Building Java Programs
Chapter 9

Inheritance and Interfaces

The software crisis

- **software engineering**: The practice of developing, designing, documenting, testing large computer programs.

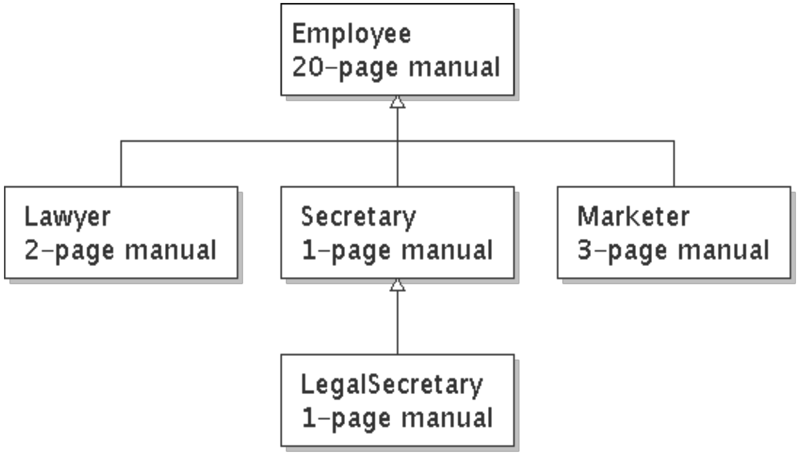
- Large-scale projects face many issues:
  - getting many programmers to work together
  - getting code finished on time
  - avoiding redundant code
  - finding and fixing bugs
  - maintaining, improving, and reusing existing code

- **code reuse**: The practice of writing program code once and using it in many contexts.

Law firm employee analogy

- common rules: hours, vacation, benefits, regulations ...
  - all employees attend a common orientation to learn general company rules
  - each employee receives a 20-page manual of common rules

- each subdivision also has specific rules:
  - employee receives a smaller (1-3 page) manual of these rules
  - smaller manual adds some new rules and also changes some rules from the large manual



Separating behavior

- Why not just have a 22 page Lawyer manual, a 21-page Secretary manual, a 23-page Marketer manual, etc.?

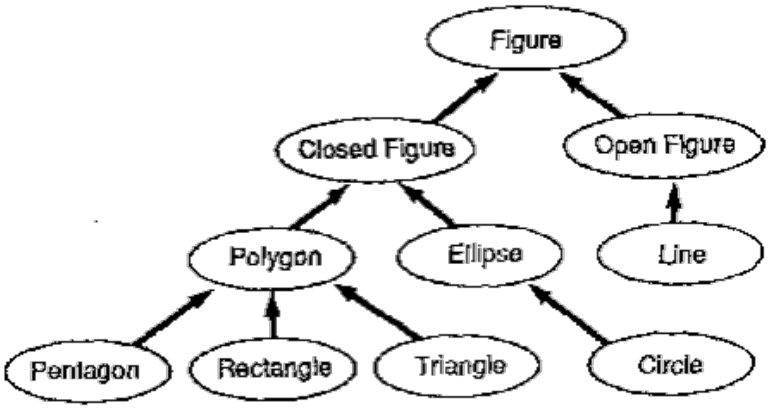
- Some advantages of the separate manuals:
  - maintenance: Only one update if a common rule changes.
  - locality: Quick discovery of all rules specific to lawyers.

- Some key ideas from this example:
  - General rules are useful (the 20-page manual).
  - Specific rules that may override general ones are also useful.

Is-a relationships, hierarchies

- **is-a relationship**: A hierarchical connection where one category can be treated as a specialized version of another.
  – every marketer *is an* employee
  – every legal secretary *is a* secretary

- **inheritance hierarchy**: A set of classes connected by is-a relationships that can share common code.



Employee regulations

- Consider the following employee regulations:
  - Employees work 40 hours / week.
  - Employees make $40,000 per year, except legal secretaries who make $5,000 extra per year ($45,000 total), and marketers who make $10,000 extra per year ($50,000 total).
  - Employees have 2 weeks of paid vacation leave per year, except lawyers who get an extra week (a total of 3).
  - Employees should use a yellow form to apply for leave, except for lawyers who use a pink form.

- Each type of employee has some unique behavior:
  - Lawyers know how to sue.
  - Marketers know how to advertise.
  - Secretaries know how to take dictation.
  - Legal secretaries know how to prepare legal documents.

An `Employee` class

```
// A class to represent employees in general (20-page manual).
public class Employee {
    public int getHours() {
        return 40;           // works 40 hours / week
    }

    public double getSalary() {
        return 40000.0;      // $40,000.00 / year
    }

    public int getVacationDays() {
        return 10;           // 2 weeks' paid vacation
    }

    public String getVacationForm() {
        return "yellow";     // use the yellow form
    }
}
```

– Exercise: Implement class `Secretary`, based on the previous employee regulations. (Secretaries can take dictation.)

Redundant `Secretary` class

```
// A redundant class to represent secretaries.
public class Secretary {
    public int getHours() {
        return 40;            // works 40 hours / week
    }

    public double getSalary() {
        return 40000.0;       // $40,000.00 / year
    }

    public int getVacationDays() {
        return 10;            // 2 weeks' paid vacation
    }

    public String getVacationForm() {
        return "yellow";      // use the yellow form
    }

    public void takeDictation(String text) {
        System.out.println("Taking dictation of text: " + text);
    }
}
```

Desire for code-sharing

- `takeDictation` is the only unique behavior in `Secretary`.

