CSE 143
Lecture 23

Inheritance and the `Object` class; Polymorphism

read 9.2 - 9.4

slides adapted from Marty Stepp, Hélène Martin, and Ethan Apter
http://www.cs.washington.edu/143/

Recall: Inheritance

- **inheritance**: Forming new classes based on existing ones.
  - **superclass**: Parent class being extended.
  - **subclass**: Child class that inherits behavior from superclass.
    - gets a copy of every field and method from superclass

- **override**: To replace a superclass's method by writing a new version of that method in a subclass.

```
public class Lawyer extends Employee {
    // overrides getSalary in Employee; a raise!
    public double getSalary() {
        return 55000.00;
    }
}
```

The super keyword

`super.`**method**`(`**parameters**`)`
`super(`**parameters**`);`

– Subclasses can call overridden methods/constructors with `super`

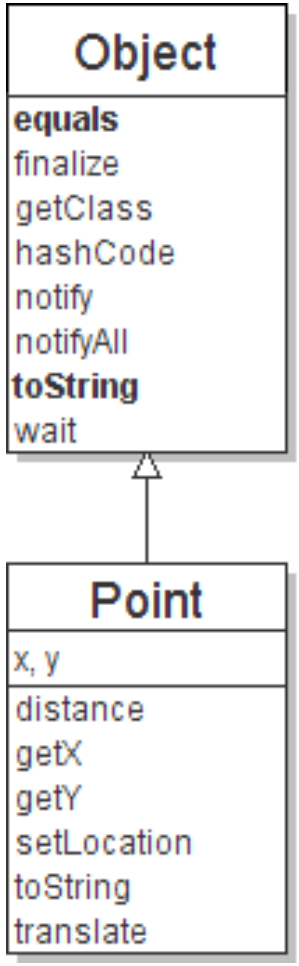
```
public class Lawyer extends Employee {
    private boolean passedBarExam;

    public Lawyer(int vacationDays, boolean bar) {
        super(vacationDays * 2);
        this.passedBarExam = bar;
    }

    public double getSalary() {
        double baseSalary = super.getSalary();
        return baseSalary + 5000.00;   // $5K raise
    }
    ...
}
```

The class Object

- The class `Object` forms the root of the overall inheritance tree of all Java classes.
  - Every class is implicitly a subclass of `Object`

- The `Object` class defines several methods that become part of every class you write. For example:

  - `public String toString()`
    Returns a text representation of the object, usually so that it can be printed.



Object methods

method	description
`protected Object clone()`	creates a copy of the object
`public boolean equals(Object o)`	returns whether two objects have the same state
`protected void finalize()`	used for garbage collection
`public Class<?> getClass()`	info about the object's type
`public int hashCode()`	a code suitable for putting this object into a hash collection
`public String toString()`	text representation of object

`public void notify()`
`public void notifyAll()`
`public void wait()`
`public void wait(...)`
	methods related to concurrency and locking (seen later)

- What does this list of methods tell you about Java's design?

Using the Object class

- You can store any object in a variable of type `Object`.

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";
```

- You can write methods that accept an `Object` parameter.

