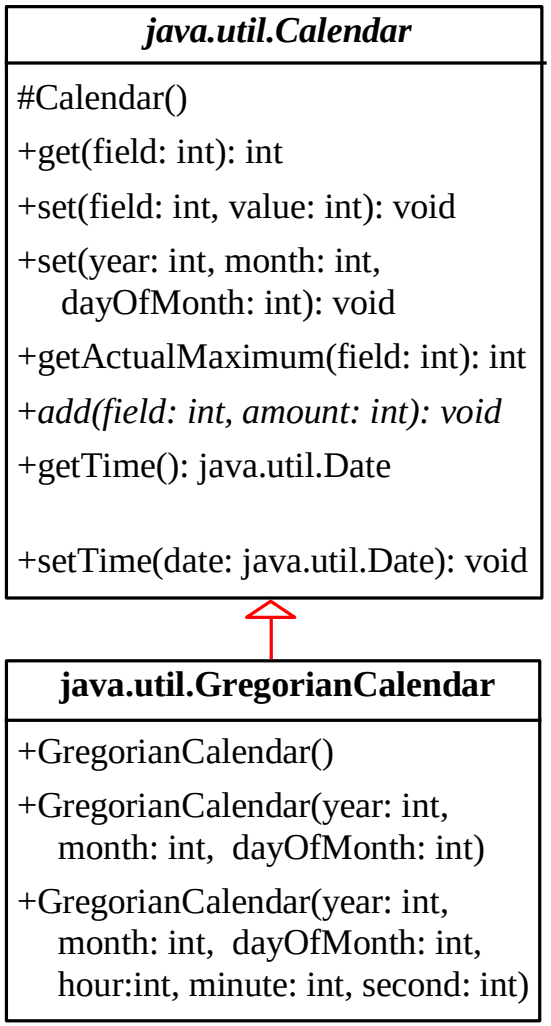
The *abstract* Calendar class and its GregorianCalendar subclass

- 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 modern 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, 1 is for February, …, 11 is for December.

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 the 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 in Calendar, 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

- An ***interface*** is a class-like construct that contains only abstract methods and constants.
- 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: a class can implement multiple interfaces.

Define an Interface

- Declaration:

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

Interface Example

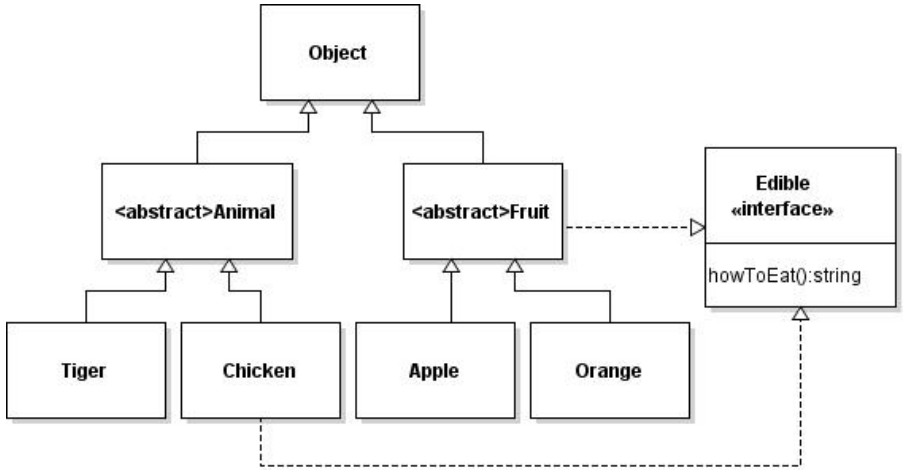
- The **Edible** interface specifies whether an object is edible

```
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 */
}
abstract class Animal { }
class Chicken extends Animal implements Edible {
  public String howToEat() {
    return "Chicken: Fry it";
  }
}
class Tiger extends Animal {
}/** Does not extend 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());
  }
}
```



In-Class Quiz 2: Edible Interface

- What is wrong with the class Banana?

```
1  public class Banana extends Edible {
2      String howToEat() {
3          return 'Peel and eat';
4      }
5  }
```

  - `implements` instead of `extends`
  - `howToEat()` must be `public`
  - `howToEat()` must return a `String`
  - all the above

Omitting Modifiers in Interfaces

- In an interface:
  - All data fields are **`public static final`**
  - All methods are **`public abstract`**
  - 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

Interfaces

- 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 of interfaces are like for abstract classes:
    - as a data type for a variable
    - as the result of casting