- We'd like to be able to say:

```
// A class to represent secretaries.
public class Secretary {
    copy all the contents from the Employee class;

    public void takeDictation(String text) {
        System.out.println("Taking dictation of text: " + text);
    }
}
```

Inheritance

- **inheritance**: A way to form new classes based on existing classes, taking on their attributes/behavior.
  - a way to group related classes
  - a way to share code between two or more classes

- One class can *extend* another, absorbing its data/behavior.
  - **superclass**: The parent class that is being extended.
  - **subclass**: The child class that extends the superclass and inherits its behavior.
    - Subclass gets a copy of every field and method from superclass

Inheritance syntax

```
public class name extends superclass {
```

– Example:

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

- By extending `Employee`, each `Secretary` object now:
  - receives a `getHours`, `getSalary`, `getVacationDays`, and `getVacationForm` method automatically
  - can be treated as an `Employee` by client code (seen later)

Improved `Secretary` code

```
// A class to represent secretaries.
public class Secretary extends Employee {
    public void takeDictation(String text) {
        System.out.println("Taking dictation of text: " + text);
    }
}
```

- Now we only write the parts unique to each type.
  - `Secretary` inherits `getHours`, `getSalary`, `getVacationDays`, and `getVacationForm` methods from `Employee`.
  - `Secretary` adds the `takeDictation` method.

Implementing `Lawyer`

- Consider the following lawyer regulations:
  - Lawyers who get an extra week of paid vacation (a total of 3).
  - Lawyers use a pink form when applying for vacation leave.
  - Lawyers have some unique behavior: they know how to sue.

- Problem: We want lawyers to inherit *most* behavior from employee, but we want to replace parts with new behavior.

Overriding methods

- **override**: To write a new version of a method in a subclass that replaces the superclass's version.
  - No special syntax required to override a superclass method. Just write a new version of it in the subclass.

```
public class Lawyer extends Employee {
    // overrides getVacationForm method in Employee class
    public String getVacationForm() {
        return "pink";
    }
    ...
}
```

  - Exercise: Complete the `Lawyer` class.
    - (3 weeks vacation, pink vacation form, can sue)

Lawyer class

```
// A class to represent lawyers.
public class Lawyer extends Employee {
    // overrides getVacationForm from Employee class
    public String getVacationForm() {
        return "pink";
    }

    // overrides getVacationDays from Employee class
    public int getVacationDays() {
        return 15;           // 3 weeks vacation
    }

    public void sue() {
        System.out.println("I'll see you in court!");
    }
}
```

– Exercise: Complete the `Marketer` class. Marketers make $10,000 extra ($50,000 total) and know how to advertise.

Marketer class

```
// A class to represent marketers.
public class Marketer extends Employee {
    public void advertise() {
        System.out.println("Act now while supplies last!");
    }

    public double getSalary() {
        return 50000.0;      // $50,000.00 / year
    }
}
```

Levels of inheritance

- Multiple levels of inheritance in a hierarchy are allowed.
  - Example: A legal secretary is the same as a regular secretary but makes more money ($45,000) and can file legal briefs.

```
public class LegalSecretary extends Secretary {
    ...
}
```

  - Exercise: Complete the `LegalSecretary` class.

LegalSecretary class

```
// A class to represent legal secretaries.
public class LegalSecretary extends Secretary {
    public void fileLegalBriefs() {
        System.out.println("I could file all day!");
    }

    public double getSalary() {
        return 45000.0;      // $45,000.00 / year
    }
}
```

Interacting with the superclass

Changes to common behavior

- Let's return to our previous company/employee example.

- Imagine a company-wide change affecting all employees.

  Example: Everyone is given a $10,000 raise due to inflation.
  - The base employee salary is now $50,000.
  - Legal secretaries now make $55,000.
  - Marketers now make $60,000.

- We must modify our code to reflect this policy change.

Modifying the superclass

```
// A class to represent employees (20-page manual).
public class Employee {
    public int getHours() {
        return 40;              // works 40 hours / week
    }

    public double getSalary() {
        return 50000.0;         // $50,000.00 / year
    }

    ...
}
```

- Are we finished?

- The `Employee` subclasses are still incorrect.
  - They have overridden `getSalary` to return other values.

An unsatisfactory solution

```
public class LegalSecretary extends Secretary {
    public double getSalary() {
        return 55000.0;
    }
    ...
}

public class Marketer extends Employee {
    public double getSalary() {
        return 60000.0;
    }
    ...
}
```

– Problem: The subclasses' salaries are based on the Employee salary, but the `getSalary` code does not reflect this.

Calling overridden methods

- Subclasses can call overridden methods with `super`

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

  – Example:

```
public class LegalSecretary extends Secretary {
    public double getSalary() {
        double baseSalary = super.getSalary();
        return baseSalary + 5000.0;
    }
    ...
}
```

  – Exercise: Modify `Lawyer` and `Marketer` to use `super`.

Improved subclasses

```java
public class Lawyer extends Employee {
    public String getVacationForm() {
        return "pink";
    }

    public int getVacationDays() {
        return super.getVacationDays() + 5;
    }

    public void sue() {
        System.out.println("I'll see you in court!");
    }
}

public class Marketer extends Employee {
    public void advertise() {
        System.out.println("Act now while supplies last!");
    }

    public double getSalary() {
        return super.getSalary() + 10000.0;
    }
}
```

Inheritance and constructors

- Imagine that we want to give employees more vacation days the longer they've been with the company.
  - For each year worked, we'll award 2 additional vacation days.
  - When an Employee object is constructed, we'll pass in the number of years the person has been with the company.
  - This will require us to modify our `Employee` class and add some new state and behavior.
  - Exercise: Make necessary modifications to the `Employee` class.

Modified `Employee` class

```
public class Employee {
    private int years;

    public Employee(int initialYears) {
        years = initialYears;
    }

    public int getHours() {
        return 40;
    }

    public double getSalary() {
        return 50000.0;
    }

    public int getVacationDays() {
        return 10 + 2 * years;
    }

    public String getVacationForm() {
        return "yellow";
    }
}
```

Problem with constructors

- Now that we've added the constructor to the `Employee` class, our subclasses do not compile. The error:

```
Lawyer.java:2: cannot find symbol
symbol  : constructor Employee()
location: class Employee
public class Lawyer extends Employee {
       ^
```

  – The short explanation: Once we write a constructor (that requires parameters) in the superclass, we must now write constructors for our employee subclasses as well.

