# Polymorphism

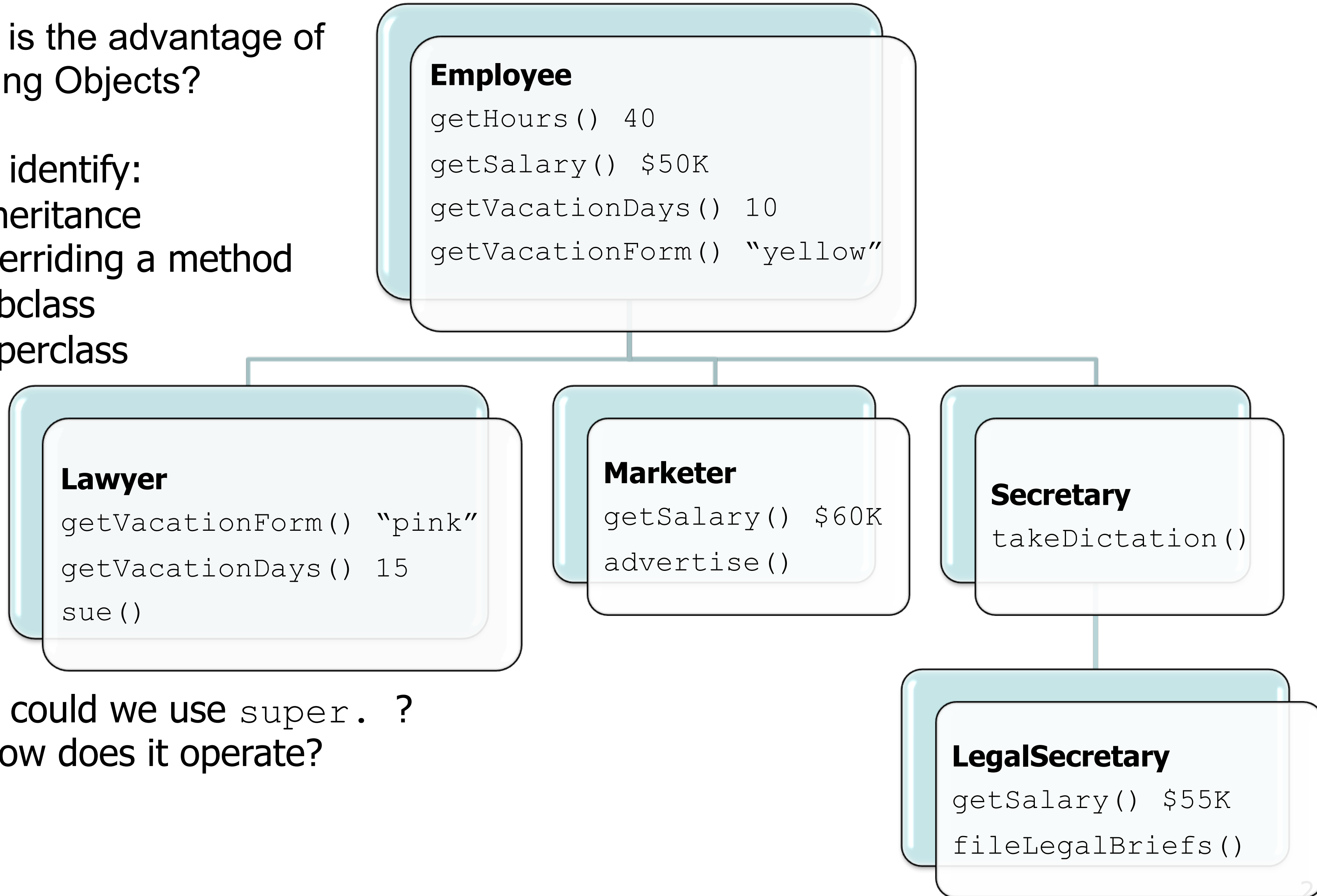
The Full Set of Slides…

Subset of the Supplement Lesson slides from: Building Java Programs, Chapter 9.3
by Stuart Reges and Marty Stepp (http://www.buildingjavaprograms.com/ ).