The **Comparable** Interface

- The **Comparable** interface is defined in the **java.lang** package and it is used by **Arrays.sort**

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

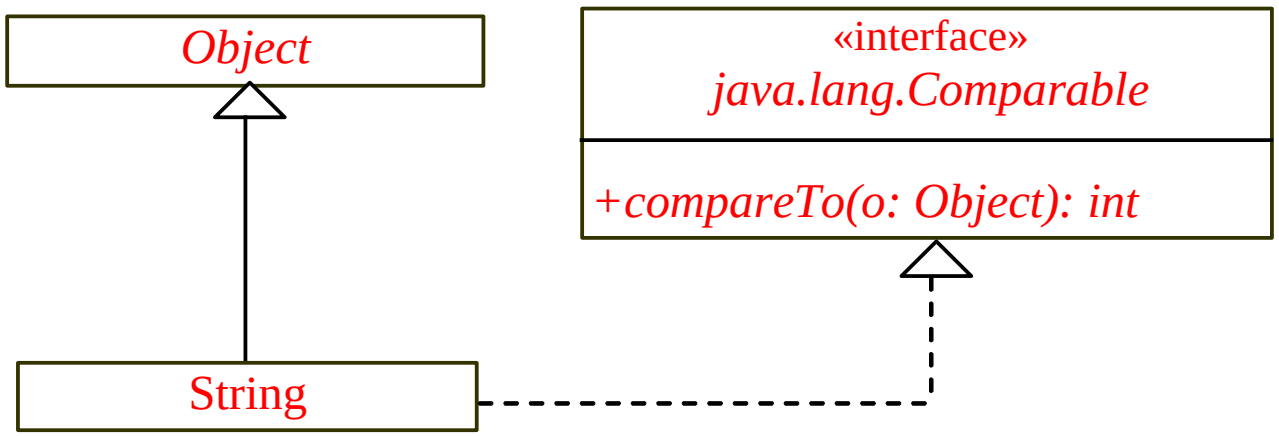
The **Comparable** Interface

- Many classes in the Java library implement **Comparable** (e.g., **String** and **Date**) 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

Writing a 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)

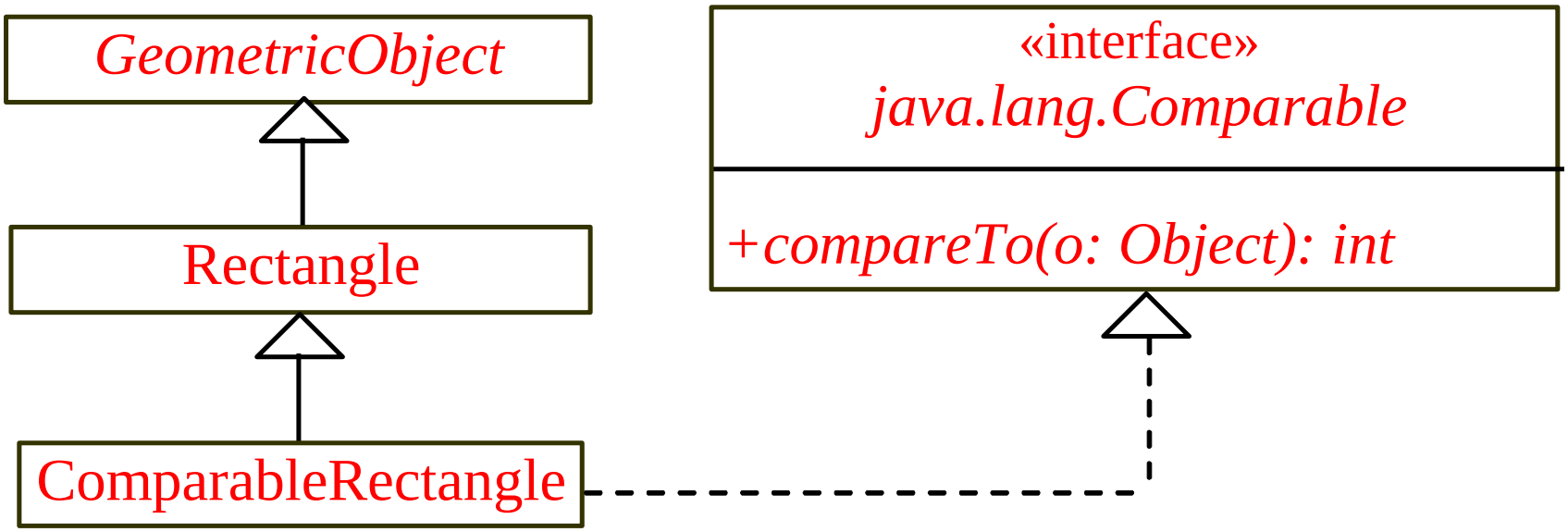
```
String s1 = "abcdef";
String s2 = "abcdee";
String s3 = (String)Max.max(s1, s2);
```

```
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));
  }
}
```

