Abstract Classes and Interfaces

CSE 114: Introduction to Object-Oriented Programming

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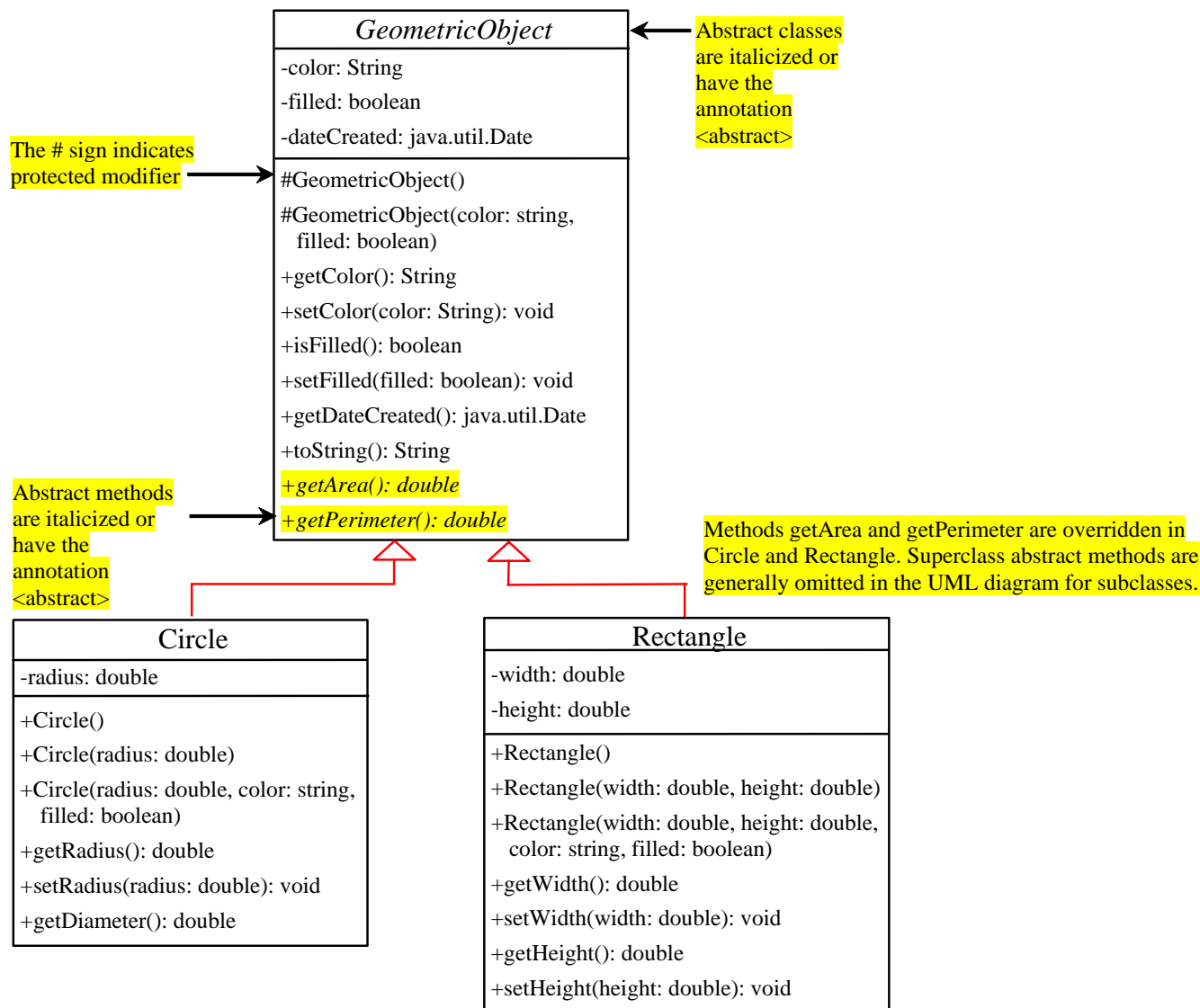
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Contents

