CSE 143
Lecture 12

Inheritance

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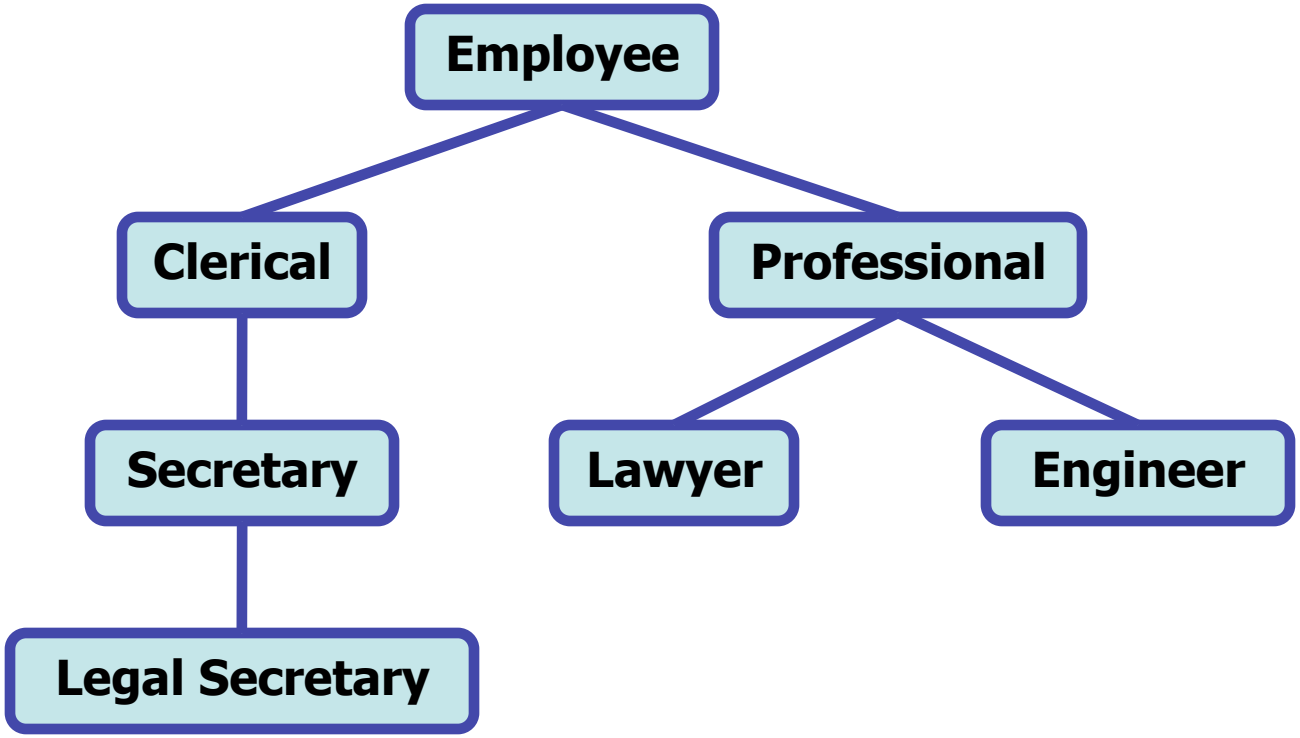
Intuition: Employee Types

- Consider this (partial) hierarchy of employee types:



- What kind of tasks can each employee type perform?

Intuition: Employee Types

- What tasks should *all* employees be able to do?
  - show up for work
  - work
  - collect paychecks
- What tasks can a lawyer do that an engineer cannot?
  - sue
  - file legal briefs
- Which kind of secretary (regular or legal) can accomplish a greater variety of tasks?
  - legal secretaries can do all regular secretarial work and have special training for additional tasks