```
public void checkNotNull(Object o) {
    if (o != null) {
        throw new IllegalArgumentException();
    }
```

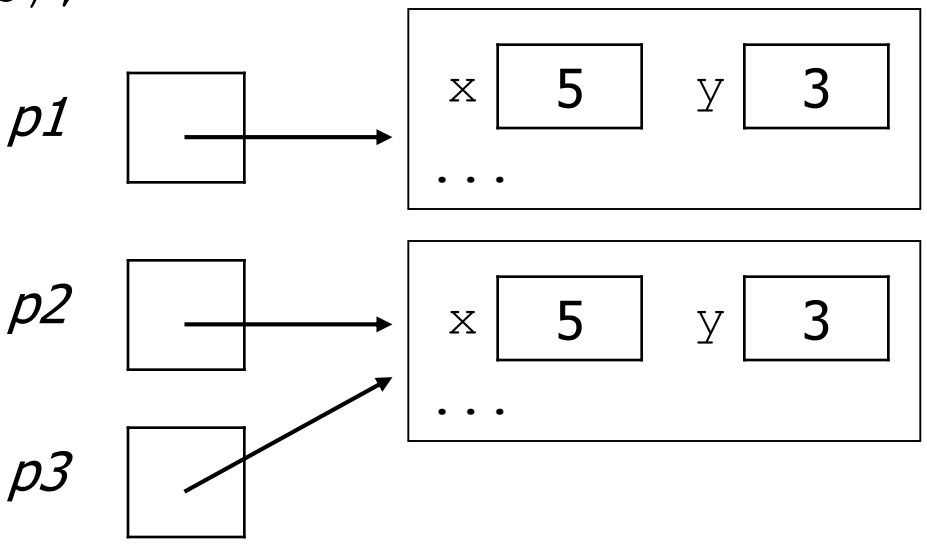
- You can make arrays or collections of `Object`s.

```
Object[] a = new Object[5];
a[0] = "hello";
a[1] = new Random();
List<Object> list = new ArrayList<Object>();
```

Recall: comparing objects

- The == operator does not work well with objects.
  - It compares references, not objects' state.
  - It produces `true` only when you compare an object to itself.

```
Point p1 = new Point(5, 3);
Point p2 = new Point(5, 3);
Point p3 = p2;

// p1 == p2 is false;
// p1 == p3 is false;
// p2 == p3 is true

// p1.equals(p2)?
// p2.equals(p3)?
```



Default equals method

- The `Object` class's `equals` implementation is very simple:

```
public class Object {
    ...
    public boolean equals(Object o) {
        return this == o;
    }
}
```

- However:
  - When we have used equals with various objects, it didn't behave like `==`. Why not? `if (str1.equals(str2)) { ...`
  - The Java API documentation for equals is elaborate. Why?

Implementing equals

```
public boolean equals(Object name) {
    statement(s) that return a boolean value ;
}
```

- The parameter to `equals` must be of type `Object`.
- Having an `Object` parameter means *any* object can be passed.
  - If we don't know what type it is, how can we compare it?

Casting references

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";

((Point) o1).translate(6, 2);      // ok
int len = ((String) o2).length();  // ok
Point p = (Point) o1;
int x = p.getX();                  // ok
```

- Casting references is different than casting primitives.
  - Really casting an `Object` reference into a `Point` reference.
  - Doesn't actually change the object that is referred to.
  - Tells the compiler to *assume* that `o1` refers to a `Point` object.

The instanceof keyword

```
if (variable instanceof type) {
    statement(s);
}
```

- Asks if a variable refers to an object of a given type.
  - Used as a `boolean` test.

```
String s = "hello";
Point p = new Point();
```

expression	result
`s instanceof Point`	`false`
`s instanceof String`	`true`
`p instanceof Point`	`true`
`p instanceof String`	`false`
`p instanceof Object`	`true`
`s instanceof Object`	`true`
`null instanceof String`	`false`
`null instanceof Object`	`false`

equals method for Points

```
// Returns whether o refers to a Point object with
// the same (x, y) coordinates as this Point.
public boolean equals(Object o) {
    if (o instanceof Point) {
        // o is a Point; cast and compare it
        Point other = (Point) o;
        return x == other.x && y == other.y;
    } else {
        // o is not a Point; cannot be equal
        return false;
    }
}
```

More about equals

- Equality is expected to be reflexive, symmetric, and transitive:

  `a.equals(a)` is `true` for every object `a`
  `a.equals(b)` ↔ `b.equals(a)`
  `(a.equals(b) && b.equals(c))` ↔ `a.equals(c)`

- No non-`null` object is equal to `null`:

  `a.equals(null)` is `false` for every object `a`

- Two sets are equal if they contain the same elements:

```
Set<String> set1 = new HashSet<String>();
Set<String> set2 = new TreeSet<String>();
for (String s : "hi how are you".split(" ")) {
    set1.add(s);    set2.add(s);
}
System.out.println(set1.equals(set2));   // true
```

The hashCode method

`public int hashCode()`

Returns an integer hash code for this object, indicating its preferred to place it in a hash table / hash set.