In-Class Quiz 3: Comparable Interface

```
1  public class Student implements Comparable {
2      int id;
3
4      public int compareTo(Object o) {
5          if (this.id > ((Student)o).id)
6              return 1;
7          if (this.id == ((Student)o).id)
8              return 0;
9          return -1;
10     }
11 }
```

- What is an equivalent implementation of `compareTo()` for `Student`?
  - `return this.id + ((Student)o).id;`
  - `return this.id - ((Student)o).id;`
  - `return this.id * ((Student)o).id;`
  - `return this.id / ((Student)o).id;`

The `Cloneable` Interface

- ***Marker Interface***: is an empty interface (does not contain constants or methods), but it is used to denote that a class possesses certain desirable properties to the compiler and the JVM.

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

- A class that **`implements`** the **`Cloneable`** interface is marked cloneable:
  - its objects can be cloned using the **`clone()`** method defined in the **`Object`** class, and we can override this method in our classes

The `Cloneable` Interface

- **`Calendar`** (in the Java library) implements **`Cloneable`**:

```
Calendar calendar = new GregorianCalendar(2022, 1, 1);
Calendar calendarCopy = (Calendar)(calendar.clone());
System.out.println("calendar == calendarCopy is "
    +(calendar == calendarCopy));
```

Displays:

`calendar == calendarCopy is false`

because the references are different

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

`calendar.equals(calendarCopy) is true`

because the **`calendarCopy`** is a copy of **`calendar`**

Implementing the `Cloneable` Interface

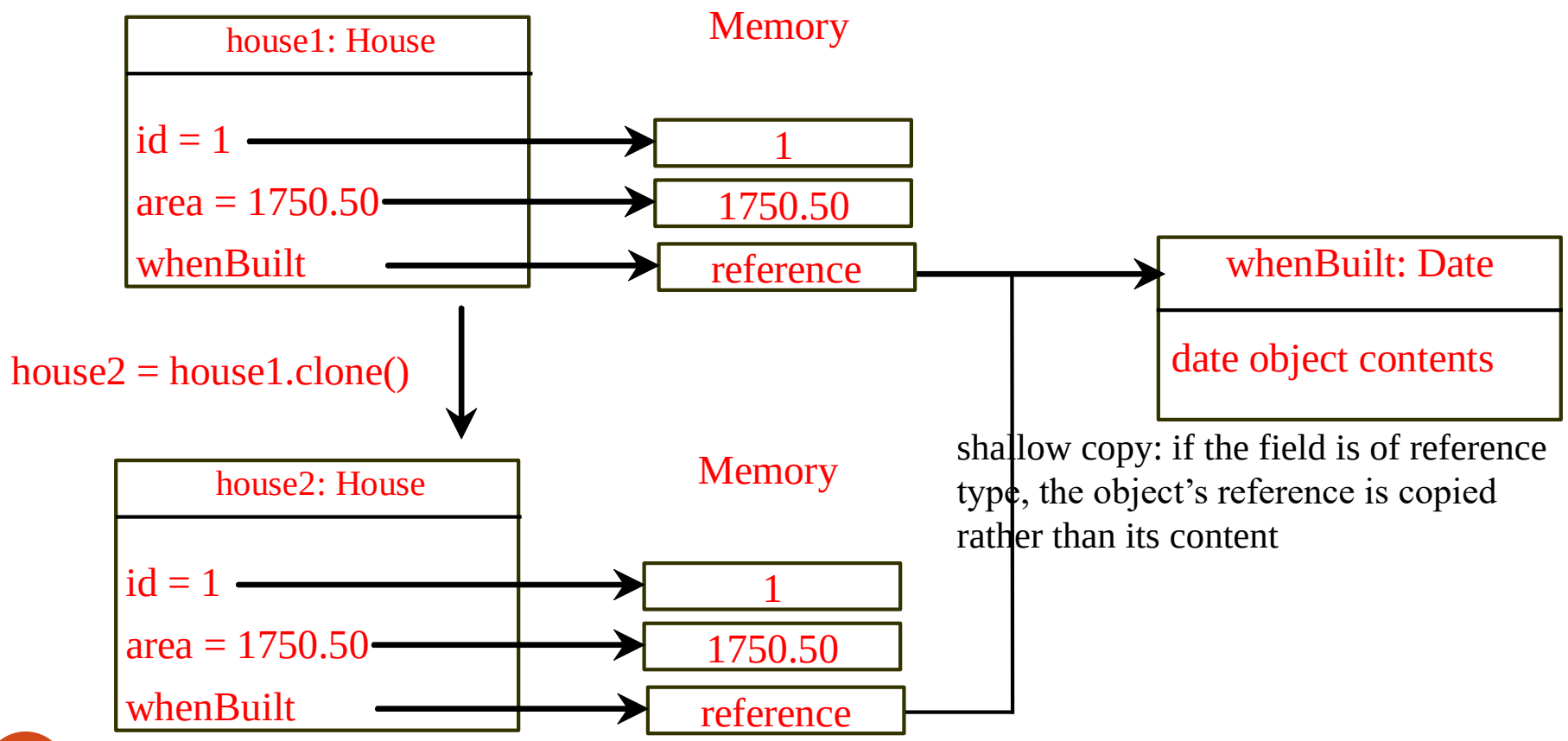
- If we try to create a clone of an object instance of a class that does not implement the **`Cloneable`** interface, it throws **`CloneNotSupportedException`**
- The **`clone()`** method in the **`Object`** class creates a new instance of the class of this object and initializes all its fields with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

```
public class SomethingCloneable implements Cloneable {
  public boolean equals(Object o){
    return true;
  }
  public static void main(String[] args)
      throws CloneNotSupportedException {
    SomethingCloneable s1 = new SomethingCloneable();
    SomethingCloneable s2 = (SomethingCloneable) s1.clone();
    System.out.println("s1 == s2 is " + (s1 == s2));
       // false
    System.out.println("s1.equals(s2) is " + s1.equals(s2));
       // true
  }
}
```

```
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;
      }
   }
   ...
}
```