- Abstract Classes and Abstract Methods
  - Constraints on the subclasses of abstract classes
  - Uses of abstract classes
  - The abstract Calendar class and its GregorianCalendar subclass
- Interfaces:
  - Defining Interfaces
  - Implementing Interfaces
  - The Comparable Interface
    - Writing a generic max Method
    - Defining Classes to Implement Comparable
  - The Cloneable Interface
    - Implementing the **Cloneable** Interface
    - Shallow vs. Deep Copy
  - Interfaces vs. Abstract Classes
  - Interfaces Inheritance
  - Conflicting interfaces

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Abstract Classes and Abstract Methods

GeometricObject

-color: String

-filled: boolean

-dateCreated: java.util.Date

#GeometricObject()

#GeometricObject(color: string, filled: boolean)

+getColor(): String

+setColor(color: String): void

+isFilled(): boolean

+setFilled(filled: boolean): void

+getDateCreated(): java.util.Date

+toString(): String

+getArea(): double

+getPerimeter(): double

Abstract classes are italicized or have the annotation

The # sign indicates protected modifier

Abstract methods are italicized or have the annotation

Methods getArea and getPerimeter are overridden in Circle and Rectangle. Superclass abstract methods are generally omitted in the UML diagram for subclasses.

Circle

-radius: double

+Circle()

+Circle(radius: double)

+Circle(radius: double, color: string, filled: boolean)

+getRadius(): double

+setRadius(radius: double): void

+getDiameter(): double

Rectangle

-width: double

-height: double

+Rectangle()

+Rectangle(width: double, height: double)

+Rectangle(width: double, height: double, color: string, filled: boolean)

+getWidth(): double

+setWidth(width: double): void

+getHeight(): double

+setHeight(height: double): void

3

```java
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();
}
```

```java
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;
  }
}
```

```java
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);
  }
}
```

```java
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();
  }
}
```

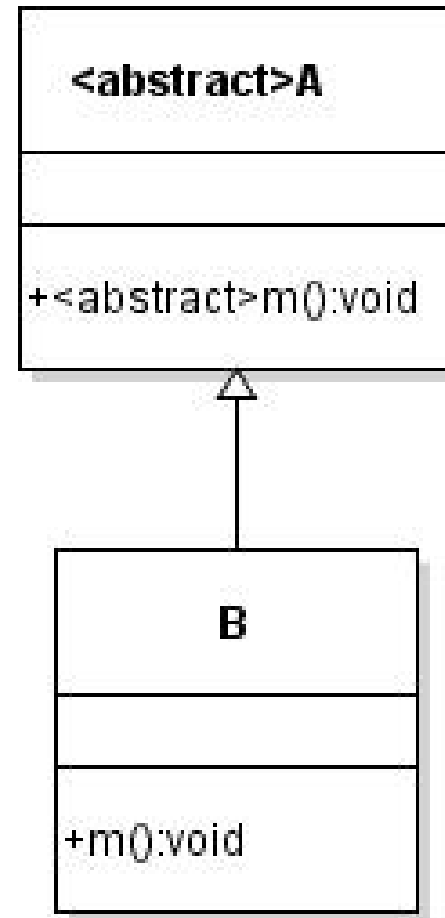# *abstract* methods <u>in</u> *abstract* classes

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

subclasses <u>of</u> *abstract* classes

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

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

```
┌─────────────────────┐
│ <abstract>A         │
├─────────────────────┤
│                     │
├─────────────────────┤
│ +<abstract>m():void │
└─────────────────────┘
          △
          │
    ┌───────────┐
    │     B     │
    ├───────────┤
    │           │
    ├───────────┤
    │ +m():void │
    └───────────┘
```

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subclasses <u>of</u> *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.