# Review our Office Classes

1. What is the advantage of creating Objects?

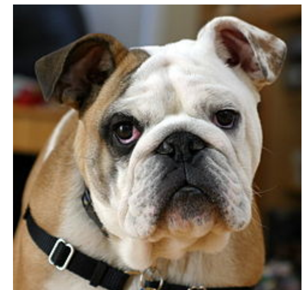
2. Let's identify:
   - Inheritance
   - Overriding a method
   - Subclass
   - Superclass




3. How could we use `super.` ? & how does it operate?

# Polymorphism

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently with each.
  - `System.out.println` can print any type of object.
    - Each one displays in its own way on the console.
  - `Collections.sort` can order any type of list.
    - provided the objects of the list implements the Comparable interface.
  - `ActorWorld` can interact with any type of Actor.
    - Each one moves, etc. in its own way.
  - In biology, Mammals can be a variety of animals.
    - Each one has fur, born live, etc.



# Coding with polymorphism

- A variable of type *T* can hold an object of any subclass of *T*.

```
TypeSuperclass name = new Subclass ();
```

variable object

```
Employee ed = new Lawyer();
```

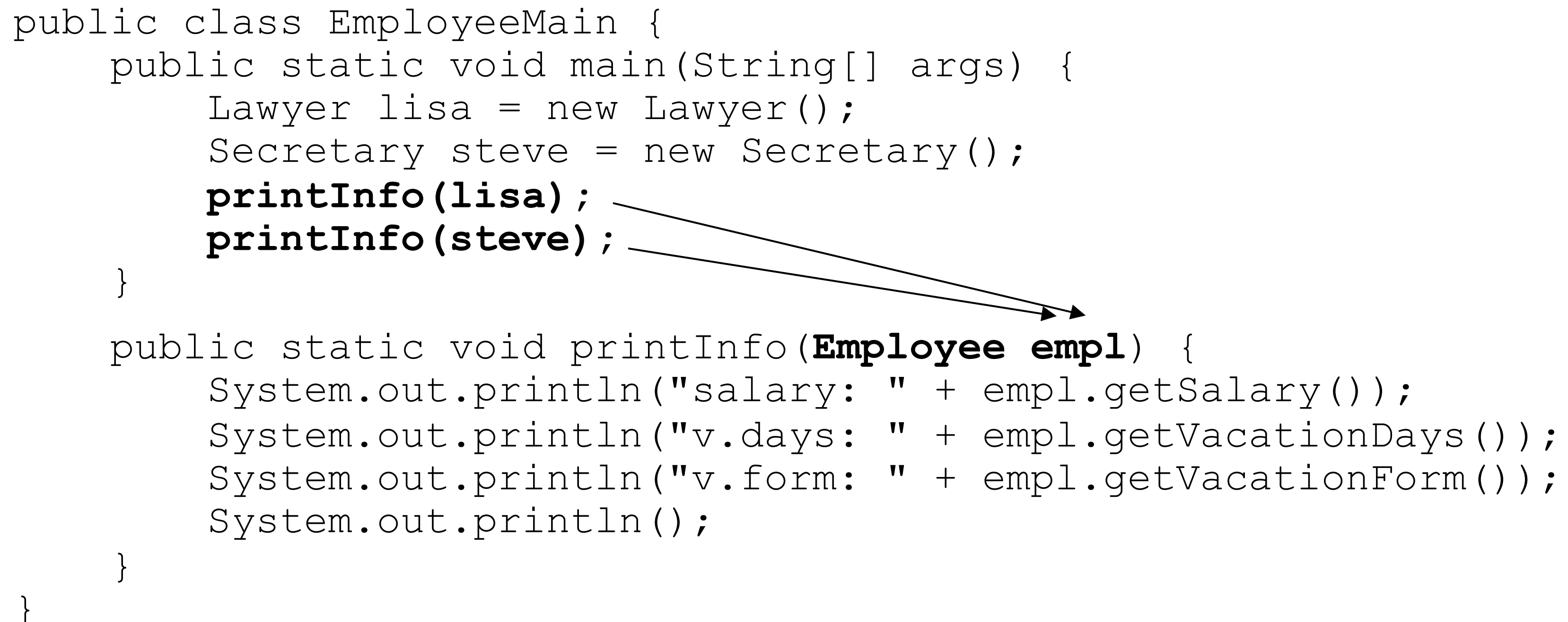
**Rules:**

- You can call any & <u>only</u> methods from the Type (`Employee`) class for `ed`. (i.e. `getSallary()` & `getVacationsForm()`)
- Method calls are always determined by the type of the actual object, not the type of the superclass object reference, so when a method is called on `ed`, it behaves as a `Lawyer`.

```
System.out.println(ed.getSalary());           // 50000.0
System.out.println(ed.getVacationForm());     // pink
```