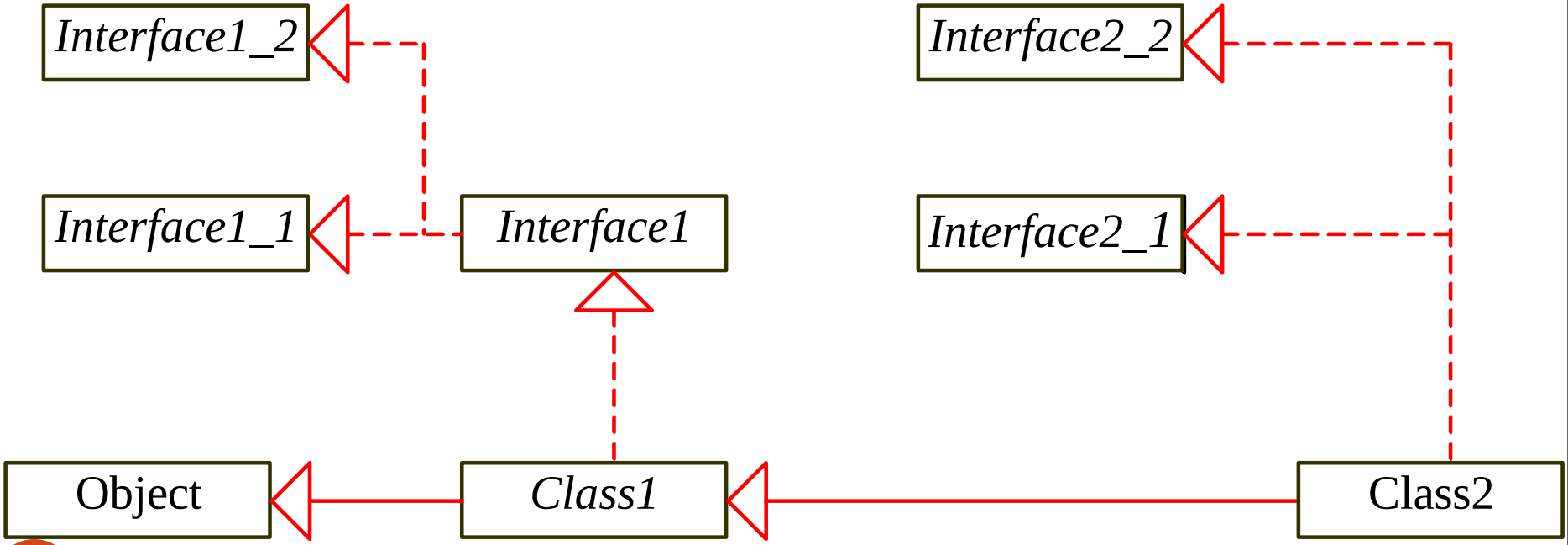
Interfaces vs. Abstract Classes

- In an interface, the data fields must be constants; an abstract class can have variable data fields
- Interfaces don't have constructors; all abstract classes have constructors
- Each method in an interface has only a signature without implementation (i.e., only abstract methods); an abstract class can have concrete methods

	Variables	**Constructors**	**Methods**
Interfaces	**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**
Abstract classes	**No restrictions**	**Constructors are invoked by subclasses through constructor chaining.** **An abstract class cannot be instantiated using the new operator.**	**No restrictions.**

Inheritance: Interfaces & Classes

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



Conflicting interfaces

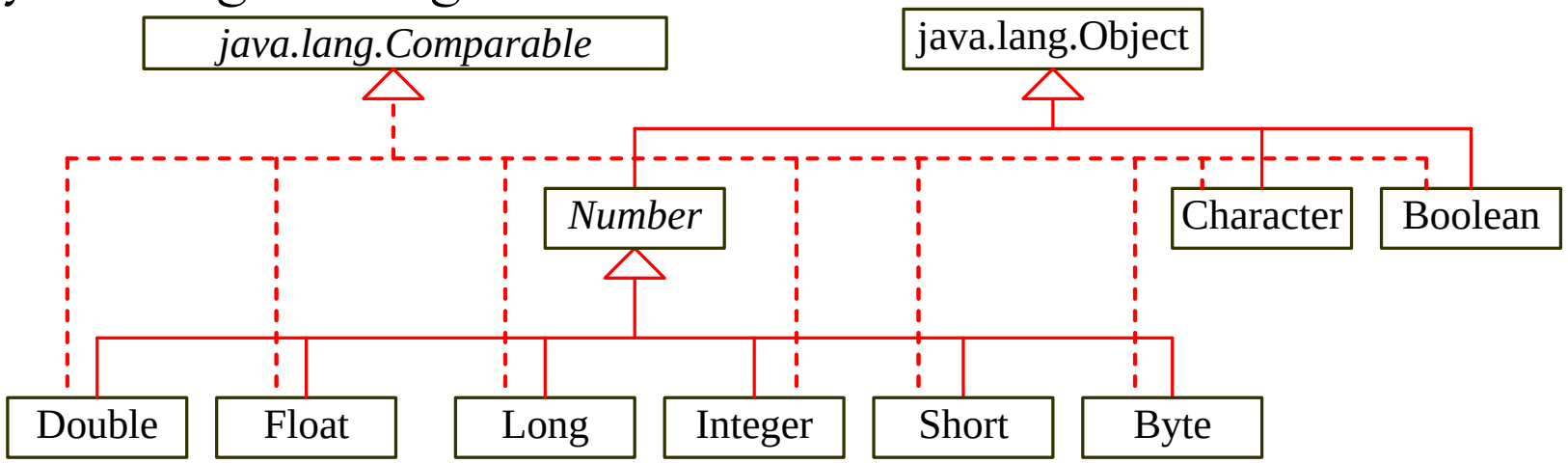
- Errors detected by the compiler:
  - If a class implements two interfaces with conflicting information, like:
    - two same constants with different values, or
    - two methods with same signature but different return type

Whether to use a class or an interface?

- *Strong is-a*: a relationship that clearly describes a parent-child relationship
  - For example: a student is a person
  - Should be modeled using class inheritance
- *Weak is-a* (or *is-kind-of*): indicates that an object possesses a certain property
  - For example: all strings are comparable, all dates are comparable
  - Should be modeled using interfaces
- You can also use interfaces to circumvent single inheritance restriction if multiple inheritance is desired

