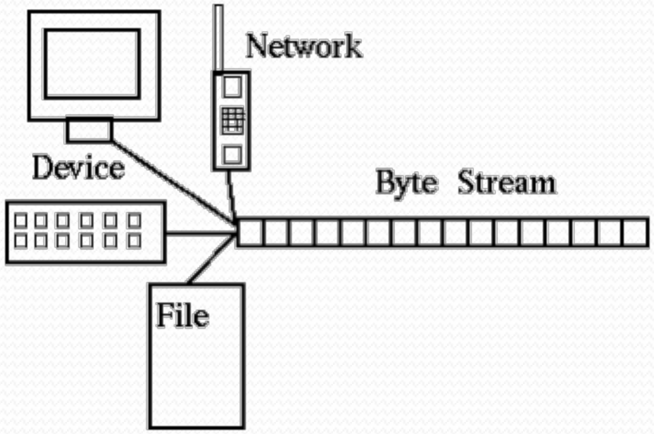
Building Java Programs

Inheritance and Polymorphism

Input and output streams

- **stream**: an abstraction of a source or target of data
  - 8-bit bytes flow to (output) and from (input) streams

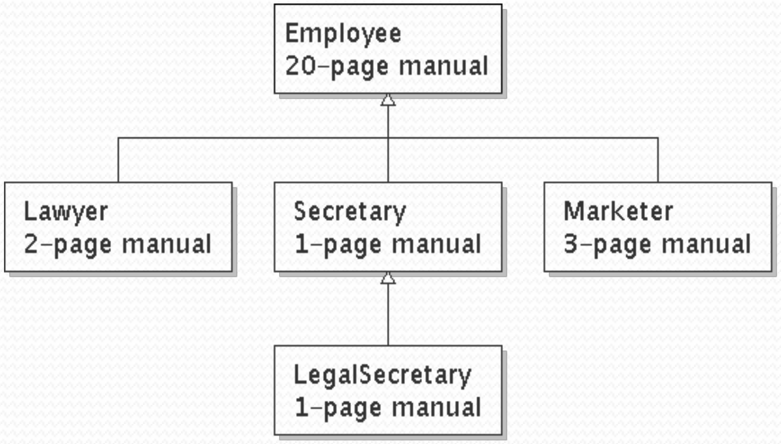
- can represent many data sources:
  - files on hard disk
  - another computer on network
  - web page
  - input device (keyboard, mouse, etc.)