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

}

abstract class B extends A {
    void m(){

    }

}

class C extends B {


}
```
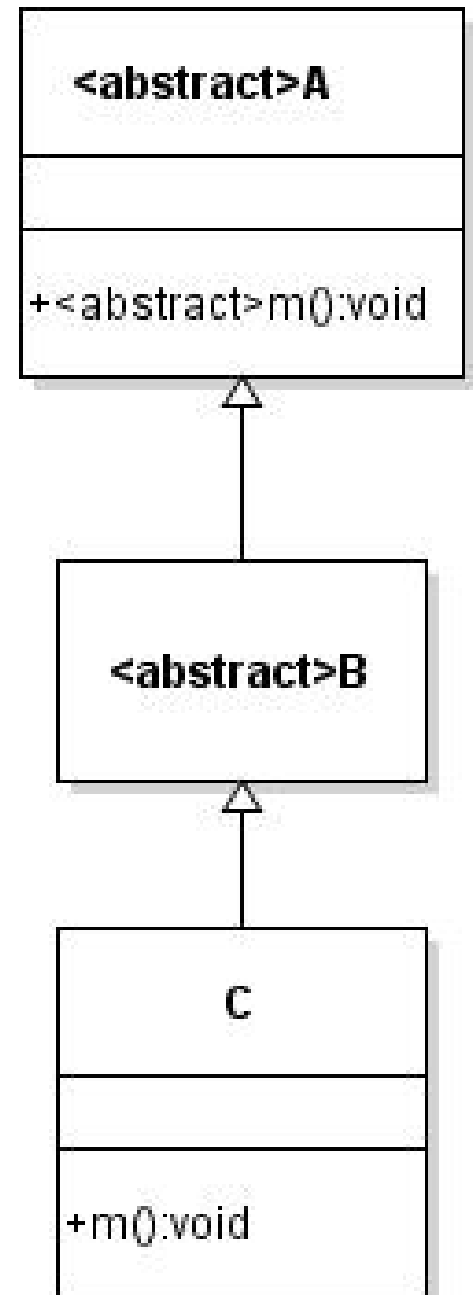
```
<abstract>A

+<abstract>m():void
```

```
<abstract>B

+m():void
```

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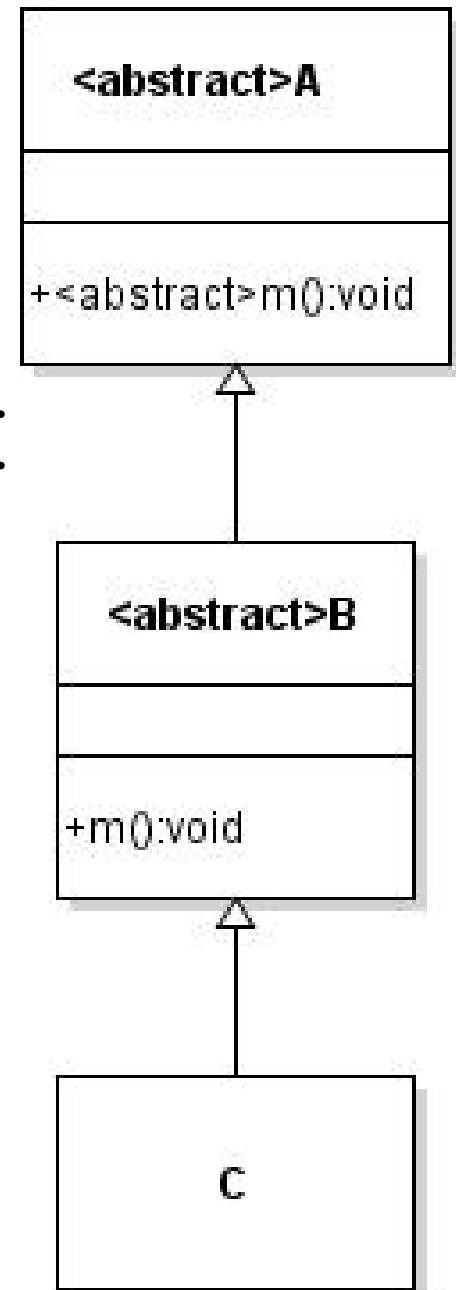
```java
abstract class A{
    abstract void m();
}