Wrapper Classes

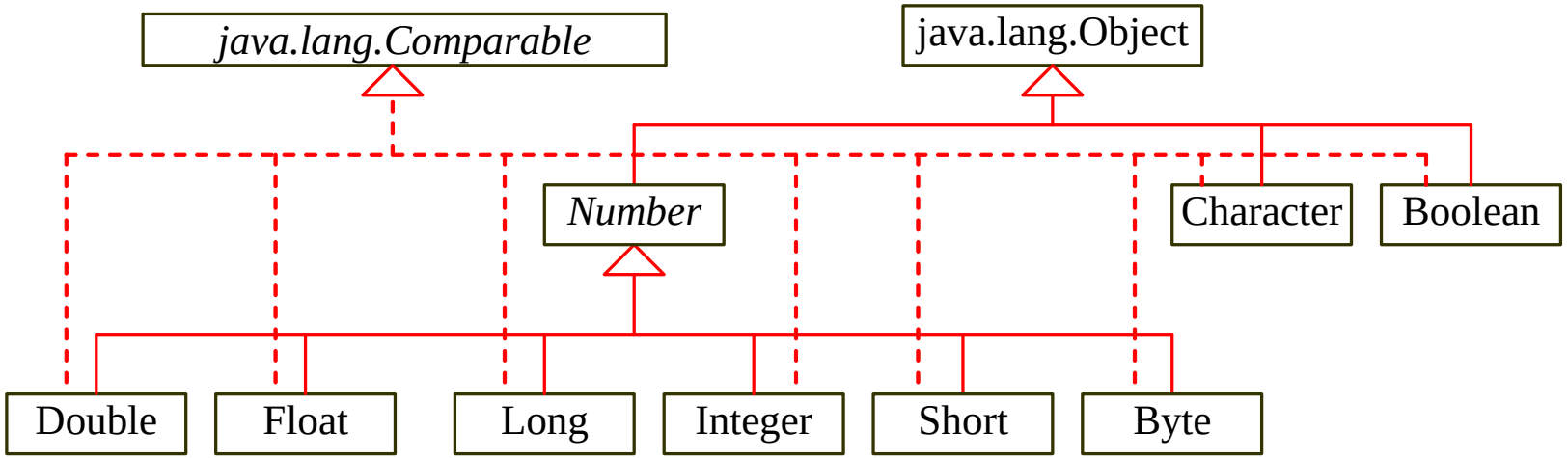
- Primitive data types in Java ➔ **Better performance**
  - However, data structures (ArrayList) expect objects as elements
- Each primitive type has a wrapper class: Boolean, Character, Short, Byte, Integer, Long, Float, Double