# Polymorphism and parameters

- You can pass any subtype of a parameter's type.



```
public class EmployeeMain {
    public static void main(String[] args) {
        Lawyer lisa = new Lawyer();
        Secretary steve = new Secretary();
        printInfo(lisa);
        printInfo(steve);
    }

    public static void printInfo(Employee empl) {
        System.out.println("salary: " + empl.getSalary());
        System.out.println("v.days: " + empl.getVacationDays());
        System.out.println("v.form: " + empl.getVacationForm());
        System.out.println();
    }
}
```

OUTPUT:

```
salary: 50000.0            salary: 50000.0
v.days: 15                 v.days: 10
v.form: pink               v.form: yellow
```

# Polymorphism and arrays

- Arrays of superclass types can store any subtype as elements.

```
public class EmployeeMain2 {
    public static void main(String[] args) {
        Employee[] e = { new Lawyer(),   new Secretary(),
                         new Marketer(), new LegalSecretary() };

        for (int i = 0; i < e.length; i++) {
            System.out.println("salary: " + e[i].getSalary());
            System.out.println("v.days: " + e[i].getVacationDays());
            System.out.println();
        }
    }
}
```

Output:

```
salary: 50000.0
v.days: 15

salary: 50000.0
v.days: 10

salary: 60000.0
v.days: 10

salary: 55000.0
v.days: 10
```

# Polymorphism problems

- 4-5 classes with inheritance relationships are shown.
- A client program calls methods on objects of each class.
- You must read the code and determine the client's output.
- We typically find such a question on AP & UW in HS exams!

# A polymorphism problem

- Suppose that the following four classes have been declared:

```
public class Foo {
    public void method1() {
        System.out.println("foo 1");
    }

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

    public String toString() {
        return "foo";
    }
}

public class Bar extends Foo {
    public void method2() {
        System.out.println("bar 2");
    }
}
```

# A polymorphism problem

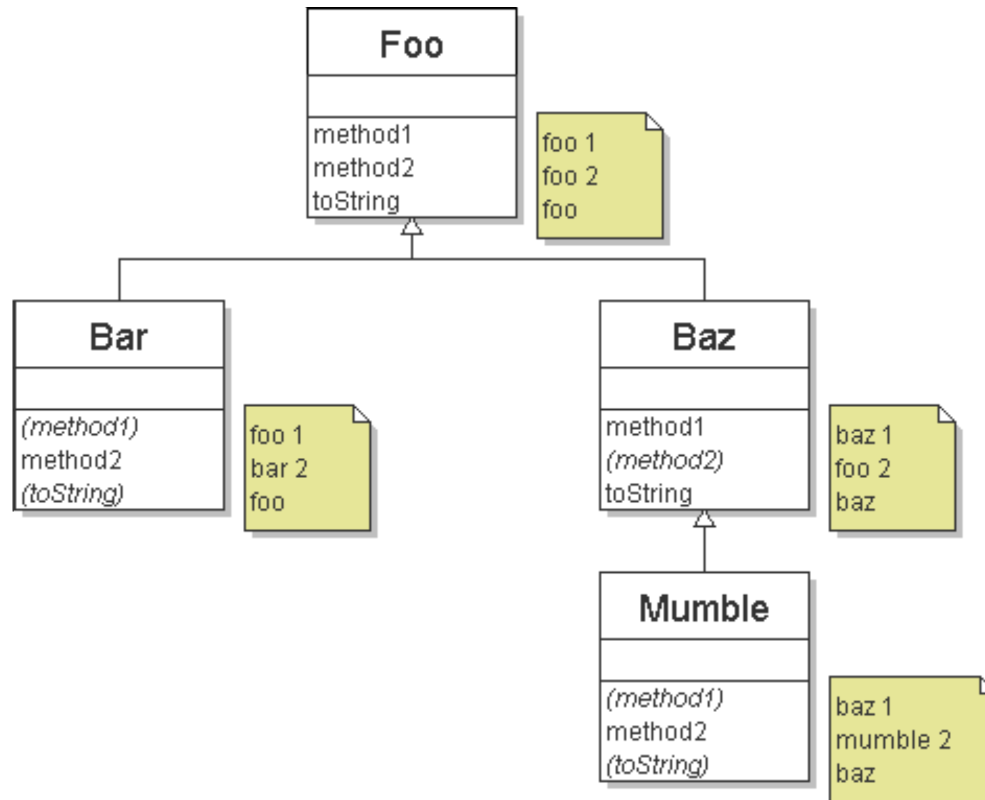
```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

    public String toString() {
        return "baz";
    }
}

public class Mumble extends Baz {
    public void method2() {
        System.out.println("mumble 2");
    }
}
```