abstract class B extends A{


}


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


UML diagram:
- A
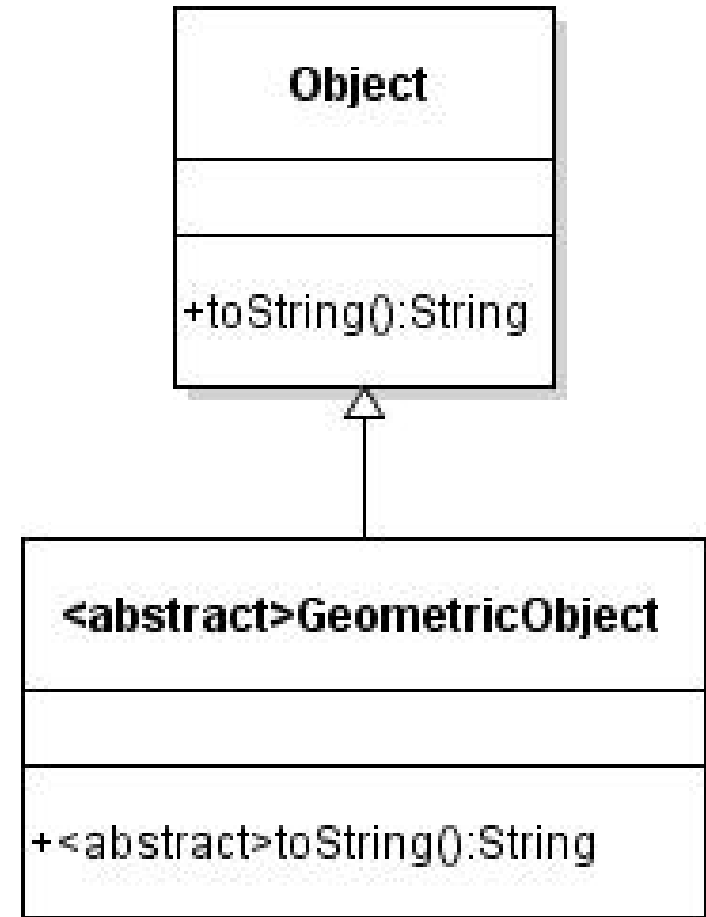 - +m():void
- B
- C
  - +m():void

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

```
┌─────────────────┐
│     Object      │
└─────────────────┘
         △
         │
┌─────────────────────────────┐
│ <abstract>GeometricObject   │
└─────────────────────────────┘
```
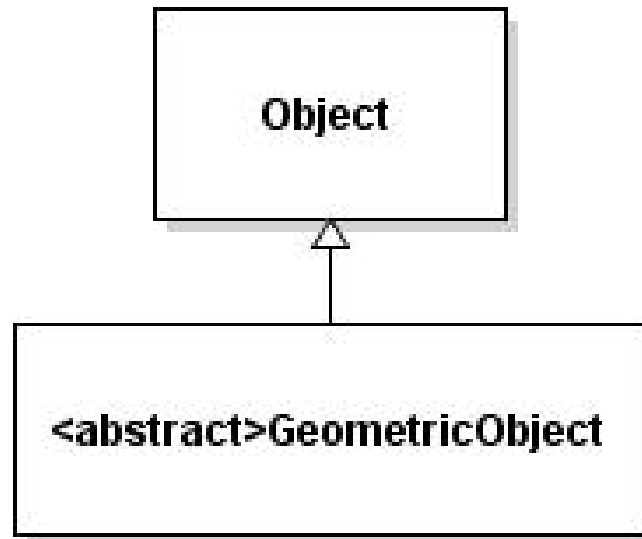
abstract classes

- 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

```
            Object
--------------------------
+toString():String
```

```
     <abstract>GeometricObject
--------------------------------------
+<abstract>toString():String
```

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.