  - 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

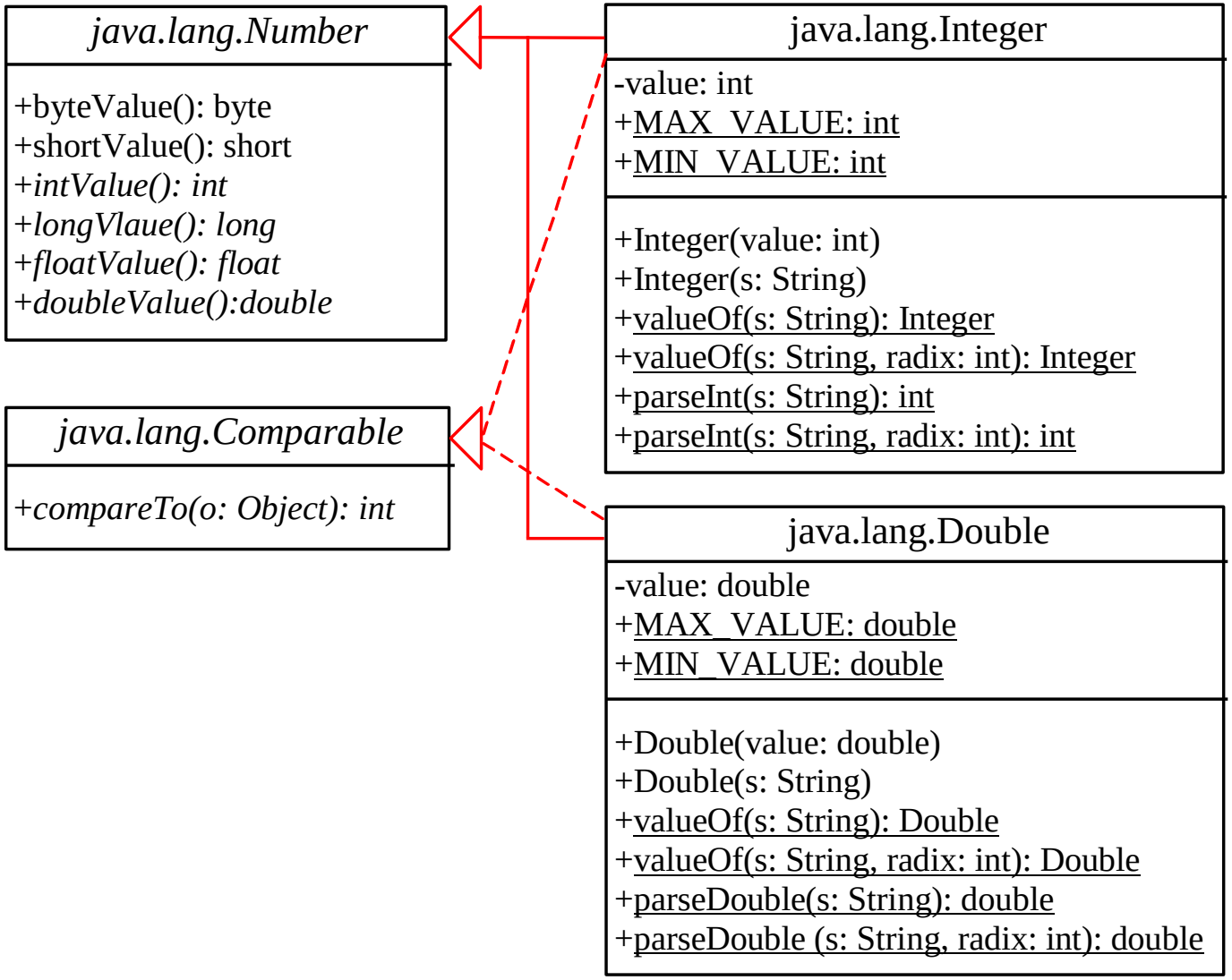
- Each wrapper class overrides the **`toString`** and **`equals`** methods defined in the **`Object`** class
- Since these classes implement the **`Comparable`** interface, the **`compareTo`** method is also implemented in these classes