- What would be the output of the following client code?

```
Foo[] pity = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```

# Diagramming the classes

- Add classes from top (superclass) to bottom (subclass).
- Include all inherited methods.



# Finding output with tables

| method | Foo | Bar | Baz | Mumble |
| --- | --- | --- | --- | --- |
| method1 | foo 1 | *foo 1* | baz 1 | *baz 1* |
| method2 | foo 2 | bar 2 | *foo 2* | mumble 2 |
| toString | foo | *foo* | baz | *baz* |

# Polymorphism answer

```
Foo[] pity = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```

- Output:

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1
mumble 2

foo
foo 1
foo 2
```

# Another problem

- The order of the classes is jumbled up.
- The methods sometimes call other methods (tricky!).

```
public class Lamb extends Ham {
    public void b() {
        System.out.print("Lamb b    ");
    }
}
public class Ham {
    public void a() {
        System.out.print("Ham a    ");
        b();
    }
    public void b() {
        System.out.print("Ham b    ");
    }
    public String toString() {
        return "Ham";
    }
}
```

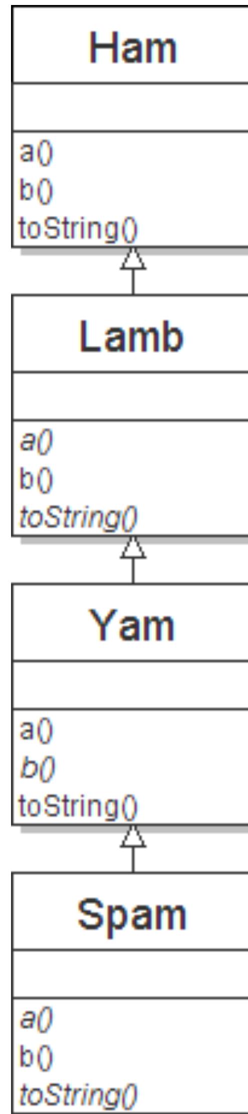
# Another problem 2

```
public class Spam extends Yam {
    public void b() {
        System.out.print("Spam b   ");
    }
}
public class Yam extends Lamb {
    public void a() {
        System.out.print("Yam a   ");
        super.a();
    }
    public String toString() {
        return "Yam";
    }
}
```

- What would be the output of the following client code?

```
Ham[] food = {new Lamb(), new Ham(), new Spam(), new Yam()};
for (int i = 0; i < food.length; i++) {
    System.out.println(food[i]);
    food[i].a();
    System.out.println();     // to end the line of output
    food[i].b();
    System.out.println();     // to end the line of output
    System.out.println();
}
```

# Class diagram



# Polymorphism at work

- `Lamb` inherits `Ham`'s `a`. `a` calls `b`. But `Lamb` overrides `b`...

```
public class Ham {
    public void a() {
        System.out.print("Ham a    ");
        b();
    }

    public void b() {
        System.out.print("Ham b    ");
    }

    public String toString() {
        return "Ham";
    }
}

public class Lamb extends Ham {
    public void b() {
        System.out.print("Lamb b    ");
    }
}
```

- `Lamb`'s output from `a`:

```
Ham a    Lamb b
```

# The table

| **method** | **Ham** | **Lamb** | **Yam** | **Spam** |
|---|---|---|---|---|
| a | Ham a<br>**b()** | *Ham a*<br>***b()*** | Yam a<br>Ham a<br>**b()** | *Yam a*<br>*Ham a*<br>***b()*** |
| b | Ham b | Lamb b | Lamb b | Spam b |
| toString | Ham | *Ham* | Yam | *Yam* |

# The answer

```
Ham[] food = {new Lamb(), new Ham(), new Spam(), new Yam()};
for (int i = 0; i < food.length; i++) {
    System.out.println(food[i]);
    food[i].a();
    food[i].b();
    System.out.println();
}
```

- Output:

```
Ham
Ham a    Lamb b
Lamb b

Ham
Ham a    Ham b
Ham b

Yam
Yam a    Ham a    Spam b
Spam b

Yam
Yam a    Ham a    Lamb b
Lamb b
```

# Casting references

- A variable can only call that type's methods, not a subtype's.