- represented by `java.io` classes
  - `InputStream`
  - `OutputStream`

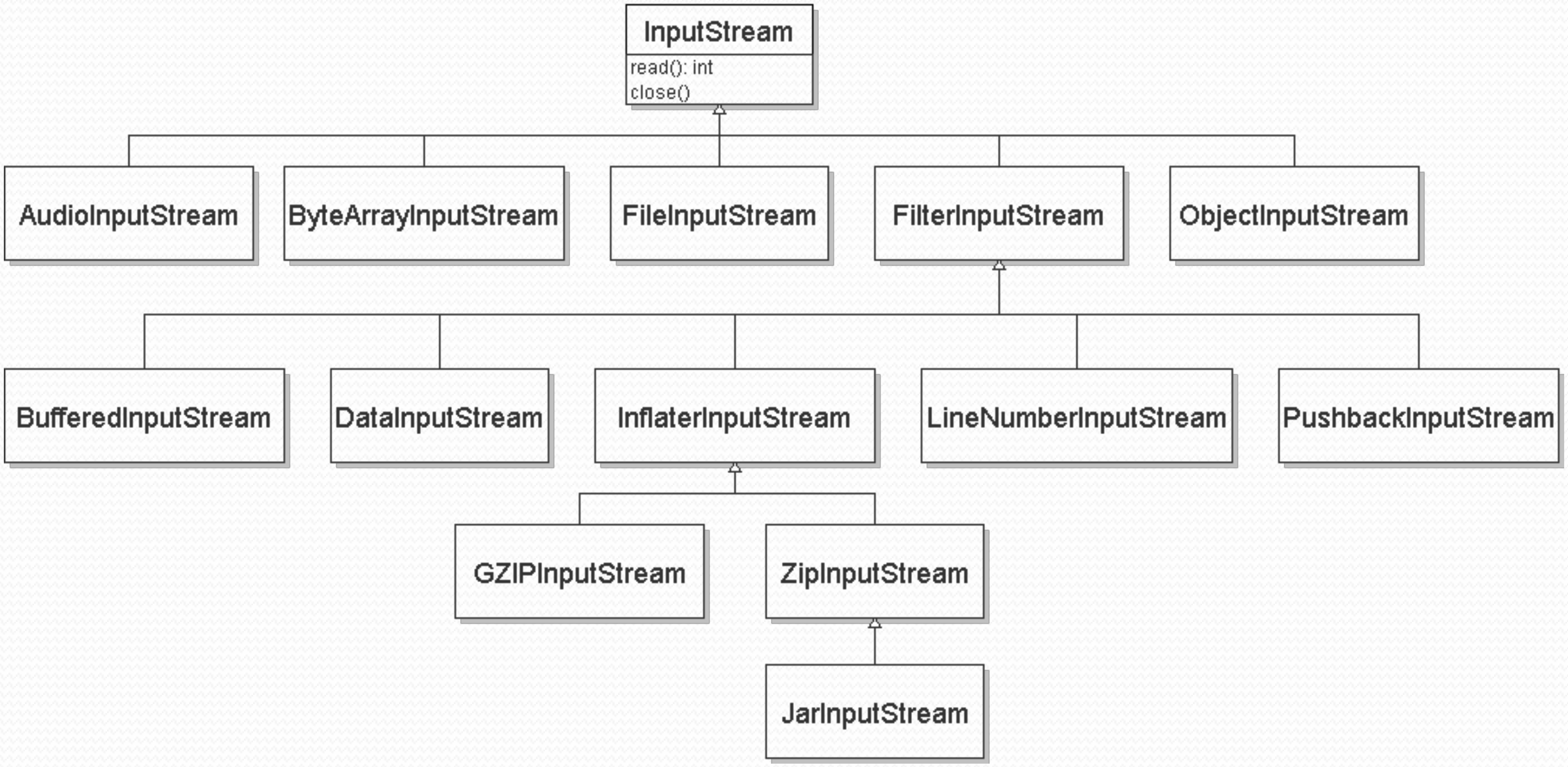
Recall: inheritance

- **inheritance**: Forming new classes based on existing ones.
  - a way to share/**reuse code** between two or more classes
  - **superclass**: Parent class being extended.
  - **subclass**: Child class that inherits behavior from superclass.
    - gets a copy of every field and method from superclass
  - **is-a relationship**: Each object of the subclass also "is a(n)" object of the superclass and can be treated as one.



Streams and inheritance

- input streams extend common superclass `InputStream`; output streams extend common superclass `OutputStream`
  - guarantees that all sources of data have the same methods
  - provides minimal ability to read/write one byte at a time



Inheritance syntax

```
public class name extends superclass {

public class Lawyer extends Employee {
    ...
}
```

- **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 method in Employee class;
    // give Lawyers a $5K raise
    public double getSalary() {
        return 55000.00;
    }
}
```

super keyword

- Subclasses can call inherited behavior with `super`

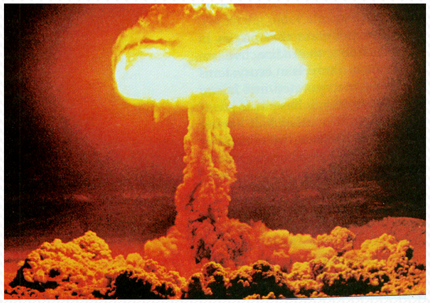
```
super.method(parameters)
super(parameters);
```

```
public class Lawyer extends Employee {
    public Lawyer(int years) {
        super(years);  // calls Employee constructor
    }

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

  - Lawyers now always make $5K more than Employees.

I/O and exceptions

- **exception**: An object representing an error.
  - **checked exception**: One that must be handled for the program to compile.