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");
```

Wrapper Classes

- Automatic Conversion Between Primitive Types and Wrapper Class Types:
  - Since JDK 1.5, Java allows primitive type and wrapper classes to be converted automatically:
    - ***boxing*** of primitive types into wrapper types when objects are needed

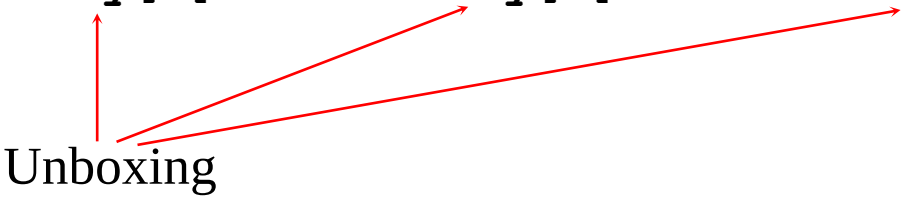
```
Integer[] intArray = {2, 4, 3};
```

Equivalent

```
Integer[] intArray = {new Integer(2),
  new Integer(4), new Integer(3)};
```

    - ***unboxing*** of wrapper types into primitive types when primitive types are needed

```
int n = intArray[0] + intArray[1] + intArray[2];
```



In-Class Quiz 4: Automatic Unboxing

- What happens to the following program when it is executed?

```
1  public class AutomaticUnboxing {
2      public static void main(String[] args) {
3          Integer num = null;
4          int x = num;
5          System.out.println(x);
6      }
7  }
```

  - compile error at line 3
  - runtime error at line 3
  - compile error at line 4
  - runtime error at line 4

Arrays are objects

- Arrays are objects:
  - An array is an instance of the **`Object`** class

```
new int[10] instanceof Object                    true
```

  - If **`A`** is a subclass of **`B`**, every instance of **`A[]`** is an instance of **`B[]`**

```
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 because they are not classes:
  - We cannot assign an **`int[]`** array to a variable of **`double[]`** array: compiler error: **`double[] a = new int[10];`**

Sorting an Array of Objects

- Java provides a **`static`** **`sort`** method for sorting an array of **`Object`** in the **`java.util.Arrays`** class that uses the **`Comparable`** interface:

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

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); // or Arrays.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.