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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

java.util.Calendar	
#Calendar()	Constructs a default calendar.
+get(field: int): int	Returns the value of the given calendar field.
+set(field: int, value: int): void	Sets the given calendar to the specified value.
+set(year: int, month: int, dayOfMonth: int): void	Sets the calendar with the specified year, month, and date. The month parameter is 0-based, that is, 0 is for January.
+getActualMaximum(field: int): int	Returns the maximum value that the specified calendar field could have.
+*add(field: int, amount: int): void*	Adds or subtracts the specified amount of time to the given calendar field.
+getTime(): java.util.Date	Returns a Date object representing this calendar's time value (million second offset from the Unix epoch).
+setTime(date: java.util.Date): void	Sets this calendar's time with the given Date object.

java.util.GregorianCalendar	
+GregorianCalendar()	Constructs a GregorianCalendar for the current time.
+GregorianCalendar(year: int, month: int, dayOfMonth: int)	Constructs a GregorianCalendar for the specified year, month, and day of month.
+GregorianCalendar(year: int, month: int, dayOfMonth: int, hour:int, minute: int, second: int)	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.

20

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).

```java
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.

Defining Interfaces

- Declaration:

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

Implementing Interfaces

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

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

- The class **Chicken** implements the **Edible** interface:

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

```java
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());
  }
}
```
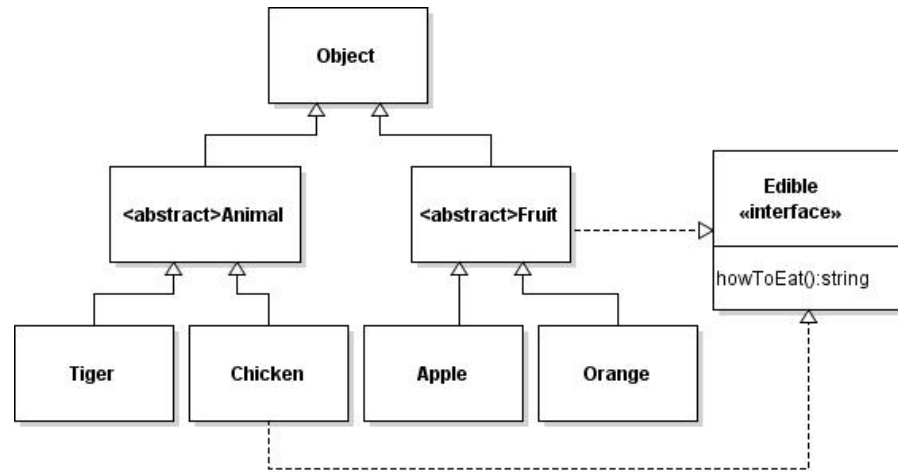
Omitting Modifiers in Interfaces

- 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

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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);
}
```
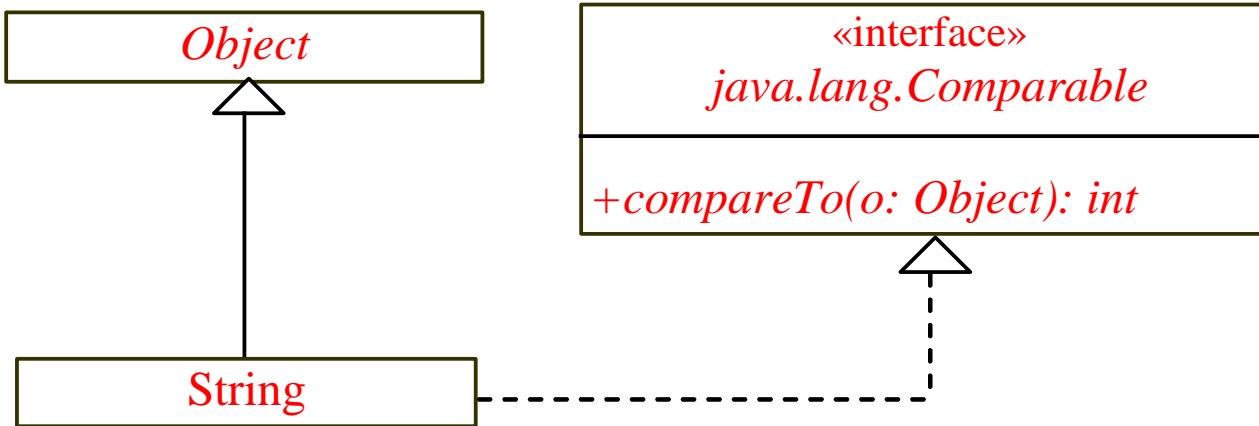
The **Comparable** Interface