- Many I/O tasks throw exceptions.
  - Why?

- When you perform I/O, you must either:
  - also **throw** that exception yourself
  - **catch** (handle) the exception

Throwing an exception

```
public type name(params) throws type {
```

- **throws clause**: Keywords on a method's header that state that it may generate an exception.
  - Example:

```
public void processFile(String filename)
                throws FileNotFoundException {
```

"I hereby announce that this method might throw an exception, and I accept the consequences if it happens."

Catching an exception

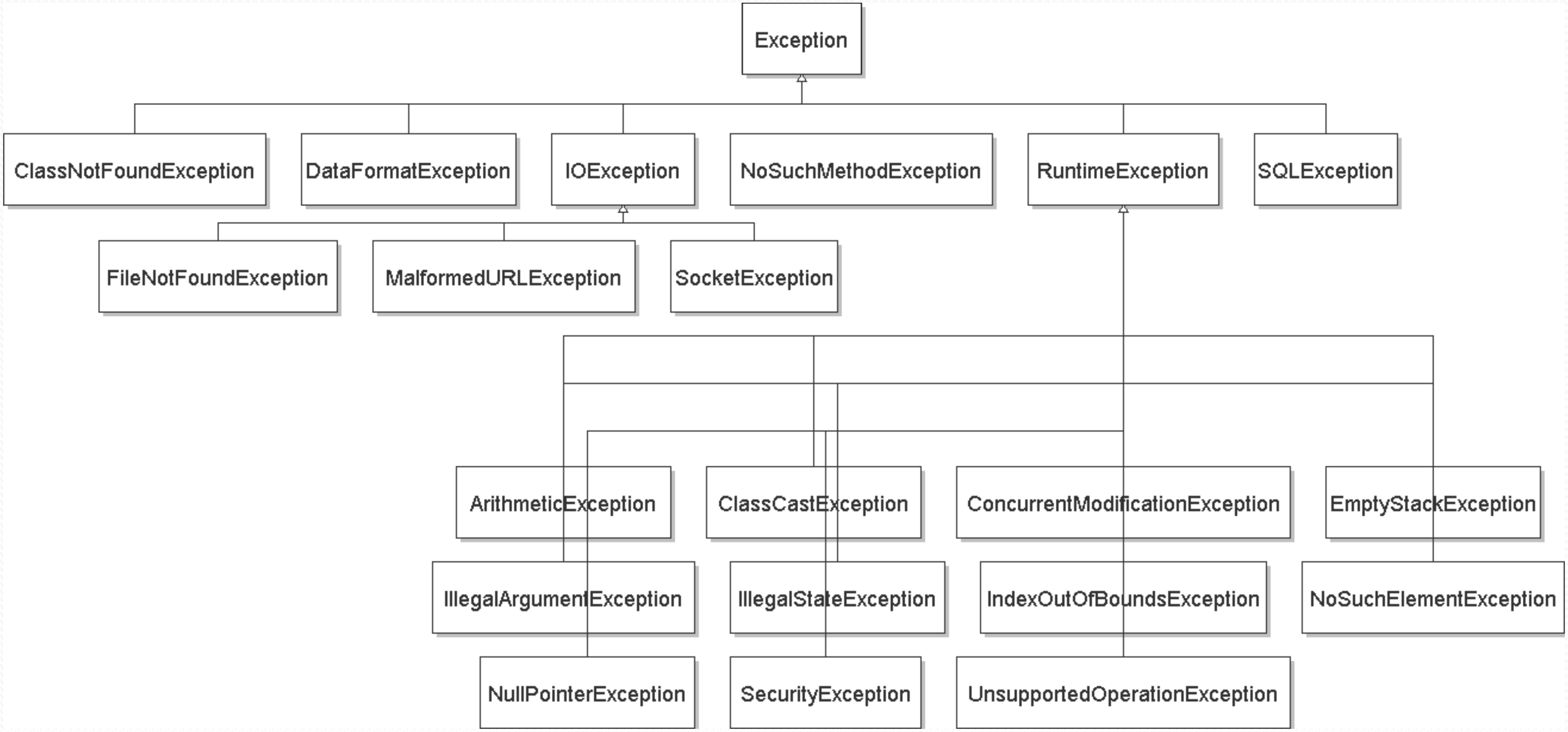
```
try {
    statement(s);
} catch (type name) {
    code to handle the exception
}
```