  – The long explanation: (next slide)

The detailed explanation

- Constructors are not inherited.
  - Subclasses don't inherit the `Employee(int)` constructor.
  - Subclasses receive a default constructor that contains:

```
public Lawyer() {
    super();            // calls Employee() constructor
}
```

- But our `Employee(int)` replaces the default `Employee()`.
  - The subclasses' default constructors are now trying to call a non-existent default `Employee` constructor.

Calling superclass constructor

`super(`**parameters**`);`

- Example:

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

- The `super` call must be the first statement in the constructor.

- Exercise: Make a similar modification to the `Marketer` class.

Modified `Marketer` class

```
// A class to represent marketers.
public class Marketer extends Employee {
    public Marketer(int years) {
        super(years);
    }

    public void advertise() {
        System.out.println("Act now while supplies last!");
    }

    public double getSalary() {
        return super.getSalary() + 10000.0;
    }
}
```

- Exercise: Modify the `Secretary` subclass.
  - Secretaries' years of employment are not tracked.
  - They do not earn extra vacation for years worked.

Modified `Secretary` class

```
// A class to represent secretaries.
public class Secretary extends Employee {
    public Secretary() {
        super(0);
    }

    public void takeDictation(String text) {
        System.out.println("Taking dictation of text: " + text);
    }
}
```

- Since `Secretary` doesn't require any parameters to its constructor, `LegalSecretary` compiles without a constructor.
  - Its default constructor calls the `Secretary()` constructor.

Inheritance and fields

- Try to give lawyers $5000 for each year at the company:

```
public class Lawyer extends Employee {
    ...
    public double getSalary() {
        return super.getSalary() + 5000 * years;
    }
    ...
}
```

- Does not work; the error is the following:

```
Lawyer.java:7: years has private access in Employee
        return super.getSalary() + 5000 * years;
                                          ^
```

- Private fields cannot be directly accessed from subclasses.
  - One reason: So that subclassing can't break encapsulation.
  - How can we get around this limitation?

Improved Employee code

Add an accessor for any field needed by the subclass.

```
public class Employee {
    private int years;

    public Employee(int initialYears) {
        years = initialYears;
    }

    public int getYears() {
        return years;
    }
    ...
}
public class Lawyer extends Employee {
    public Lawyer(int years) {
        super(years);
    }

    public double getSalary() {
        return super.getSalary() + 5000 * getYears();
    }
    ...
}
```

Revisiting `Secretary`

- The `Secretary` class currently has a poor solution.
  - We set all Secretaries to 0 years because they do not get a vacation bonus for their service.
  - If we call `getYears` on a `Secretary` object, we'll always get 0.
  - This isn't a good solution; what if we wanted to give some other reward to *all* employees based on years of service?

- Redesign our `Employee` class to allow for a better solution.

Improved `Employee` code

- Let's separate the standard 10 vacation days from those that are awarded based on seniority.

```
public class Employee {
    private int years;

    public Employee(int initialYears) {
        years = initialYears;
    }

    public int getVacationDays() {
        return 10 + getSeniorityBonus();
    }

    // vacation days given for each year in the company
    public int getSeniorityBonus() {
        return 2 * years;
    }
    ...
}
```

  - How does this help us improve the `Secretary`?

Improved `Secretary` code

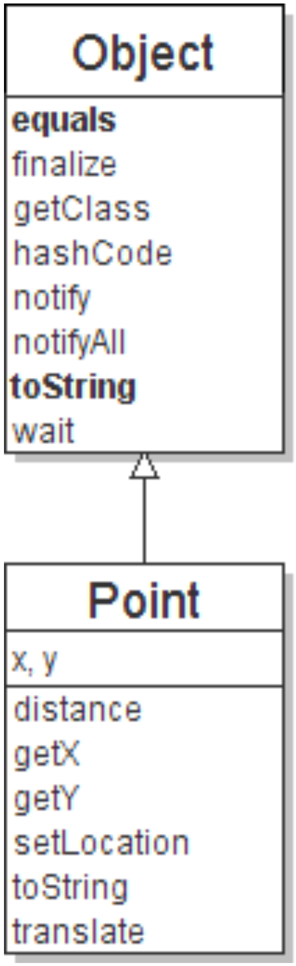
- `Secretary` can selectively override `getSeniorityBonus`; when `getVacationDays` runs, it will use the new version.
  - Choosing a method at runtime is called *dynamic binding*.

```
public class Secretary extends Employee {
    public Secretary(int years) {
        super(years);
    }

    // Secretaries don't get a bonus for their years of service.
    public int getSeniorityBonus() {
        return 0;
    }

    public void takeDictation(String text) {
        System.out.println("Taking dictation of text: " + text);
    }
}
```

Class `Object`

- All types of objects have a superclass named `Object`.
  - Every class implicitly extends `Object`

- The `Object` class defines several methods:
  - `public String toString()`
    Returns a text representation of the object, often so that it can be printed.
  - `public boolean equals(Object other)`
    Compare the object to any other for equality. Returns `true` if the objects have equal state.



`Object` variables

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

```
Object o1 = new Point(5, -3);
Object o2 = "hello there";
Object o3 = new Scanner(System.in);
```

- An `Object` variable only knows how to do general things.

```
String s = o1.toString();         // ok
int len = o2.length();            // error
String line = o3.nextLine();      // error
```

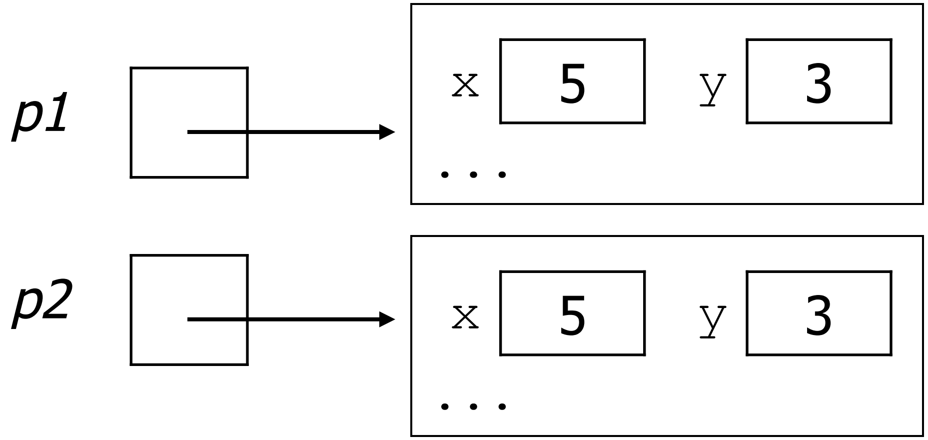
- You can write methods that accept an `Object` parameter.