- 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
```

```
┌──────────────────────────┐          ┌──────────────────────────────────────┐
│         Object           │          │             «interface»              │
└──────────────────────────┘          │         java.lang.Comparable         │
             △                        ├──────────────────────────────────────┤
             │                        │  +compareTo(o: Object): int           │
             │                        └──────────────────────────────────────┘
             │                                          △
┌──────────────────────────┐                            ┆
│         String           │┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄ ┄┘
└──────────────────────────┘
```

In UML, the interface and the methods are italicized

dashed lines and triangles are used to point to the interface

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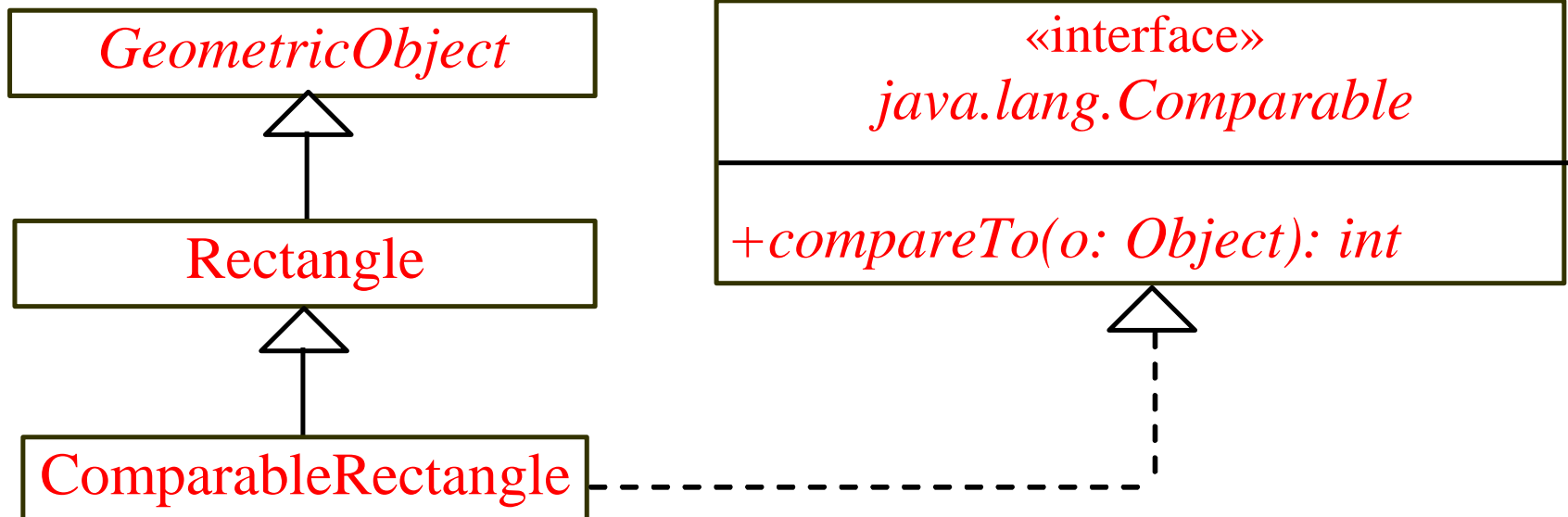
```
Date d1 = new Date();
Date d2 = new Date();
Date d3 = (Date)Max.max(d1, d2);
```

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 <u>max</u> method to find the larger of two instances of <u>Rectangle</u>, because <u>Rectangle</u> does not implement <u>Comparable</u>

- We can define a new rectangle class <u>ComparableRectangle</u> that implements <u>Comparable</u>: the instances of this new class are comparable

```
┌──────────────────────┐          ┌────────────────────────────┐
│   GeometricObject     │          │        «interface»          │
└──────────────────────┘          │   java.lang.Comparable      │
           △                       ├────────────────────────────┤
           │                       │                            │
┌──────────────────────┐          │ +compareTo(o: Object): int │
│      Rectangle        │          └────────────────────────────┘
└──────────────────────┘                       △
           △                                    ¦
           │                                    ¦
┌──────────────────────┐                        ¦
│ ComparableRectangle  │- - - - - - - - - - - - ┘
└──────────────────────┘
```