- The `try` code executes. If the given exception occurs, the `try` block stops running; it jumps to the `catch` block and runs that.

```
try {
    Scanner in = new Scanner(new File(filename));
    System.out.println(input.nextLine());
} catch (FileNotFoundException e) {
    System.out.println("File was not found.");
}
```

Exception inheritance

- Exceptions extend from a common superclass `Exception`



Dealing with an exception

- All exception objects have these methods:

Method	**Description**
`public String` **`getMessage`**`()`	text describing the error
`public String` **`toString`**`()`	a stack trace of the line numbers where error occurred

`getCause``(),` **`getStackTrace`**`(),`
`printStackTrace``()`
	other methods

- Some reasonable ways to handle an exception:
  - try again; re-prompt user; print a nice error message; quit the program; do nothing (!)

Inheritance and exceptions

- You can catch a general exception to handle any subclass:

```
try {
    Scanner input = new Scanner(new File("foo"));
    System.out.println(input.nextLine());
} catch (Exception e) {
    System.out.println("File was not found.");
}
```

- Similarly, you can state that a method throws any exception:

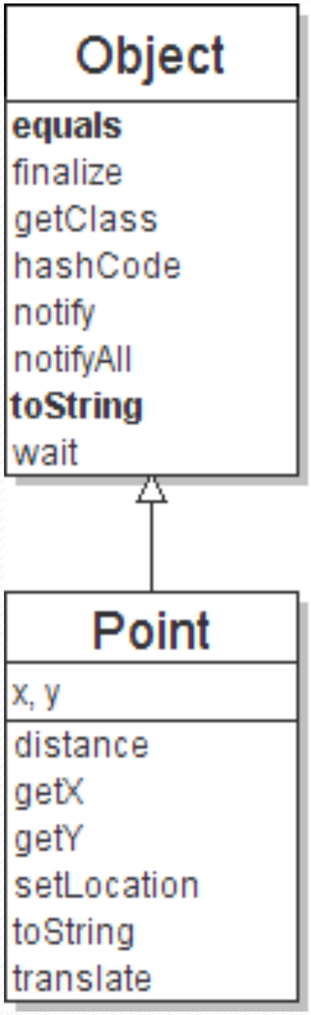
```
public void foo() throws Exception { ...
```

  - Are there any disadvantages of doing so?

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

equals
finalize
getClass
hashCode
notify
notifyAll
toString
wait

Point

x, y

distance
getX
getY
setLocation
toString
translate

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 (take a data structures course!)

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();
    }
```

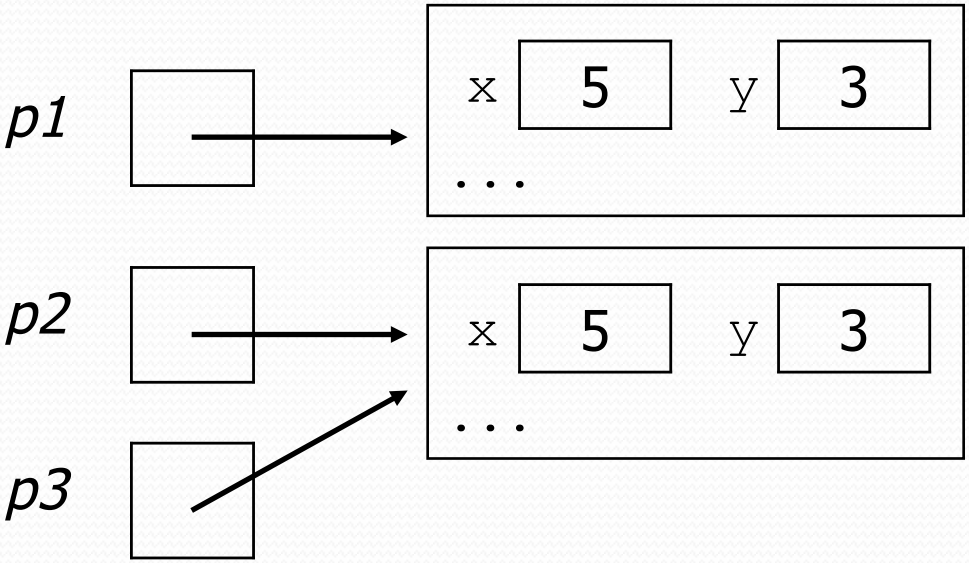
- You can make arrays or collections of `Object`s.