```
Employee ed = new Lawyer();
int hours = ed.getHours();  // ok; it's in Employee
ed.sue();                   // compiler error
```

  - The compiler's reasoning is, variable `ed` could store any kind of employee, and not all kinds know how to `sue` .

- To use `Lawyer` methods on `ed`, we can type-cast it.

```
Lawyer theRealEd = (Lawyer) ed;
theRealEd.sue();                 // ok

((Lawyer) ed).sue();             // shorter version
```

# More about casting

- The code crashes if you cast an object too far down the tree.

```
Employee eric = new Secretary();
((Secretary) eric).takeDictation("hi");      // ok
((LegalSecretary) eric).fileLegalBriefs();  // exception

// (Secretary object doesn't know how to file briefs)
```

- You can cast only up and down the tree, not sideways.

```
Lawyer linda = new Lawyer();
((Secretary) linda).takeDictation("hi");    // error
```

- Casting doesn't actually change the object's behavior.
  It just gets the code to compile/run.

```
((Employee) linda).getVacationForm()    // pink (Lawyer's)
```

# Another exercise

- Assume that the following classes have been declared:

```
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");
    }
}
```

# Exercise

```
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");
    }
}
```

# Exercise

What happens when the following examples are executed?

- Example 1:

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

- Example 2:

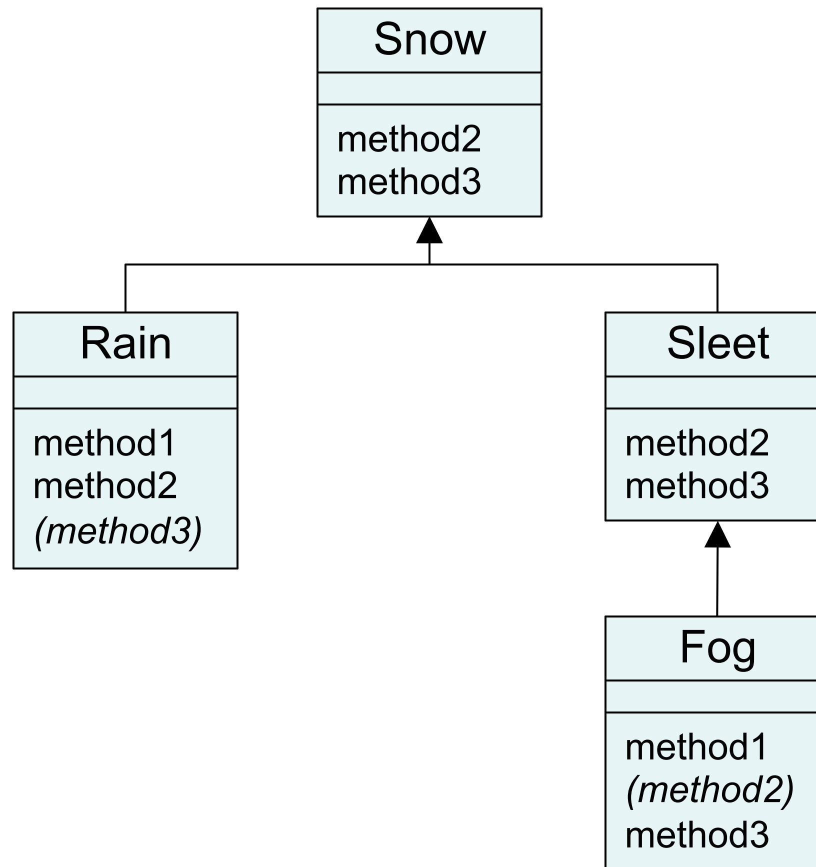
```
Snow var2 = new Rain();
var2.method1();
```

- Example 3:

```
Snow var3 = new Rain();
((Sleet) var3).method3();
```

# 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<br>Snow 2<br>**method3()** | *Sleet 2*<br>*Snow 2*<br>***method3()*** |
| method3 | Snow 3 | *Snow 3* | Sleet 3 | Fog 3 |

*Italic* - inherited behavior
**Bold** - dynamic method call

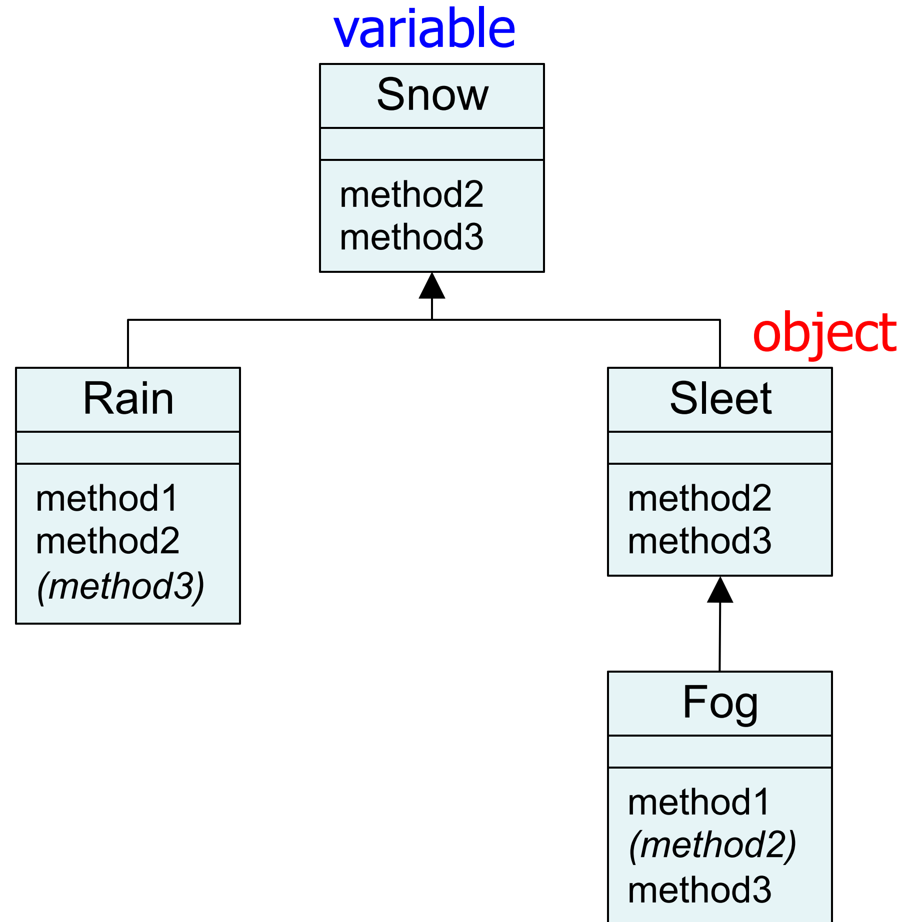
# Example 1

- Example:

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

- Output:

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



# Example 1 b

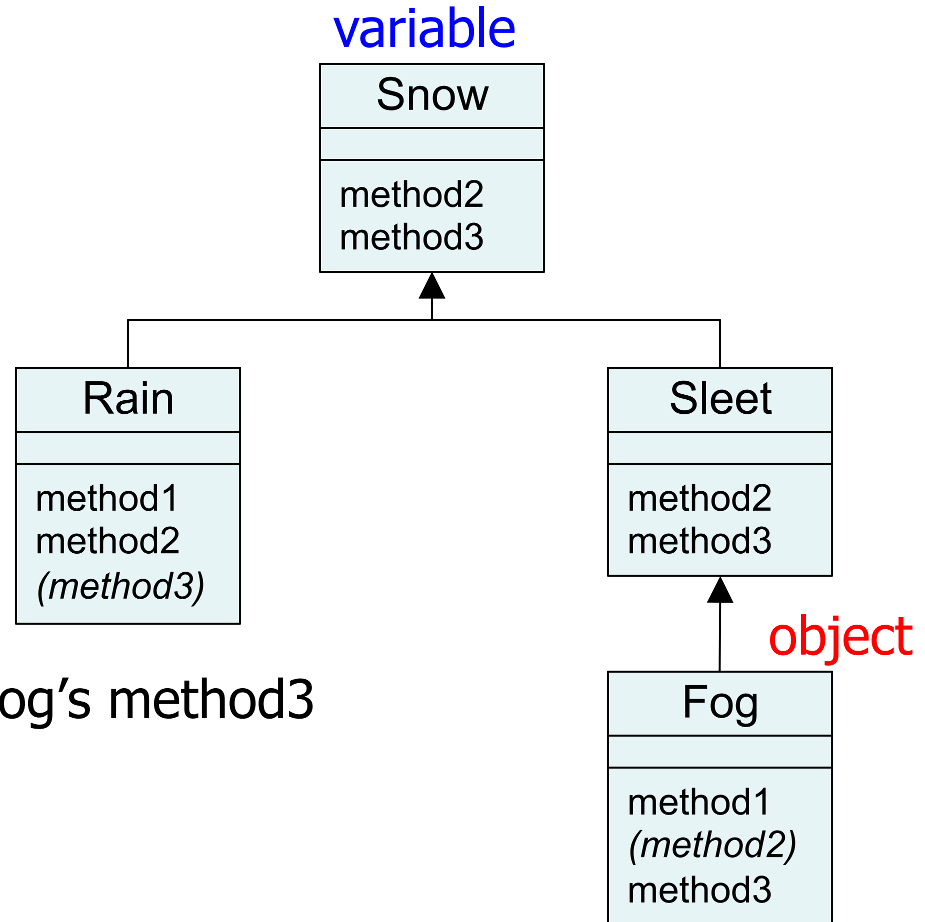