Intuition: Employee Training

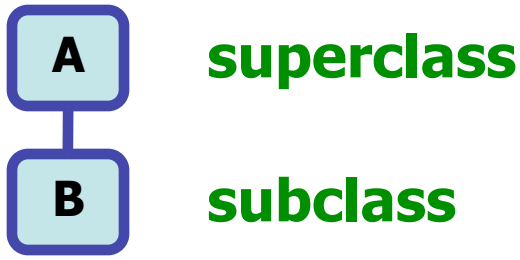
- On your first day at work, you'll likely receive some general training for your new job
- If it's a big company (like Microsoft), you'll likely receive this with many other types of employees
  - engineers, business people, lawyers, etc
- After this general training, you'll probably receive some specialized training
  - "I know yesterday they told you to fill out your time-card on the white sheet, but here we do it online instead"
- We call this kind of replacement **overriding**
  - the new behavior overrides/replaces the old behavior

Inheritance Overview

- Java does something similar with inheritance
- If we want to show an inheritance relationship between two classes, we use the **`extends`** keyword:

```
public class B extends A {
    ...
}
```

- Which sets up the following inheritance hierarchy:



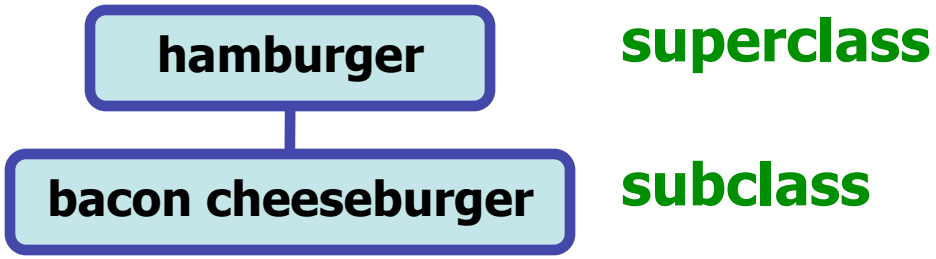
superclass

subclass

Superclasses and Subclasses

- In the previous example, **`A`** is the **superclass** of **`B`** (**`A`** is above **`B`** on the hierarchy), and **`B`** is a **subclass** of **`A`** (**`B`** is below **`A`** on the hierarchy)

- This wording is somewhat different from standard English:

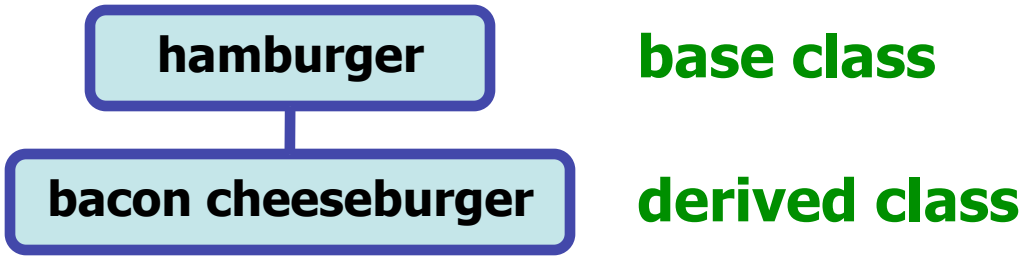


- So, a "super bacon cheeseburger" is just a hamburger
  - that doesn't seem right: it's missing bacon and cheese!
  - but that's how inheritance works

Base and Derived Classes

- We also say **`A`** is the **base class** of **`B`**, and **`B`** is a **derived class** of **`A`**

- This makes a little more sense:



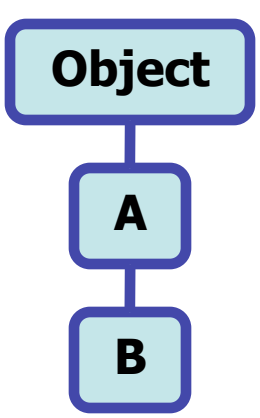
- A hamburger provides the basic form of a bacon cheeseburger. Alternately, a bacon cheeseburger is a hamburger with minor additions

Extending `Object`

- Consider the class **`A`** that we've been discussing:

```
public class A {
    ...
}
```

- We didn't write that **`A`** extends anything, but it automatically extends **`Object`**:



This diagram is more complete than before. However, we often don't draw `Object` because we know it *must* be there

- All the classes you've written so far extend **`Object`**

`Object`

- **`Object`** is a very general class

- Since every class must extend **`Object`**, either directly like **`A`** or indirectly like **`B`**, **`Object`** must have only state and behavior that is needed by every class:
  - **`equals`**
  - **`toString`**
    - this is where the weird default **`toString`** comes from
  - and more (but we won't bother with the others)

- Why doesn't **`Object`** contain a **`compareTo`** method?