```java
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));
  }
}
```

Sorting an Array of Objects

- The **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);

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**

37

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

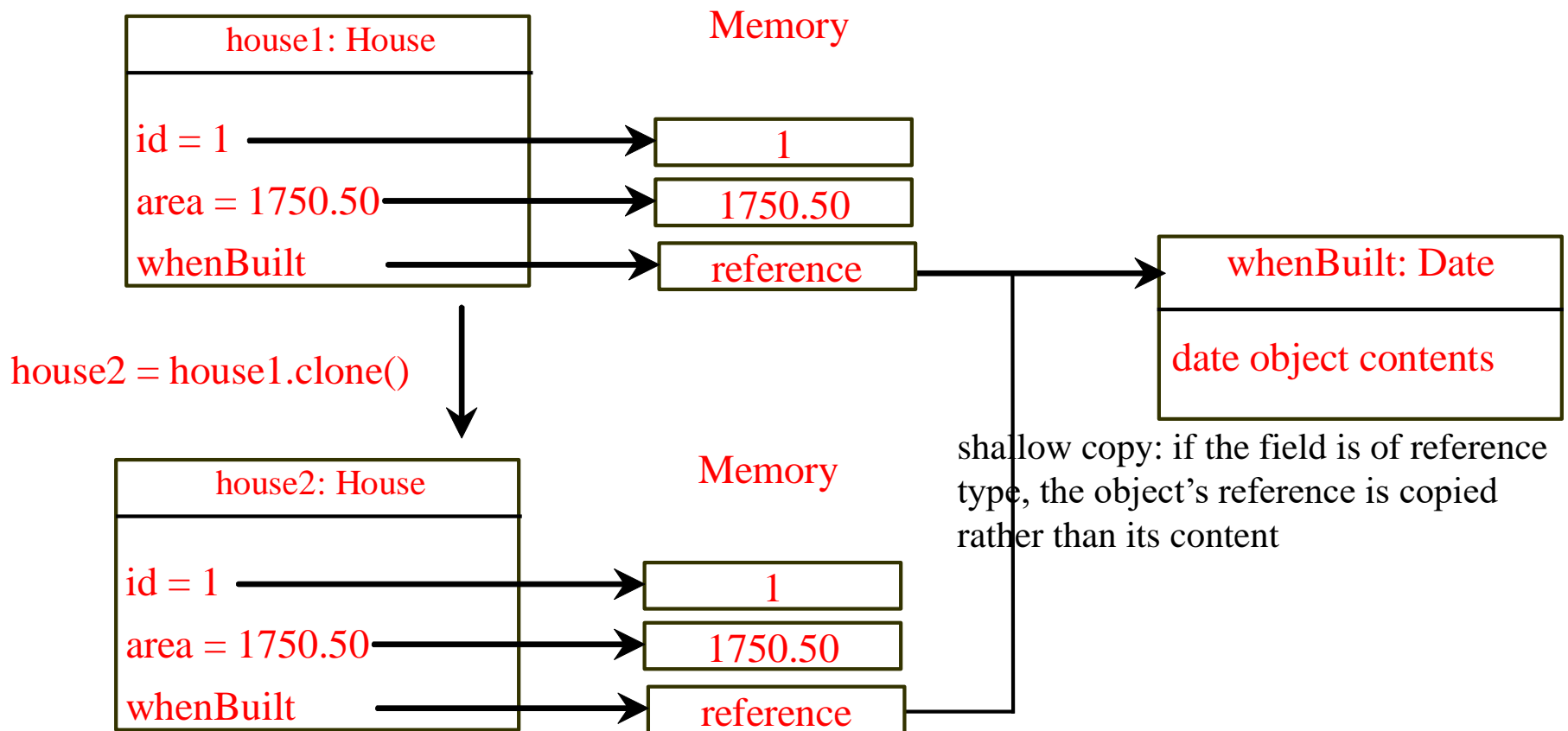- We can override the `clone()` method from the `Object` class to create custom clones