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

Recall: comparing objects

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

```
Point p1 = new Point(5, 3);
Point p2 = new Point(5, 3);
if (p1 == p2) {    // false
    System.out.println("equal");
}
```



The `equals` method

- The `equals` method compares the state of objects.

```
if (str1.equals(str2)) {
    System.out.println("the strings are equal");
}
```

- But if you write a class, its `equals` method behaves like `==`

```
if (p1.equals(p2)) {    // false :-(
    System.out.println("equal");
}
```

  - This is the behavior we inherit from class `Object`.
  - Java doesn't understand how to compare `Point`s by default.

Flawed `equals` method

- We can change this behavior by writing an `equals` method.
  - Ours will *override* the default behavior from class `Object`.
  - The method should compare the state of the two objects and return `true` if they have the same x/y position.

- A flawed implementation:

```
public boolean equals(Point other) {
    if (x == other.x && y == other.y) {
        return true;
    } else {
        return false;
    }
}
```

Flaws in our method

- The body can be shortened to the following:

```
// boolean zen
return x == other.x && y == other.y;
```

- It should be legal to compare a `Point` to any object (not just other `Point`s):

```
// this should be allowed
Point p = new Point(7, 2);
if (p.equals("hello")) {    // false
    ...
```

  - `equals` should always return `false` if a non-`Point` is passed.

`equals` and `Object`

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

- The parameter to `equals` must be of type `Object`.
- `Object` is a general type that can match any 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?

Another flawed version

- Another flawed `equals` implementation:

```
public boolean equals(Object o) {
    return x == o.x && y == o.y;
}
```

- It does not compile:

```
Point.java:36: cannot find symbol
symbol  : variable x
location: class java.lang.Object
return x == o.x && y == o.y;
               ^
```

  - The compiler is saying,
    "`o` could be any object. Not every object has an `x` field."

Type-casting objects

- Solution: *Type-cast* the object parameter to a `Point`.

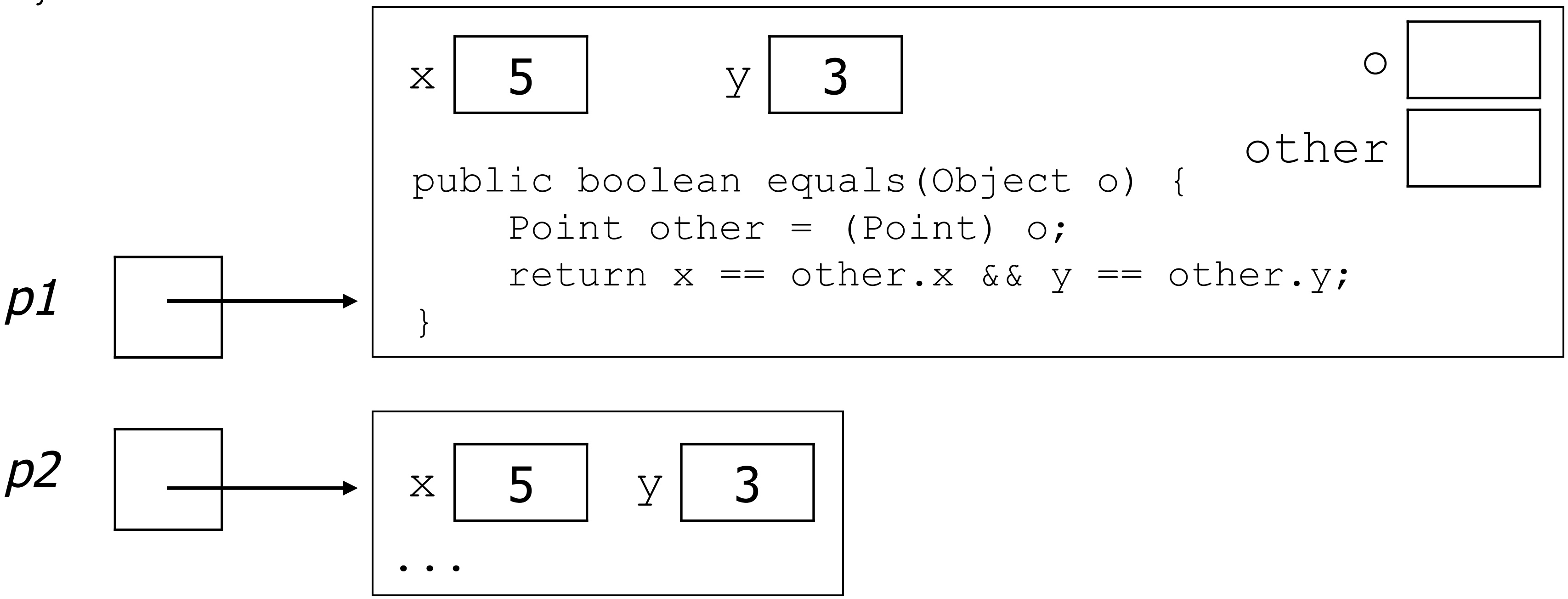
```
public boolean equals(Object o) {
    Point other = (Point) o;
    return x == other.x && y == other.y;
}
```

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

Casting objects diagram

- Client code:

```
Point p1 = new Point(5, 3);
Point p2 = new Point(5, 3);
if (p1.equals(p2)) {
    System.out.println("equal");
}
```



Comparing different types

```
Point p = new Point(7, 2);
if (p.equals("hello")) {    // should be false
    ...
}
```

- Currently our method crashes on the above code:

```
Exception in thread "main"
java.lang.ClassCastException: java.lang.String
        at Point.equals(Point.java:25)
        at PointMain.main(PointMain.java:25)
```

- The culprit is the line with the type-cast:

```
public boolean equals(Object o) {
    Point other = (Point) o;
```

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`

Final `equals` method

```
// 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;
    }
}
```

Polymorphism

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.