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);
```

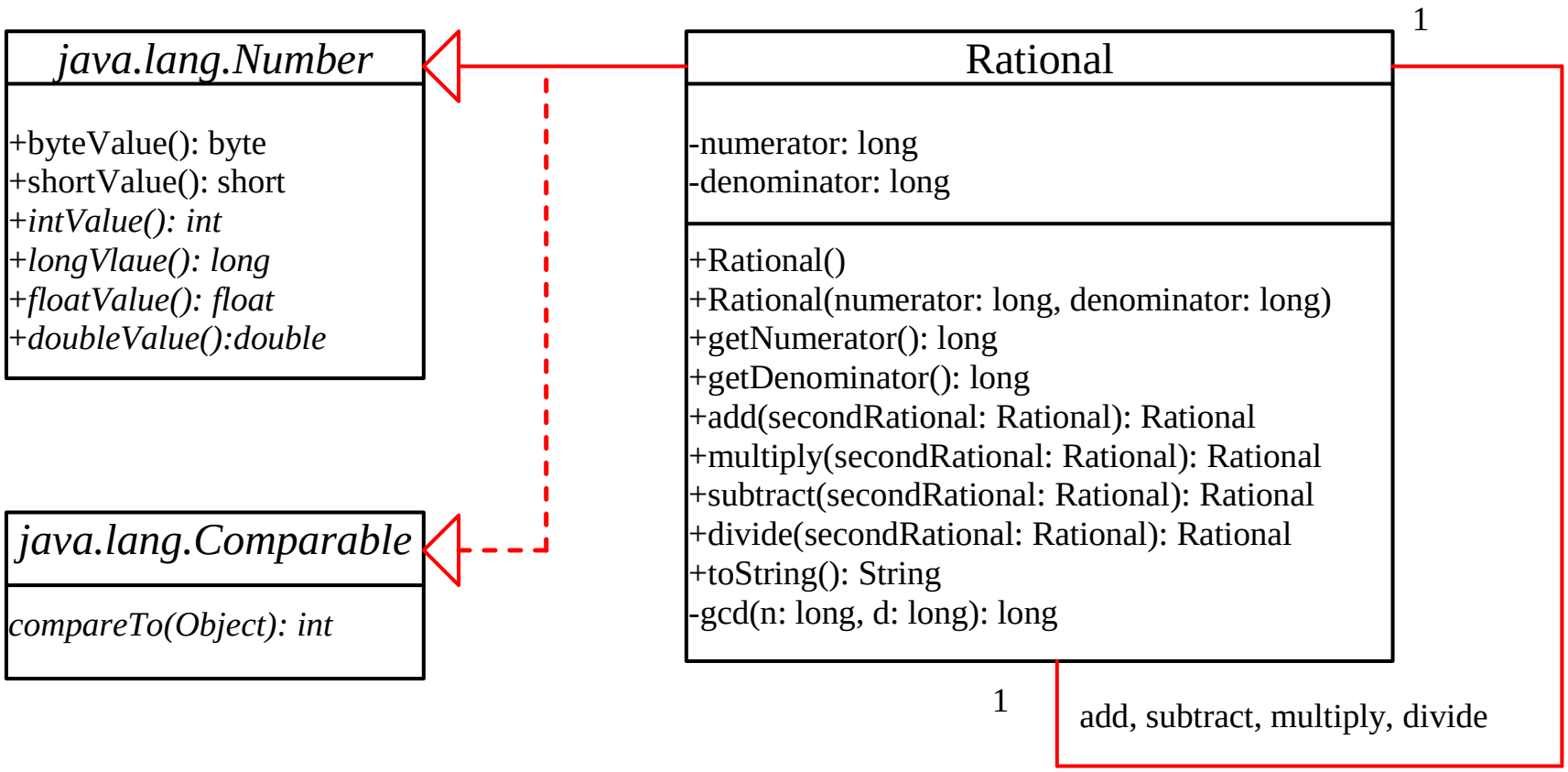
```
                    0.33333333333333333334
```

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;
  }
  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;
  }
  public Rational add(Rational secondRational) {
    long n = numerator * secondRational.getDenominator() +
      denominator * secondRational.getNumerator();
    long d = denominator * secondRational.getDenominator();
    return new Rational(n, d);
  }
```

$$\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}$$

```
  public Rational subtract(Rational secondRational) {
    ...                                  // or implement inverse and use add method
  }
  // multiply, divide

  /** Override the abstract intValue method in java.lang.Number */
  public int intValue() {   return (int)doubleValue();  }
  public double doubleValue() {
    return ((double)numerator)/denominator;
  }
  // ... 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));
  }
}
```

$$\frac{a}{b} - \frac{c}{d} = \frac{ad - bc}{bd}$$

$$-\left(\frac{a}{b}\right) = \frac{-a}{b}$$