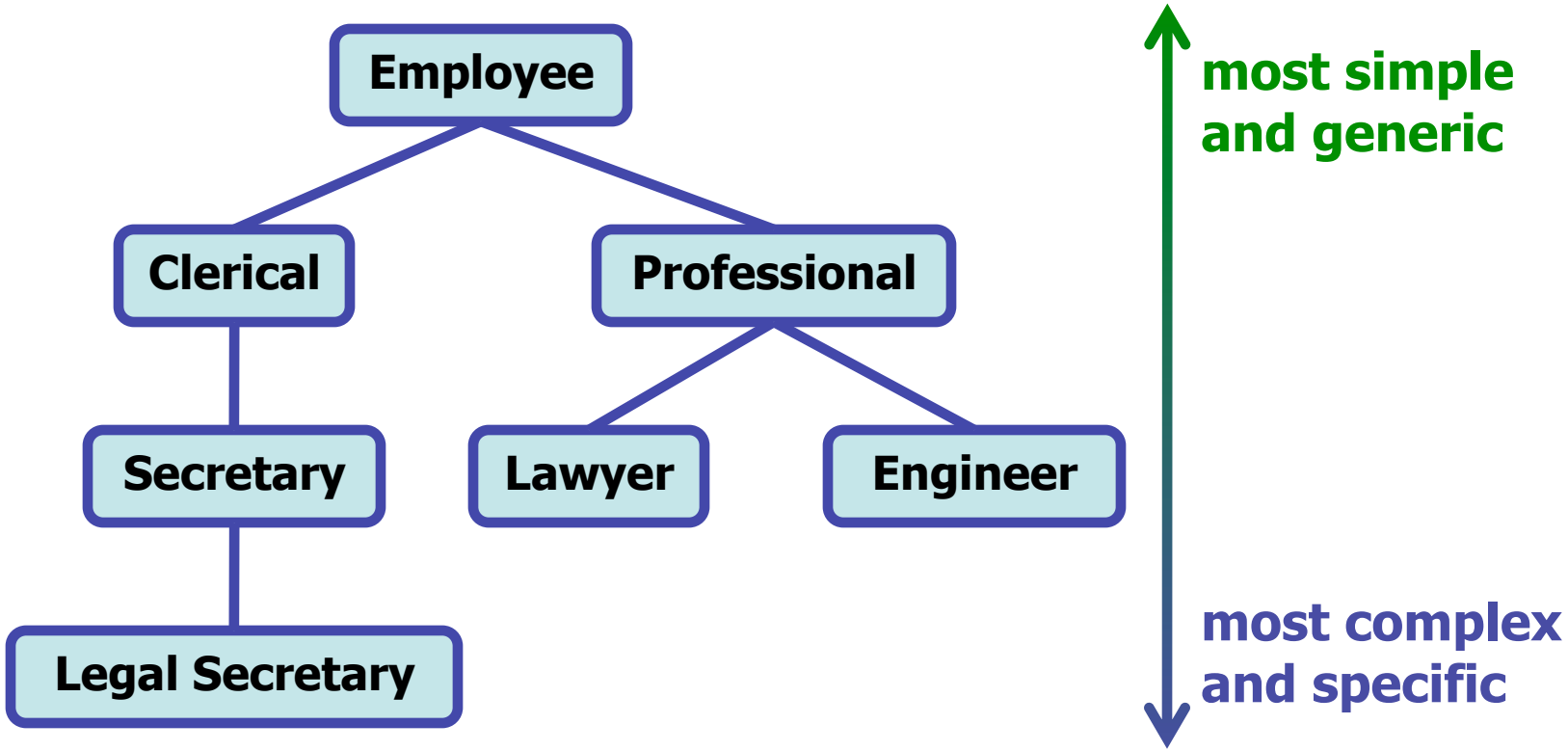
Why Use Inheritance?