  - `CritterMain` can interact with any type of critter.
    - Each one moves, fights, etc. in its own way.

Coding with polymorphism

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

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

  - You can call any methods from the `Employee` class on `ed`.

- 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 always put such a question on our final 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

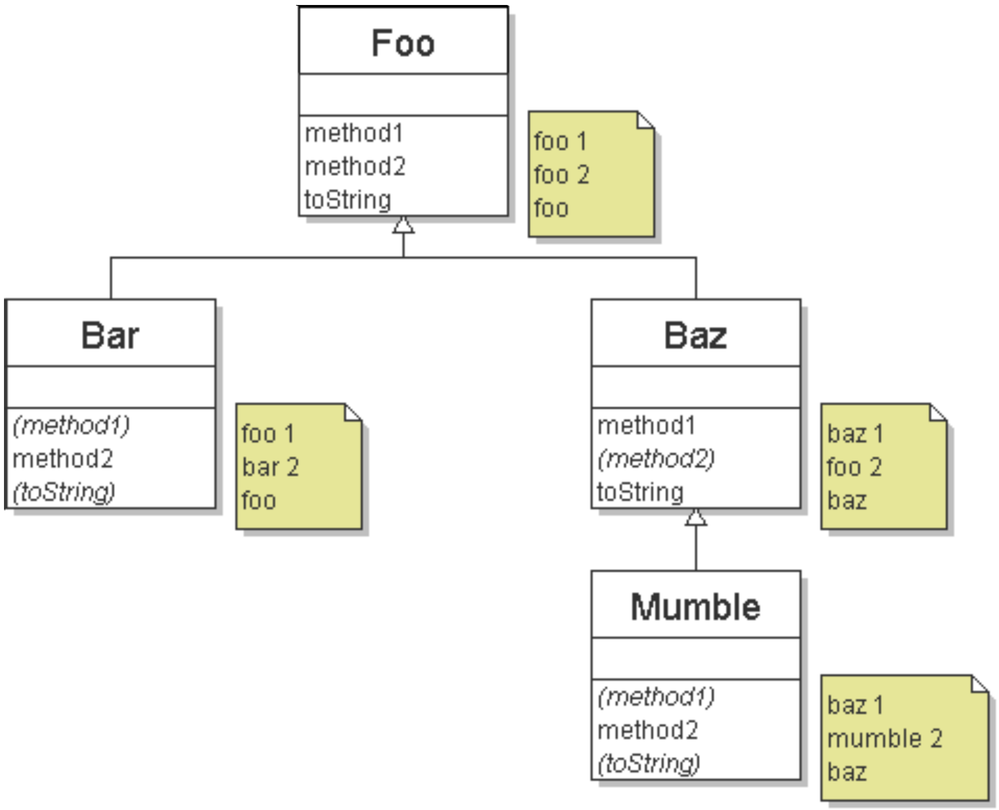
```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

    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";
    }
}
```

