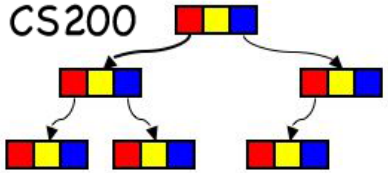
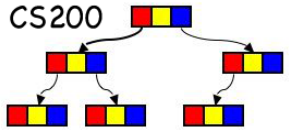



# CS200: Advanced OO in Java interfaces, inheritance, abstract classes, generics

Prichard Ch. 9

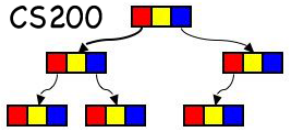
# Basic Component: Class




A Class is a software bundle of **related states** (**properties**, or **variables**) and **behaviors** (**methods**)

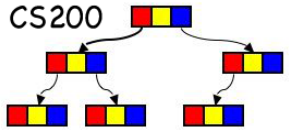
- State is stored in instance variables
- Method exposes behavior

# Basic Components



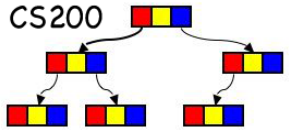

- **Class**: ***Blueprint*** from which objects are created
  - Multiple Object Instances created from a class
- **Interface**: A ***Contract*** between classes and the outside world.
  - When a class **implements** an interface, it **promises to provide the behavior** published by that interface.
- **Package**: a ***namespace*** (directory) for organizing classes and interfaces

# Data Encapsulation



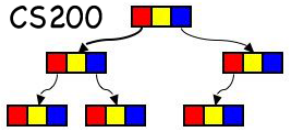

- An ability of an object **to be a container** (or capsule) for related properties and methods.
  - Preventing unexpected change or reuse of the content
- **Data hiding**
  - Object can shield variables from external access.
    - Private variables
    - Public **accessor** and **mutator** methods, with potentially limited capacities, e.g. only read access, or write only valid data.

# Data Encapsulation



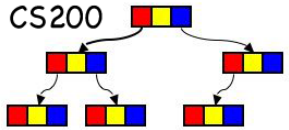

```
public class Clock{
   private long time, alarm_time;

   public void setTime(long time){
       this.time = time;
   }
   public void setAlarmTime(long time){
       this.alarm_time = time;
   }
   public long getTime(){return time}
   public long getAlarmTime(){return alarm_time}
   public void noticeAlarm(){ … //ring alarm }
   }
```

# Inheritance




- The ability of a class to ***derive*** properties from a previously defined class.
- **Relationship** among classes.
- Enables **reuse** of software components
  - e.g., java.lang.Object()
  - toString(), notifyAll(), equals(), etc.