```java
public class House implements Cloneable {
  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 House(int id, double area, java.util.Date whenBuilt) {
    this.id = id; this.area = area; this.whenBuilt = whenBuilt;}
  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() {
    // return new House(id,area,whenBuilt); // OR
    try {
      return super.clone();
    }catch (CloneNotSupportedException ex) {
      return null;
    }
  }
}
```

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Shallow vs. Deep Copy

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

house1: House	
id = 1	
area = 1750.50	
whenBuilt	

Memory

1
1750.50
reference

house2 = house1.clone()

whenBuilt: Date
date object contents

house2: House	
id = 1	
area = 1750.50	
whenBuilt	

Memory

1
1750.50
reference

shallow copy: if the field is of reference type, the object's reference is copied rather than its content

40

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

```java
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 <u>public</u> <u>static</u> <u>final</u>**	**No constructors.** **An interface cannot be instantiated using the new operator.**	**All methods must be <u>public</u> <u>abstract</u> 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.**

42

Interfaces Inheritance

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

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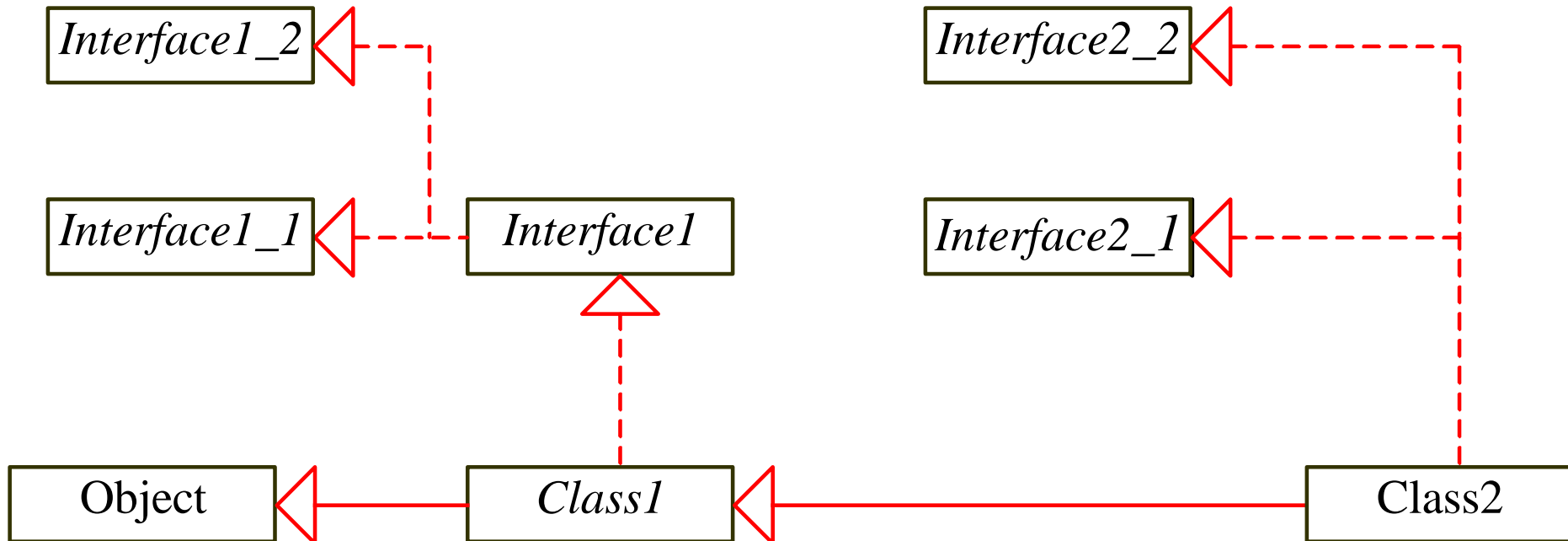
Conflicting interfaces

- 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

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