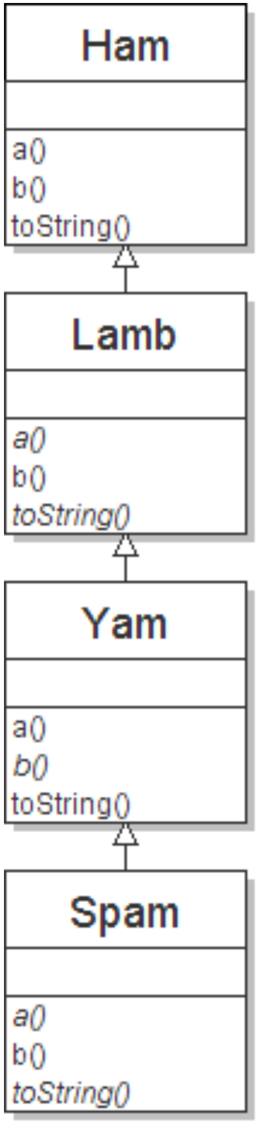
Another problem 2

```
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 **b()**	*Ham a* ***b()***	Yam a Ham a **b()**	*Yam a* *Ham a* ***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:

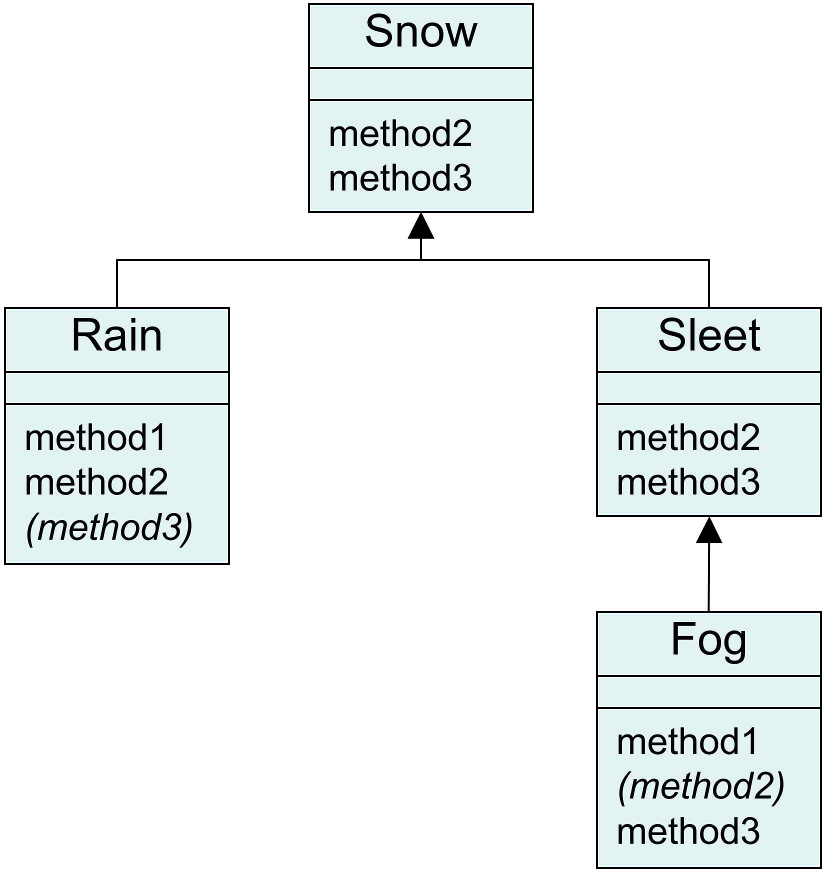
```
Snow var2 = new Rain();
var2.method1();
```

- 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`
			`Snow 2`
			`method3()`
				`Sleet 2`
				`Snow 2`
				`method3()`

`method3`	`Snow 3`	*`Snow 3`*	`Sleet 3`	`Fog 3`

Italic - inherited behavior
Bold - dynamic method call

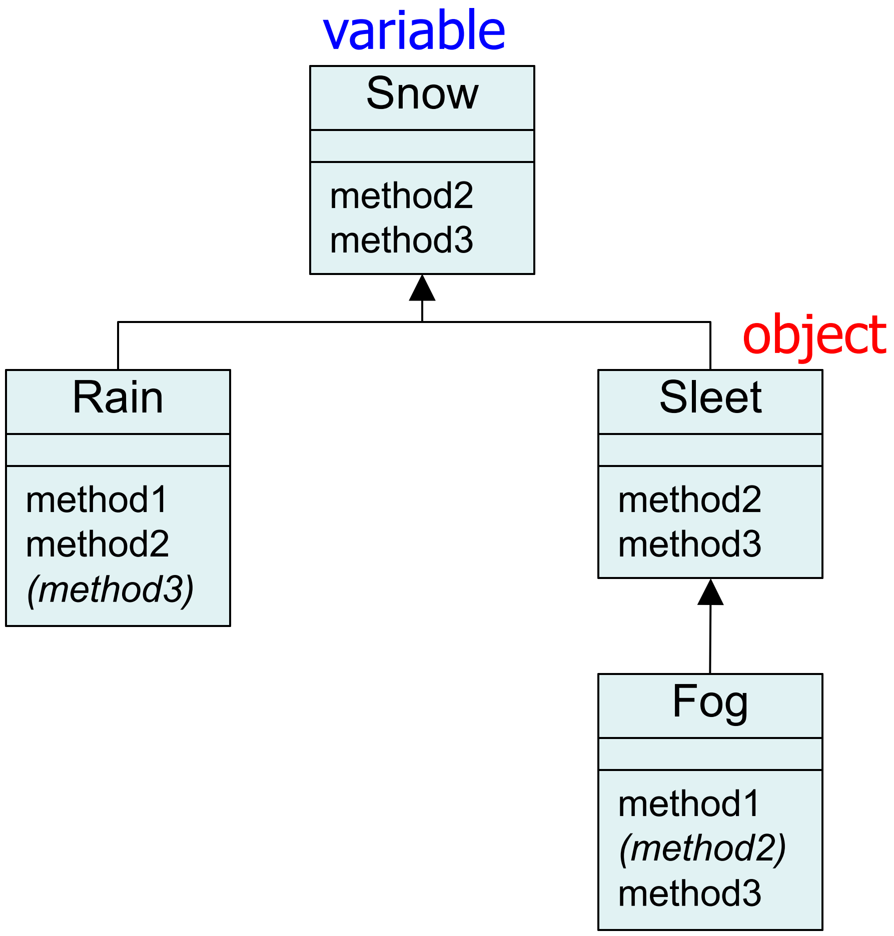
Example 1

- Example:

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

- Output:

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



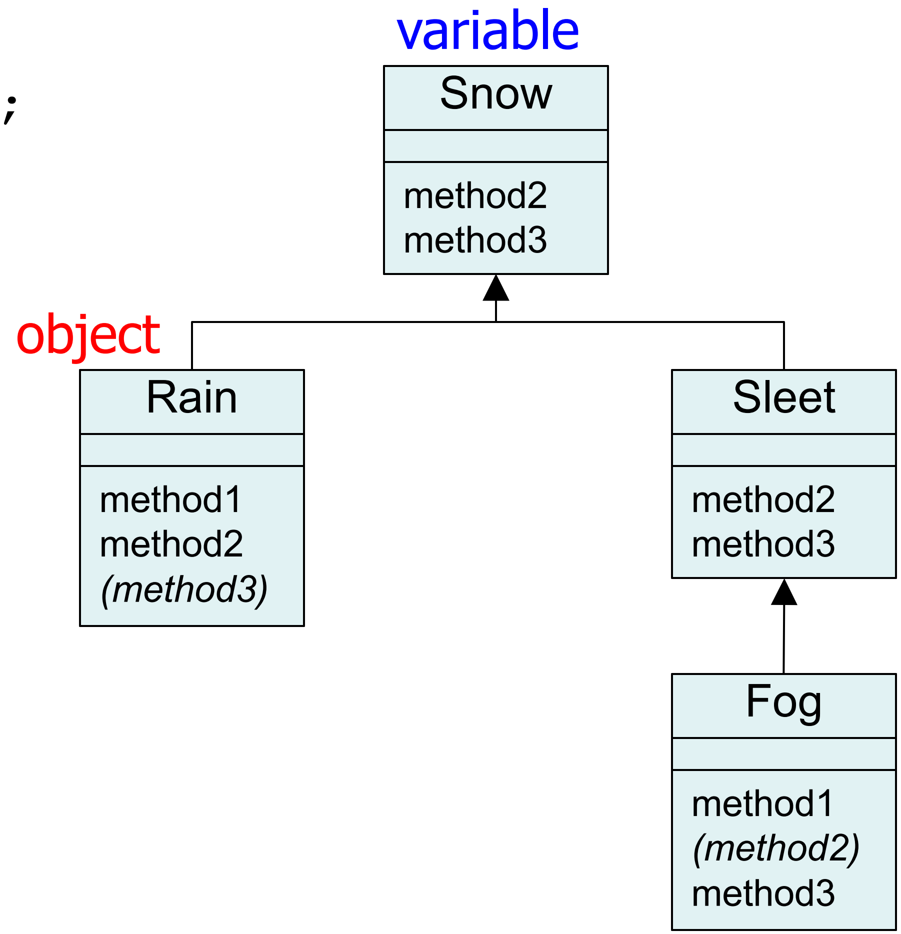
Example 2

- Example:

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

- Output:

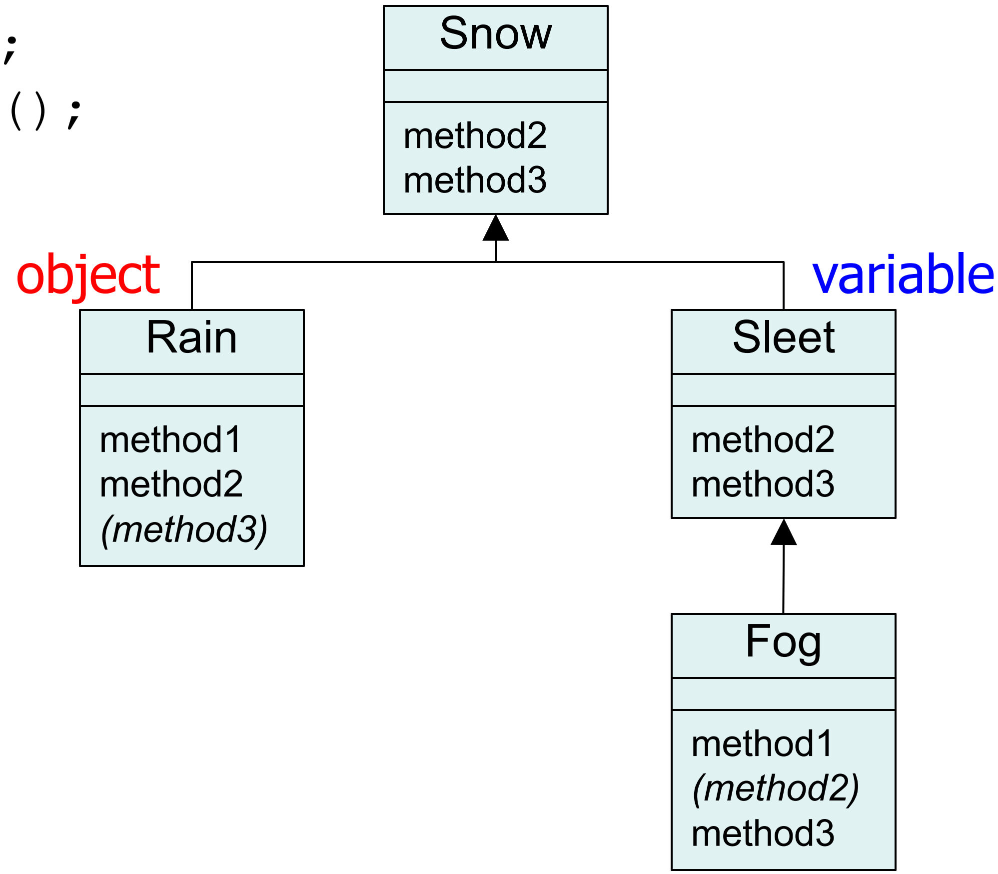
None!
There is an error,
because `Snow` does not
have a `method1`.



Example 3

- Example:

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



- Output:

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

Interfaces

Relatedness of types

Write a set of `Circle`, `Rectangle`, and `Triangle` classes.

- Certain operations that are common to all shapes.

  perimeter - distance around the outside of the shape

  area - amount of 2D space occupied by the shape

- Every shape has them but computes them differently.

Shape area, perimeter

- Rectangle (as defined by width w and height h):