- Inheritance allows us to reuse code we've already written
  - this makes it a powerful tool
- Inheritance also allows us to express the core relationship between different classes
- Subclasses allow us to do two things:
  - add new state and behavior (fields and methods)
    - useful when a superclass has most of the needed state and behavior
  - override inherited methods
    - useful when you need to modify the way an inherited method functions

Substituting

- When can we substitute one object for another?

- Recall our employee hierarchy:



Substituting

- We can always substitute a more specific object for a less specific one. With inheritance, we call this an "is-a" relationship
  - a lawyer **is-a** professional employee **is-an** employee
    - a lawyer can substitute for an employee, etc
  - a legal secretary **is-a** secretary **is-a** clerical employee **is-an** employee
    - a legal secretary can substitute for a secretary, etc

- You can see the is-a relationship by moving up the inheritance hierarchy

- It's *not* ok to substitute across the hierarchy
  - a secretary is NOT a lawyer and can't substitute for one

Substituting

- Recall our classes `B` and `A` (`B extends A`)
- Obviously we can do this:

```
A x = new A();
B y = new B();
```

variable type **object type**

- But what if the variable type and object type don't match?

```
A x = new B();
```
perfectly fine

```
B y = new A();
```
not good!

Substituting

- But, what does it mean when the variable type doesn't match the object type?

```
A x = new B();
```

- We are limited to the behaviors of the variable type
  - for **`x`** above, we are limited to using only methods defined for class **`A`** (which may be inherited from **`Object`**)

- When executed, the methods will behave as defined in the object type
  - for **`x`** above, the methods will execute as defined in **`B`** (which may be inherited from **`A`** or **`Object`**)

Casting

- Suppose that:
  - you're an unemployed legal secretary
  - you know that legal secretaries earn $20 an hour
  - you know that generic secretaries earn $15 an hour
  - you accept a job as a generic secretary for $15 an hour
- So far, this is fine (just not ideal)
- But what if:
  - your employer discovers that you're a legal secretary
  - ...and wants you to do legal secretary work
  - ...for just $15 an hour?
- Is that ok?

Casting

- No, it's not ok!

- If he wants you to do legal secretary work, he can renegotiate your contract to reflect this
  - and pay you $20 an hour

- Java lets us do something similar when we class cast
  - the class cast essentially renegotiates the contract

```
Secretary you = new LegalSecretary();
LegalSecretary youWithRaise = (LegalSecretary)you;
```

cast

Exercise: Inheritance Mystery

- 4-5 classes with inheritance relationships are shown
  - the class names *won't* make sense (inheritance *mystery*)

- A client program calls methods on objects of each class
  - some questions involve casting
  - some lines of code are illegal and produce errors

- You must read the code and determine what it does
  - if it produces output, you must be precise
  - if it produces an error, you need to specify what kind of error (either a compiler error or a runtime error)

- A similar problem **will** be on your midterm!

Exercise: Inheritance Mystery

- Assume that the following classes have been declared:

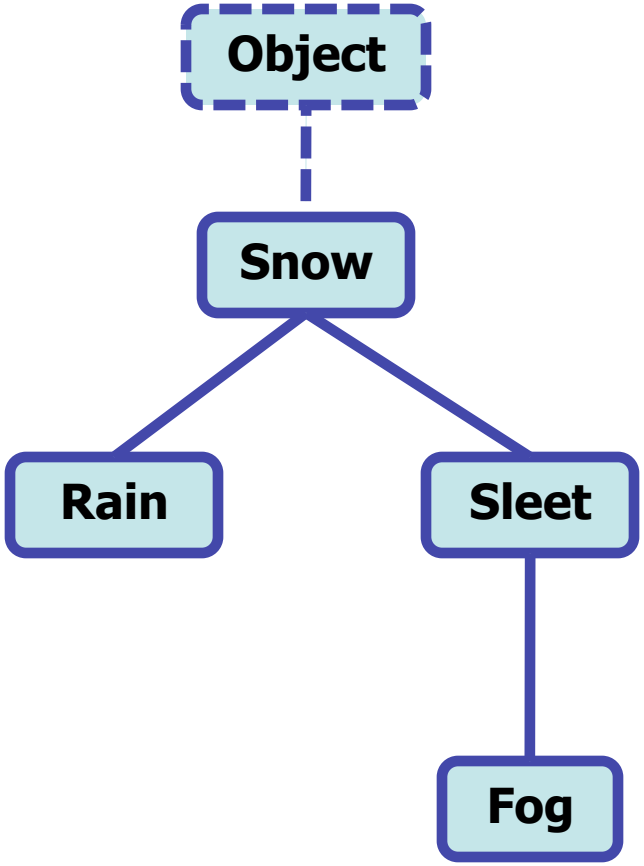
```
public class Fog extends Sleet {
    public void method1() {
        System.out.println("Fog 1");
    }

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


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

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

Exercise: Inheritance 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 Snow {
    public void method2() {
        System.out.println("Snow 2");
    }

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

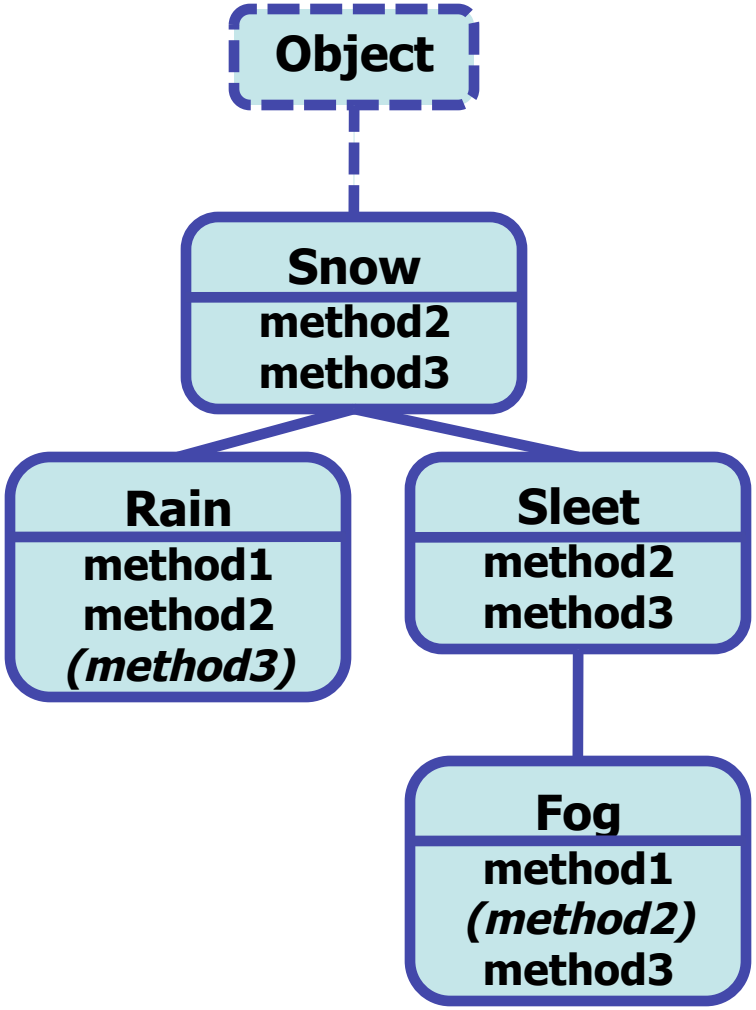
Technique: Diagramming

- First, determine the inheritance hierarchy:



Technique: Diagramming

- ...and determine where methods are defined and inherited



Method Calls

- Let's look a little closer at **`Sleet`**'s **`method2()`**:

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

- **`super`** is a Java keyword to look to the super class
  - so **`super.method2()`** is like saying **`Snow.method2()`**
  - **`super`** is static: it always refers to **`Snow`**'s methods

- however, the call on **`method3`** is dynamic
  - it always runs the current version of **`method3`**, because it's possible that another subclass can redefine **`method3`**

Technique: Behavior Table

- Then, figure out the behaviors of each type of object

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`

Italics - inherited behavior

Circled - dynamic method call

Exercise

What happens when the following examples are executed?

- Example 1 (letter a on handout #15):