```
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
```

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:

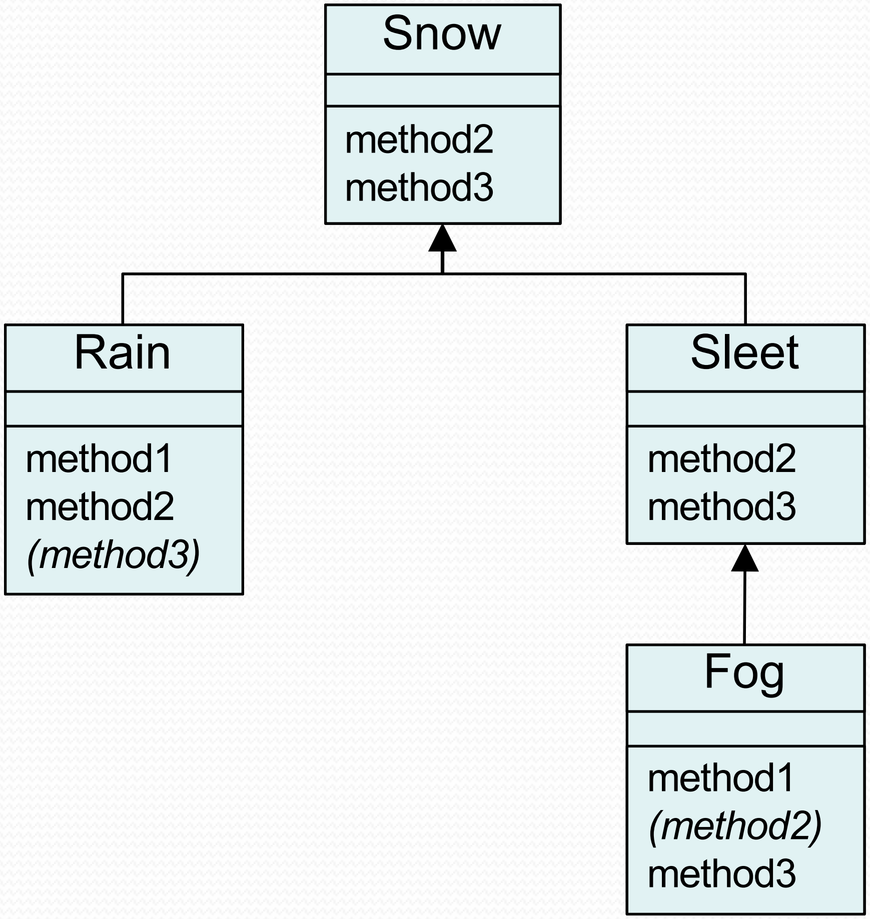
```
public class Snow {
    public void method2() {
        System.out.println("Snow 2");
    }

    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.)