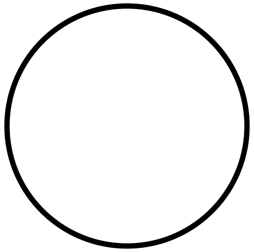
  area $= w\,h$

  perimeter $= 2w + 2h$

- Circle (as defined by radius r):

  area $= \pi\, r^2$

  perimeter $= 2\,\pi\, r$

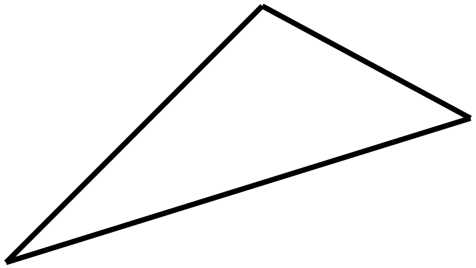


- Triangle (as defined by side lengths a, b, and c)

  area $= \sqrt{(s\,(s - a)\,(s - b)\,(s - c))}$

  where $s = ½\,(a + b + c)$

  perimeter $= a + b + c$



Common behavior

- Write shape classes with methods `perimeter` and `area`.

- We'd like to be able to write client code that treats different kinds of shape objects in the same way, such as:
  - Write a method that prints any shape's area and perimeter.
  - Create an array of shapes that could hold a mixture of the various shape objects.
  - Write a method that could return a rectangle, a circle, a triangle, or any other shape we've written.
  - Make a `DrawingPanel` display many shapes on screen.

Interfaces

- **interface**: A list of methods that a class can implement.
  - Inheritance gives you an is-a relationship and code-sharing.
    - A `Lawyer` object can be treated as an `Employee`, and `Lawyer` inherits `Employee`'s code.
  - Interfaces give you an is-a relationship *without* code sharing.
    - A `Rectangle` object can be treated as a `Shape`.
  - Analogous to the idea of roles or certifications:
    - "I'm certified as a CPA accountant. That means I know how to compute taxes, perform audits, and do consulting."
    - "I'm certified as a Shape. That means I know how to compute my area and perimeter."

Declaring an interface