- Allows us to store non-`int` values in a hash set/map:

```
public static int hashFunction(Object o) {
    return Math.abs(o.hashCode()) % elements.length;
}
```

- How is `hashCode` implemented?
  - Depends on the type of object and its state.
    - Example: a String's `hashCode` adds the ASCII values of its letters.
  - You can write your own `hashCode` methods in classes you write.
    - All classes come with a default version based on memory address.

Polymorphism

Polymorphism

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently with each.

- A variable or parameter of type *T* can refer to any subclass of *T*.

```
Employee ed = new Lawyer();
Object otto = new Secretary();
```

  - When a method is called on `ed`, it behaves as a `Lawyer`.
  - You can call any `Employee` methods on `ed`.
    You can call any `Object` methods on `otto`.
    - You can *not* call any `Lawyer`-only methods on `ed` (e.g. `sue`).
      You can *not* call any `Employee` methods on `otto` (e.g. `getHours`).

Polymorphism examples

- You can use the object's extra functionality by casting.

```
Employee ed = new Lawyer();
ed.getVacationDays();                    // ok
ed.sue();                                // compiler error
((Lawyer) ed).sue();                     // ok
```

- You can't cast an object into something that it is not.

```
Object otto = new Secretary();
System.out.println(otto.toString());     // ok
otto.getVacationDays();                  // compiler error
((Employee) otto).getVacationDays();     // ok
((Lawyer) otto).sue();                   // runtime error
```

"Polymorphism mystery"

- Figure out the output from all methods of these classes:

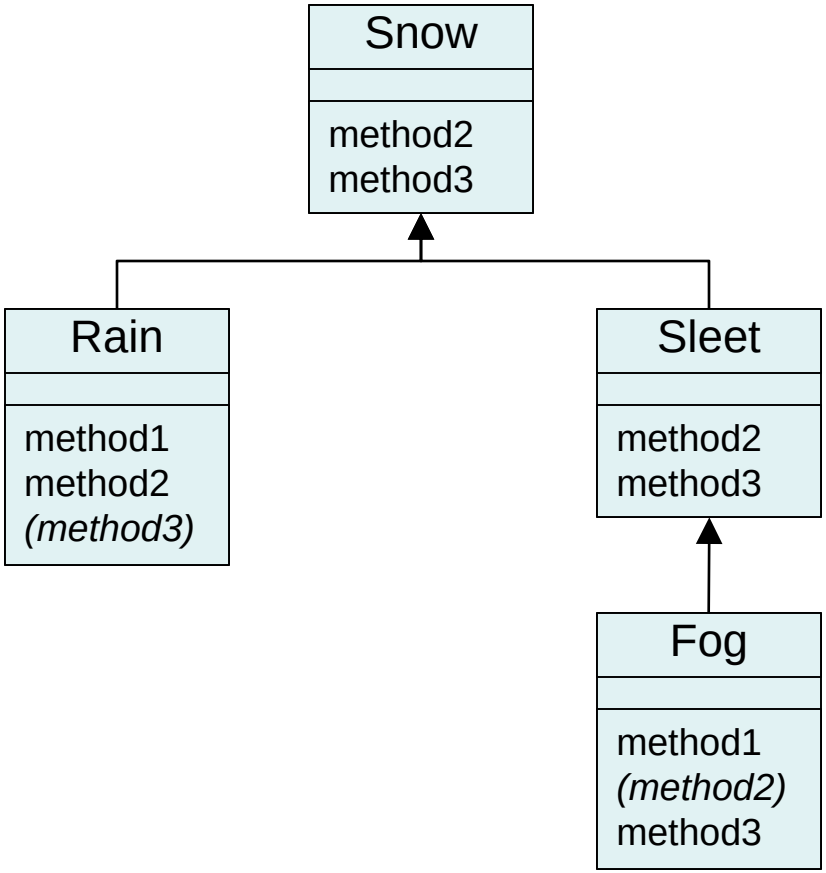
```
public class Snow {
    public void method2() {
        System.out.println("Snow 2");
    }

    public void method3() {
        System.out.println("Snow 3");
    }
}

public class Rain extends Snow {
    public void method1() {
        System.out.println("Rain 1");
    }

    public void method2() {
        System.out.println("Rain 2");
    }
}
```