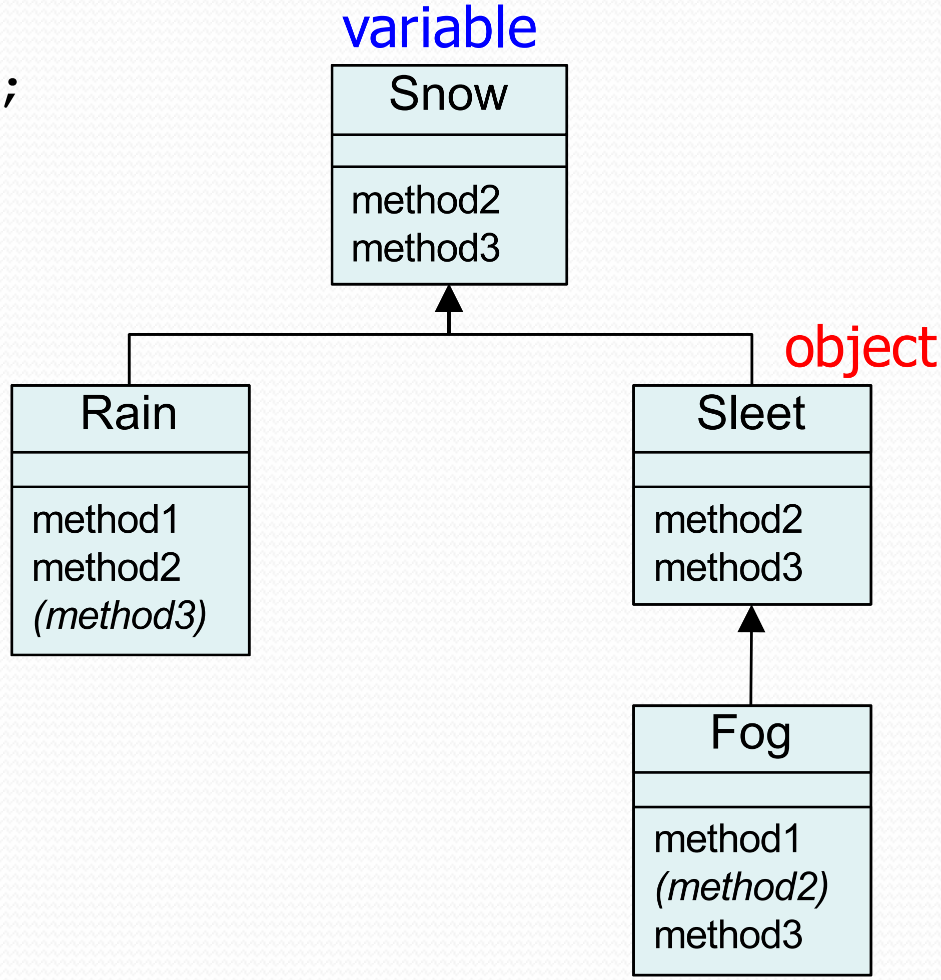
Example 1

- What is the output of the following call?

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

- Answer:

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



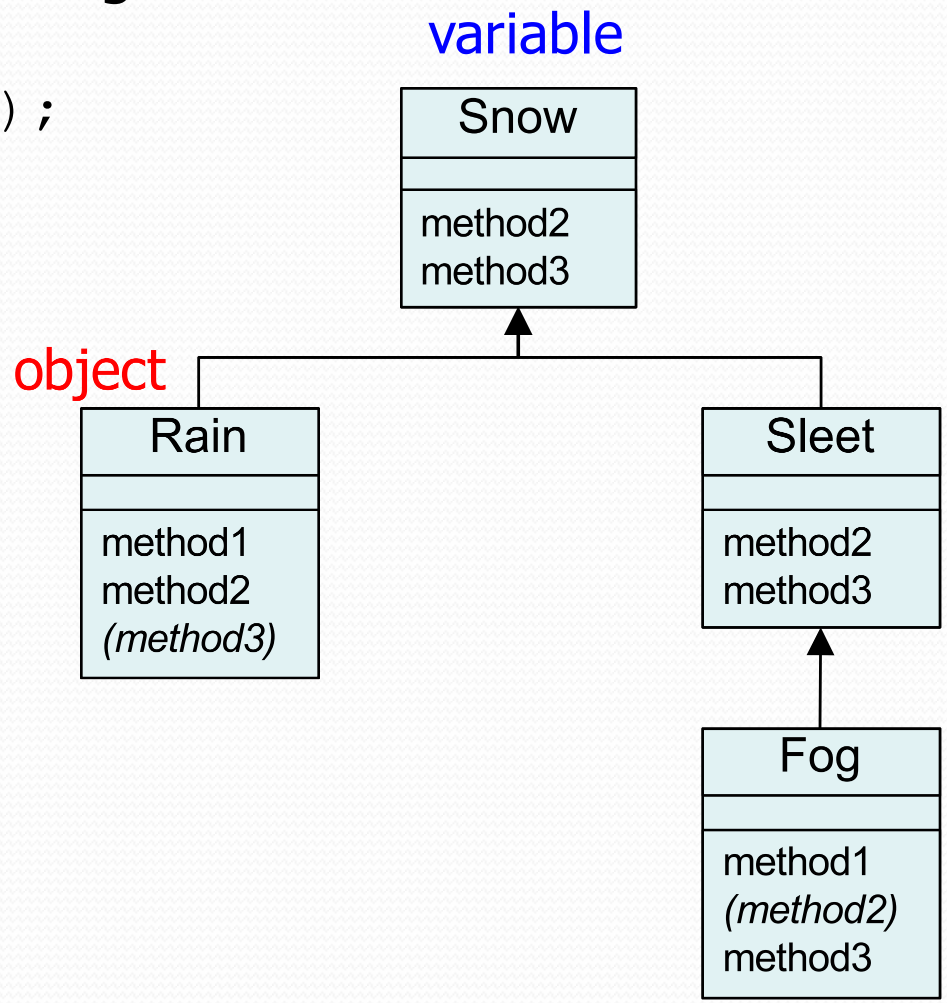
Example 2

- 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.)

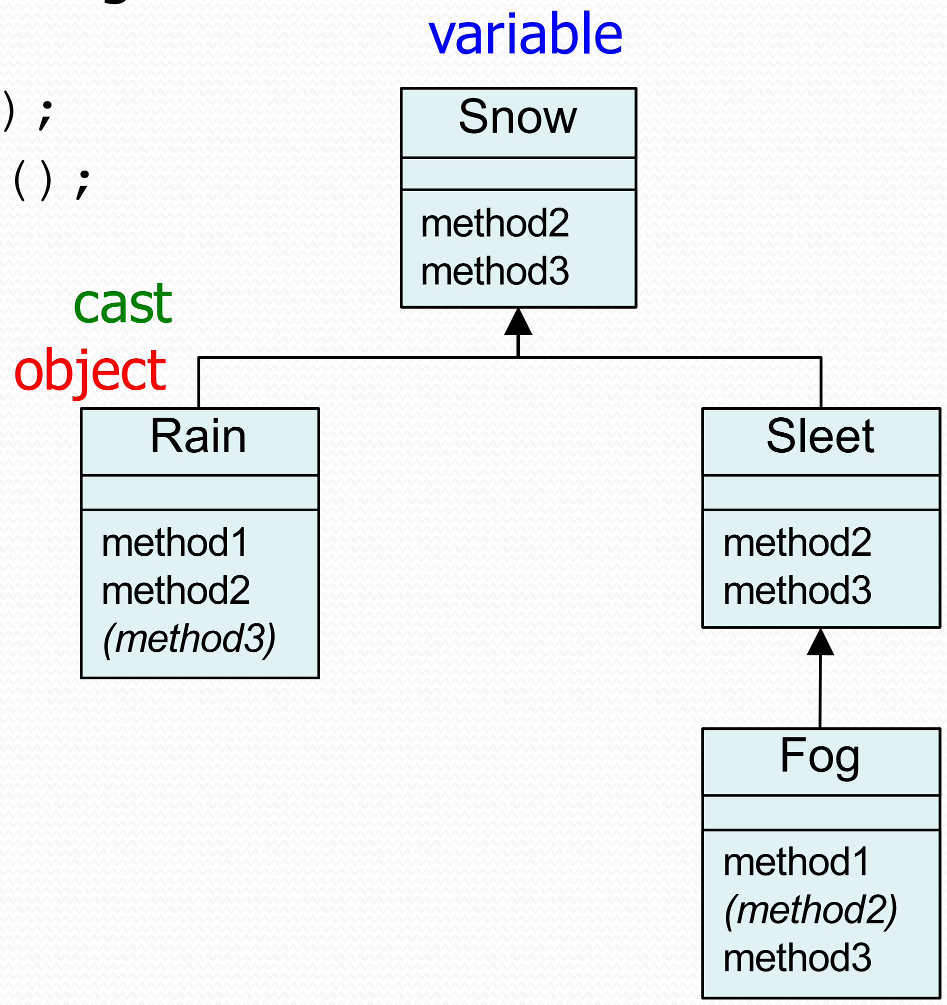
Example 3

- What is the output of the following call?