- Example:

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

- Output:

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

Because it's dynamic! Uses Fog's method3



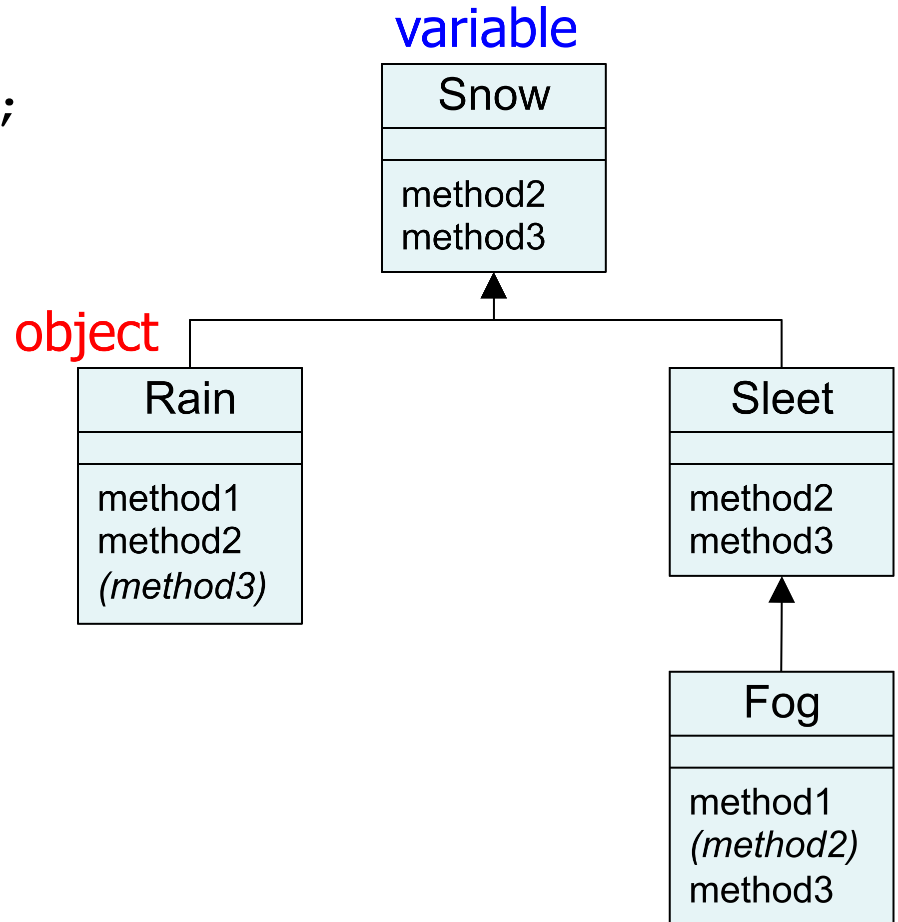
# Example 2

- Example:

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

- Output:

None!
There is an error,
because `Snow` does not
have a `method1`.



# Example 3

- Example:

```
Snow var3 = new Rain();
((Sleet) var3).method2();
```

- Output:

None!
There is an error because a `Rain` is not a `Sleet`.