"Polymorphism mystery"

```
public class Sleet extends Snow {
    public void method2() {
        System.out.println("Sleet 2");
        super.method2();
        method3();
    }

    public void method3() {
        System.out.println("Sleet 3");
    }
}

public class Fog extends Sleet {
    public void method1() {
        System.out.println("Fog 1");
    }

    public void method3() {
        System.out.println("Fog 3");
    }
}
```

Technique 1: diagram

- Diagram the classes from top (superclass) to bottom.



Technique 2: table

method	Snow	Rain	Sleet	Fog
method1		Rain 1		Fog 1
method2	Snow 2	Rain 2	Sleet 2 Snow 2 **method3()**	*Sleet 2* *Snow 2* ***method3()***
method3	Snow 3	*Snow 3*	Sleet 3	Fog 3

Italic - inherited behavior
Bold - dynamic method call

Mystery problem, no cast

```
Snow var3 = new Rain();
var3.method2();              // What's the output?
```

- If the problem does *not* have any casting, then:
  1. Look at the variable's type.
     If that type does not have the method: ERROR.

  2. Execute the method, behaving like the object's type.
     (The variable type no longer matters in this step.)

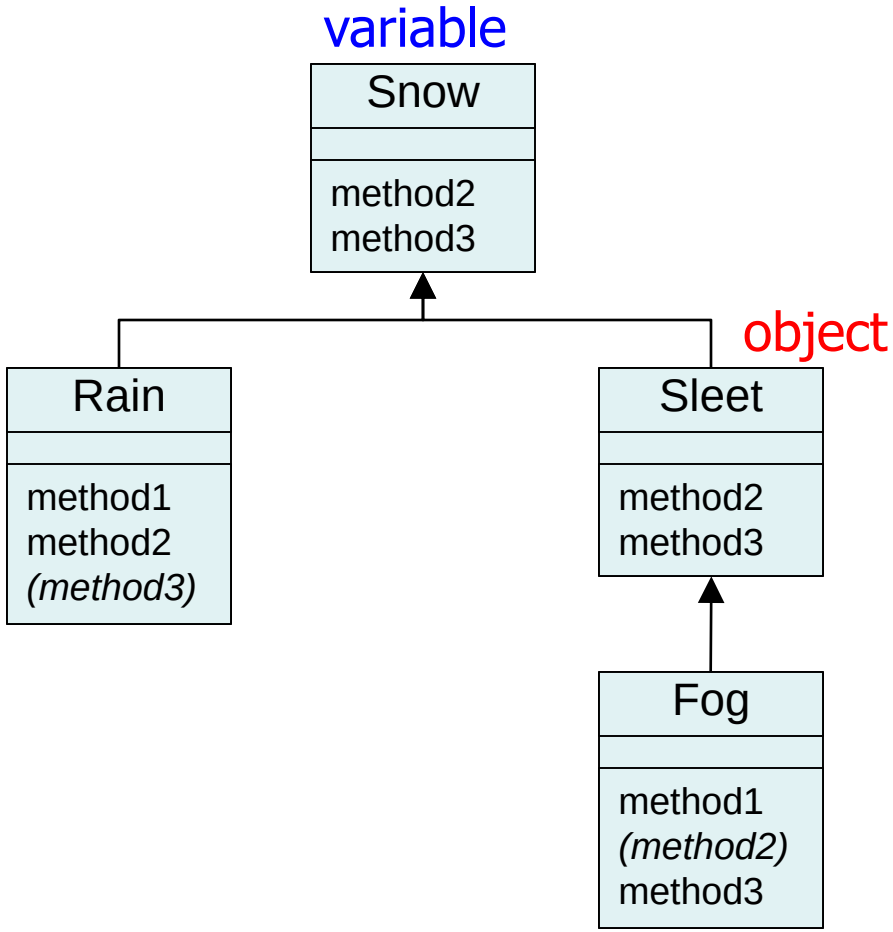
Example 1

- What is the output of the following call?

```
Snow var1 = new Sleet();
var1.method2();
```

- Answer:

```
Sleet 2
Snow 2
Sleet 3
```



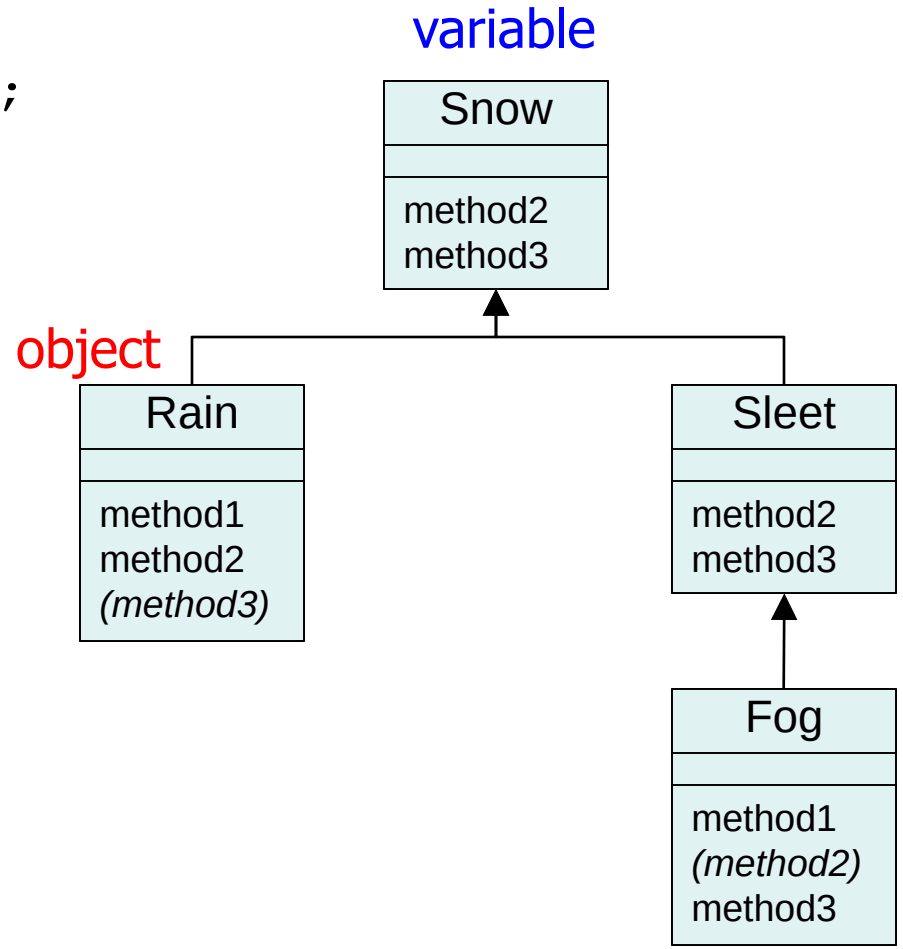
Example 2

- What is the output of the following call?

```
Snow var2 = new Rain();
var2.method1();
```