```
Snow var1 = new Sleet();
var1.method3();
```

- Example 2 (letter c on handout #15):

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

- Example 3 (letter o on handout #15):

```
Snow var3 = new Fog();
((Sleet)var3).method1();
```

- Example 4 (letter m on handout #15):

```
Snow var3 = new Fog();
((Rain)var3).method1();
```

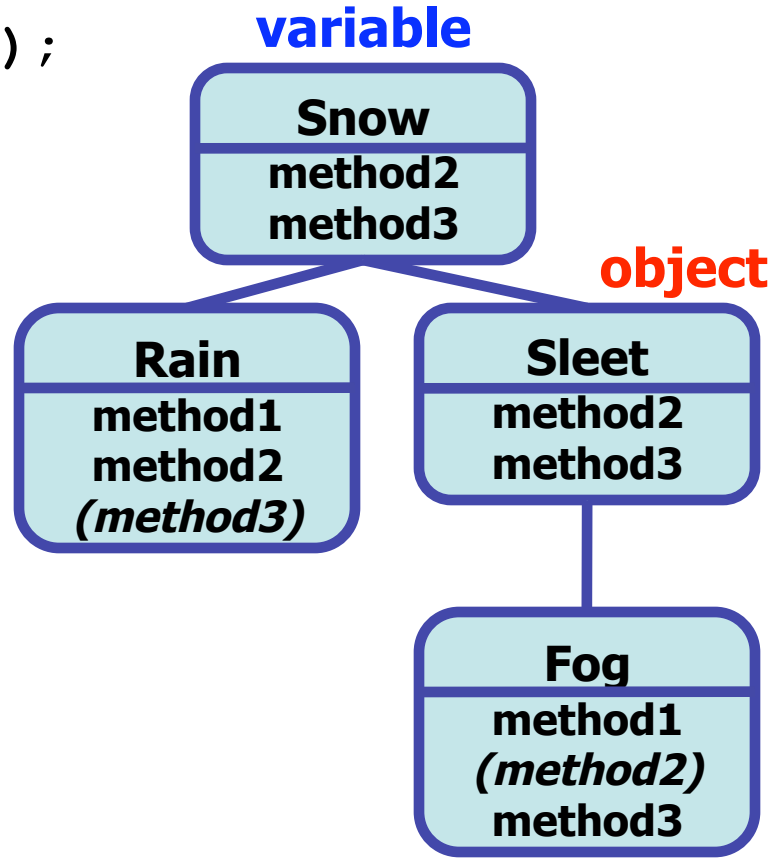
Example 1

- Problem:

```
Snow var1 = new Sleet();
var1.method3();
```

- Output:

```
Sleet 3
```



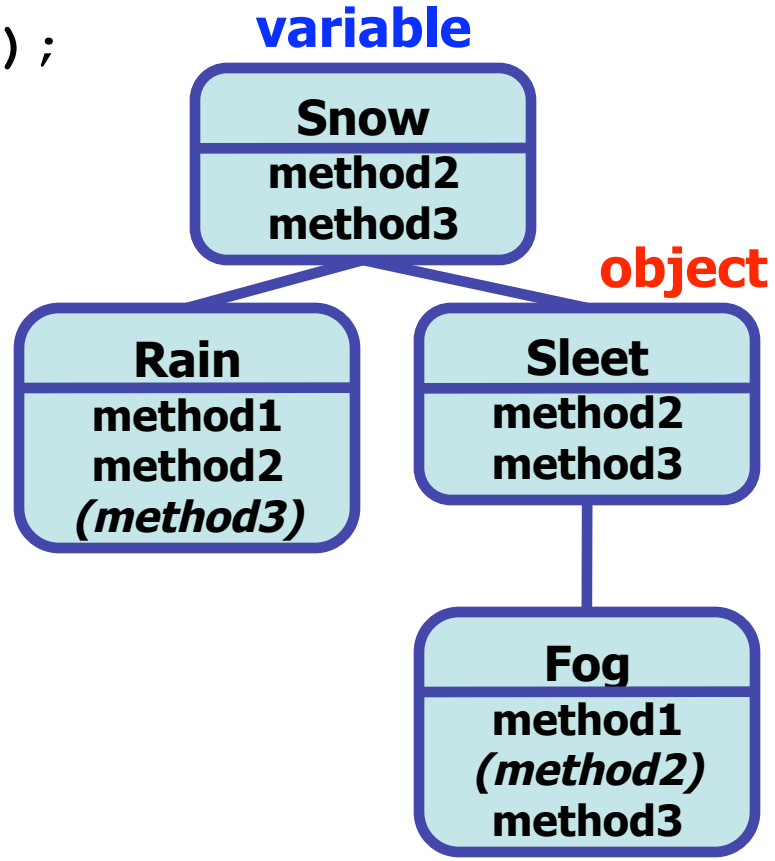
Example 2

- Problem:

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

- Output:

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



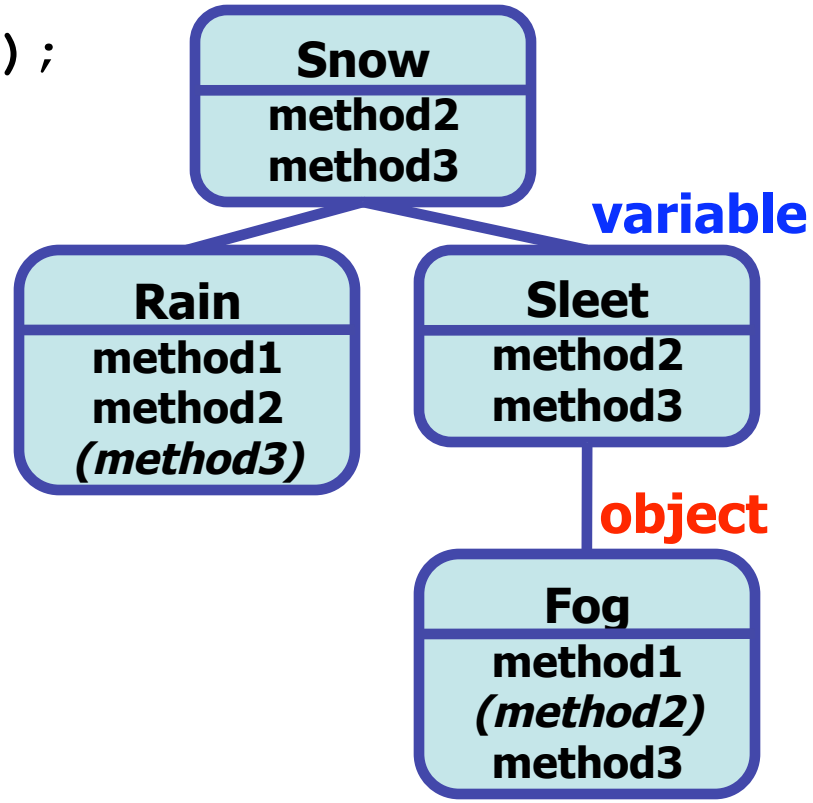
Example 3

- Problem:

```
Snow var3 = new Fog();
((Sleet)var3).method1();
```

- Output:

```
No output!
Compiler error!
Sleet doesn't have a
method1()!
```



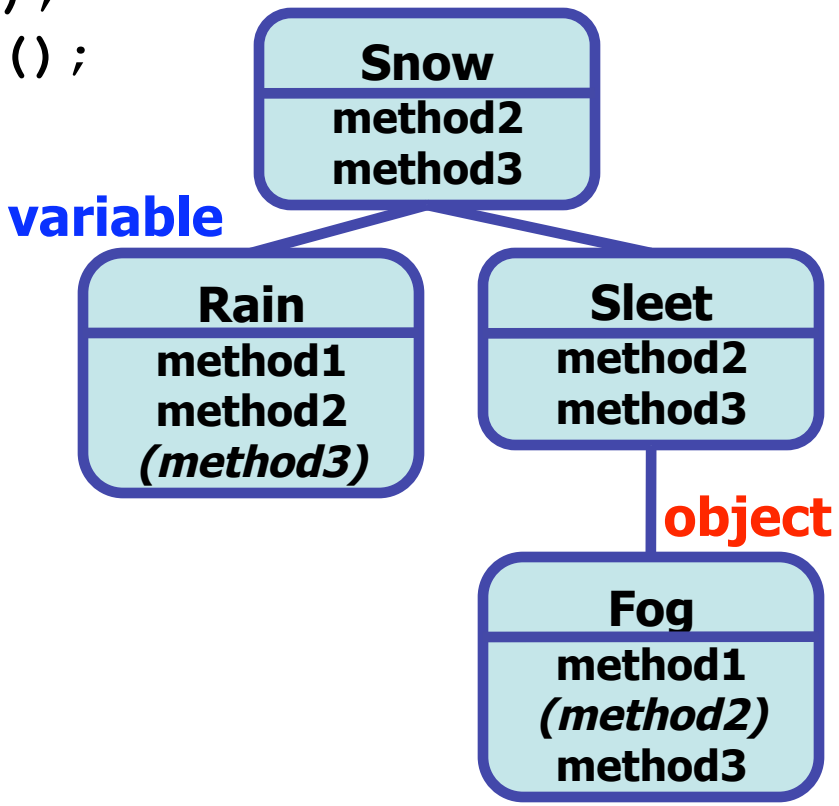
Example 4

- Problem:

```
Snow var3 = new Fog();
((Rain)var3).method1();
```

- Output:

```
No output!
Runtime error!
A Fog is not a Rain!
```



Solving Inheritance Mystery

- Steps to solving inheritance mystery:

1. Look at the variable type (if there is a cast, look at the casted variable type). If the variable type does not have the requested method the compiler will report an error.

2. If there was a cast, make sure the casted variable type is compatible with the object type (i.e. ensure the object type is a subclass of the variable type). If they are not compatible, a runtime error (**`ClassCastException`**) will occur.

3. Execute the method in question, behaving like the object type (the variable type and casted variable type no longer matter at all)

Solutions to Handout #15

- Solutions for letters a through j:

Letter	Code	Output
a	`var1.method1();`	`compiler error`
b	`var2.method1();`	`Rain 1`
c	`var1.method2();`	`Sleet 2/Snow 2/Sleet 3`
d	`var2.method2();`	`Rain 2`
e	`var3.method2();`	`Sleet 2/Snow 2/Fog 3`
f	`var4.method2();`	`compiler error`
g	`var5.method2();`	`Sleet 2/Snow 2/Fog 3`
h	`var1.method3();`	`Sleet 3`
i	`var2.method3();`	`Snow 3`
j	`var3.method3();`	`Fog 3`

Solutions to Handout #15

- Solutions for letters k through t:

Letter	Code	Output
k	`var4.method3();`	`compiler error`
l	`var5.method3();`	`Fog 3`
m	`((Rain)var3).method1();`	`runtime error`
n	`((Fog)var5).method1();`	`Fog 1`
o	`((Sleet)var3).method1();`	`compiler error`
p	`((Sleet)var3).method3();`	`Fog 3`
q	`((Fog)var6).method3();`	`runtime error`
r	`((Snow)var4).method2();`	`Snow 2`
s	`((Sleet)var4).method3();`	`runtime error`
t	`((Rain)var6).method3();`	`Snow 3`