```
public interface name {
    public type name(type name, ..., type name);
    public type name(type name, ..., type name);
    ...
}
```

Example:

```
public interface Vehicle {
    public double speed();
    public void setDirection(int direction);
}
```

- **abstract method**: A header without an implementation.
  - The actual body is not specified, to allow/force different classes to implement the behavior in its own way.

Shape interface

```
public interface Shape {
    public double area();
    public double perimeter();
}
```

- This interface describes the features common to all shapes. (Every shape has an area and perimeter.)

Implementing an interface

```
public class name implements interface {
    ...
}
```

– Example:

```
public class Bicycle implements Vehicle {
    ...
}
```

- A class can declare that it *implements* an interface.
  - This means the class must contain each of the abstract methods in that interface. (Otherwise, it will not compile.)

  (What must be true about the `Bicycle` class for it to compile?)

Interface requirements

- If a class claims to be a `Shape` but doesn't implement the `area` and `perimeter` methods, it will not compile.
  - Example:

```
public class Banana implements Shape {
    ...
}
```

  - The compiler error message:

```
Banana.java:1: Banana is not abstract and does
not override abstract method area() in Shape
public class Banana implements Shape {
                   ^
```

Complete Circle class

```
// Represents circles.
public class Circle implements Shape {
    private double radius;

    // Constructs a new circle with the given radius.
    public Circle(double radius) {
        this.radius = radius;
    }

    // Returns the area of this circle.
    public double area() {
        return Math.PI * radius * radius;
    }

    // Returns the perimeter of this circle.
    public double perimeter() {
        return 2.0 * Math.PI * radius;
    }
}
```

Complete Rectangle class

```
// Represents rectangles.
public class Rectangle implements Shape {
    private double width;
    private double height;

    // Constructs a new rectangle with the given dimensions.
    public Rectangle(double width, double height) {
        this.width = width;
        this.height = height;
    }

    // Returns the area of this rectangle.
    public double area() {
        return width * height;
    }

    // Returns the perimeter of this rectangle.
    public double perimeter() {
        return 2.0 * (width + height);
    }
}
```

Complete Triangle class

```
// Represents triangles.
public class Triangle implements Shape {
    private double a;
    private double b;
    private double c;

    // Constructs a new Triangle given side lengths.
    public Triangle(double a, double b, double c) {
        this.a = a;
        this.b = b;
        this.c = c;
    }

    // Returns this triangle's area using Heron's formula.
    public double area() {
        double s = (a + b + c) / 2.0;
        return Math.sqrt(s * (s - a) * (s - b) * (s - c));
    }

    // Returns the perimeter of this triangle.
    public double perimeter() {
        return a + b + c;
    }
}
```

Interfaces + polymorphism

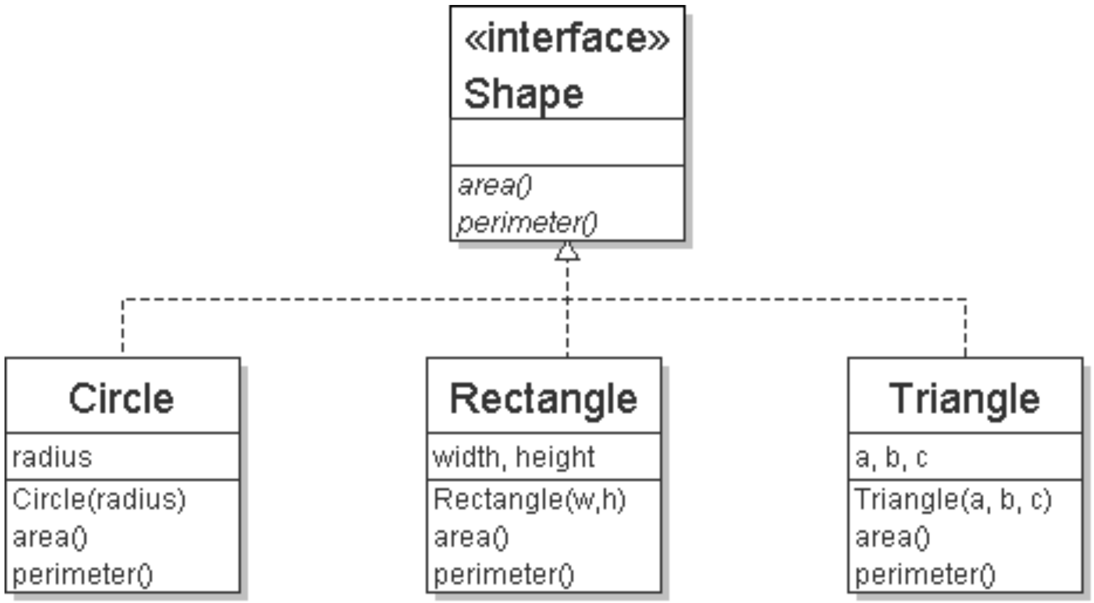
- Interfaces don't benefit the class so much as the *client.*
  - Interface's is-a relationship lets the client use polymorphism.

```
public static void printInfo(Shape s) {
    System.out.println("The shape: " + s);
    System.out.println("area : " + s.area());
    System.out.println("perim: " + s.perimeter());
}
```

  - Any object that implements the interface may be passed.

```
Circle circ = new Circle(12.0);
Rectangle rect = new Rectangle(4, 7);
Triangle tri = new Triangle(5, 12, 13);
printInfo(circ);
printInfo(tri);
printInfo(rect);

Shape[] shapes = {tri, circ, rect};
```

Interface diagram



- Arrow goes up from class to interface(s) it implements.
  - There is a supertype-subtype relationship here; e.g., all Circles are Shapes, but not all Shapes are Circles.
  - This kind of picture is also called a *UML class diagram*.