- Answer:

ERROR
(because `Snow` does not have a `method1`)



Mystery problem with cast

```
Snow var2 = new Rain();
((Sleet) var2).method2();   // What's the output?
```

- If the problem *does* have a type cast, then:
  1. Look at the cast type.
     If that type does not have the method: ERROR.
  2. Make sure the object's type is the cast type or is a subclass of the cast type. If not: ERROR. (No sideways casts!)
  3. Execute the method, behaving like the object's type.
     (The variable / cast types no longer matter in this step.)

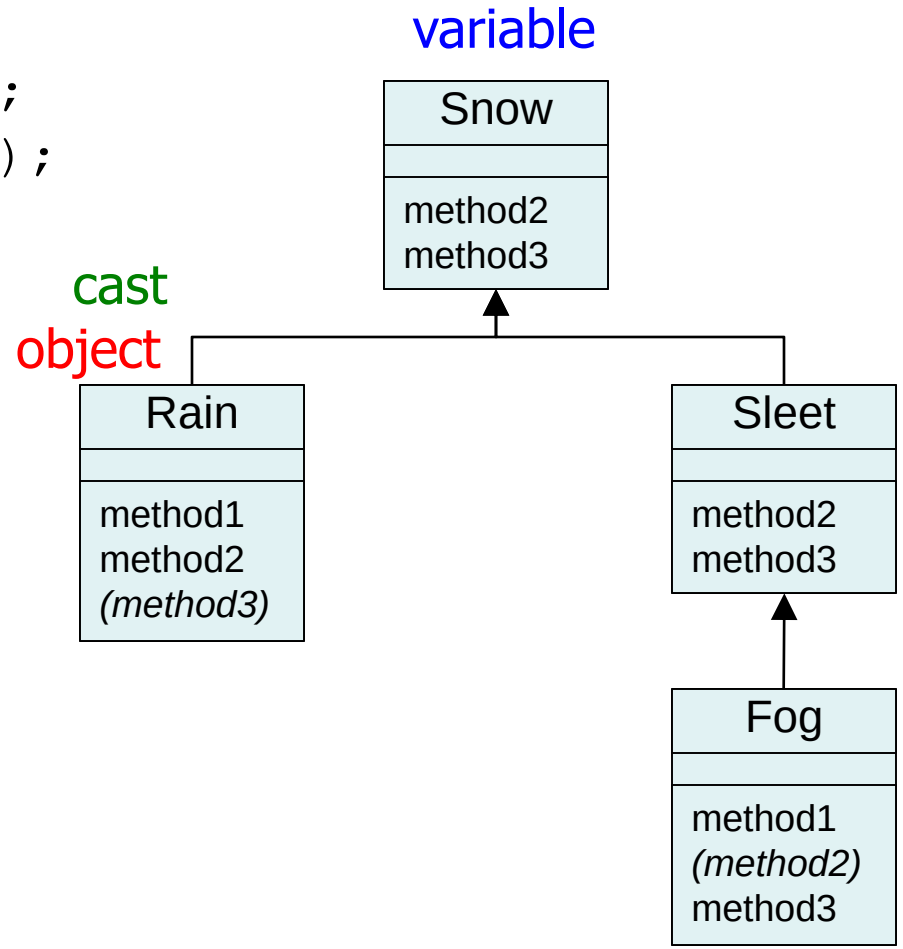
Example 3

- What is the output of the following call?

```
Snow var2 = new Rain();
((Rain) var2).method1();
```

- Answer:

```
Rain 1
```



Example 4

- What is the output of the following call?

```
Snow var2 = new Rain();
((Sleet) var2).method2();
```

- Answer:

  ERROR
  (because the object's type, `Rain`, cannot be cast into `Sleet`)