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

- Answer:

```
Rain 1
```



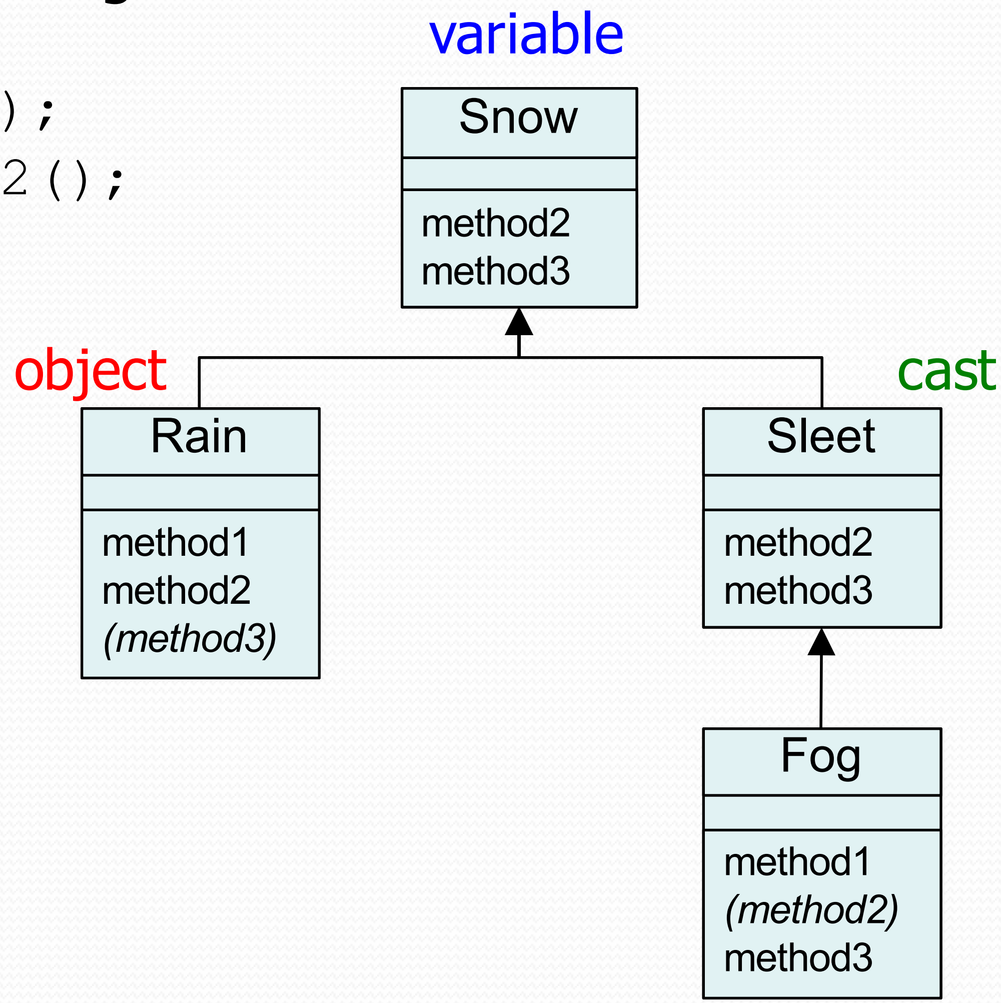
Example 4

- 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`)


variable
Snow
method2
method3
object
Rain
method1
method2
(method3)
cast
Sleet
method2
method3
Fog
method1
(method2)
method3