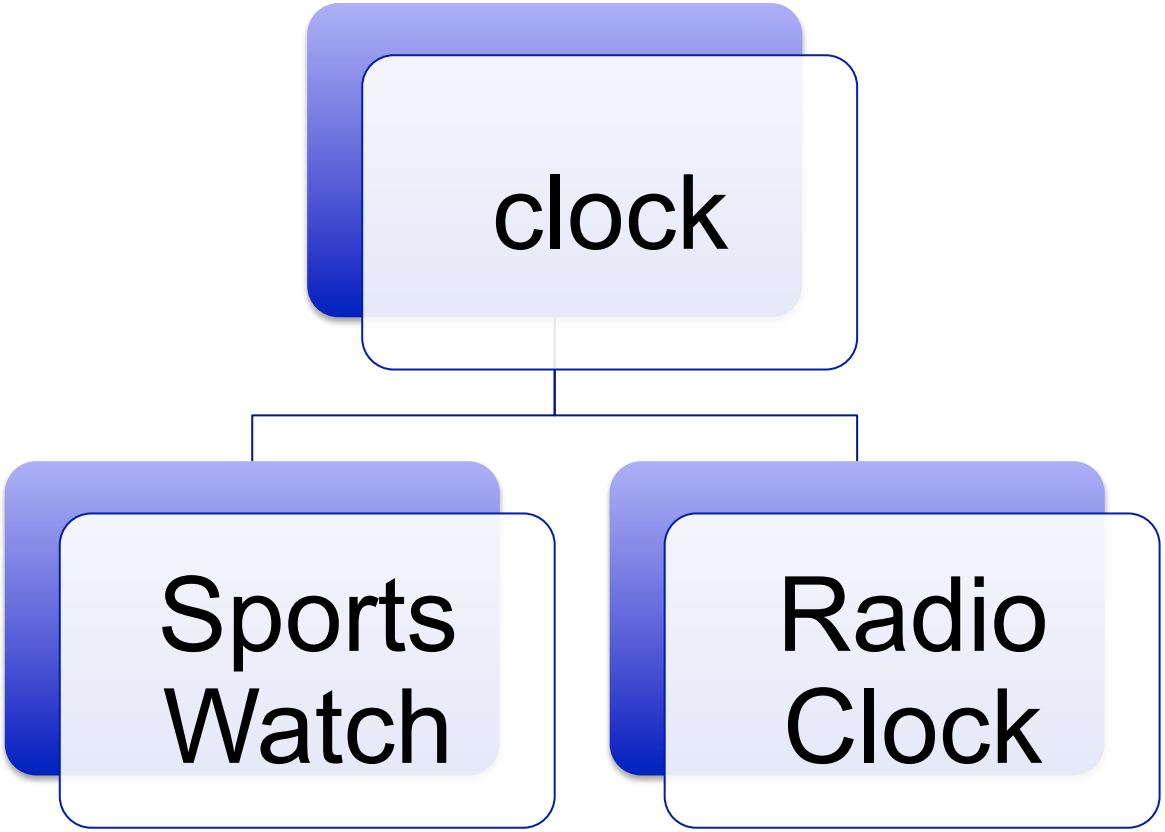
# Question



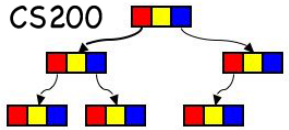

- Which of the following methods is **not** defined for java.lang.object?

A. equals
B. add
C. toString

# Example: Inheritance

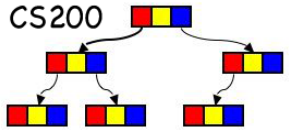


# Example: Inheritance – cont.



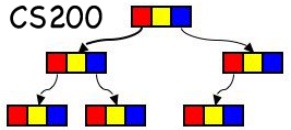

```
Public class SportsWatch extends Clock
{
    private long start_time;
    private long end_time;

    public long getDuration()
    {
      return end_time - start_time;
    }

}
```

# Overriding Methods




```
public class RadioClock
{
  @override
    public void noticeAlarm(){
          ring alarm
          turn_on_the_Radio
    }
}
```

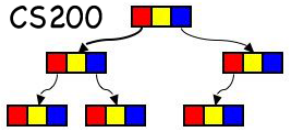
# Java Access Modifiers




- Keywords: `public`, `private,and protected`
- Control the visibility of the members of a class
  - ***Public members:*** used by anyone
  - ***Private members:*** used only by methods of the class
  - ***Protected members:*** used only by methods of the class, methods of other classes in the same package, and methods of the subclasses.
  - Members declared without an access modifier are **Package**: available to methods of the class and methods of other classes in the same package.

# Polymorphism:

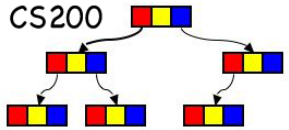
## having multiple forms




The ability for the same code to be used with several different types of objects and behave differently depending on the actual type of object used. Polymorphism is based on dynamic binding

Ability to create a variable, or an object that has more than one form.

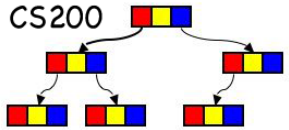
# Polymorphic method




```
RadioClock myRadioClock = new RadioClock();
//RadioClock is a Clock: has everything a clock has

Clock myClock = myRadioClock; myClock.noticeAlarm();
```


A: Clock
B: RadioClock

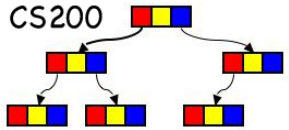
# Question




- Why would you redefine the following methods for subclasses of Object?

A. equals
B. toString

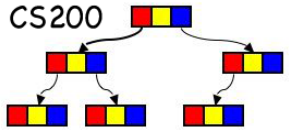
# Dynamic Binding




- The version of a method "`notifyAlarm()`" is decided at **execution time**, not at compilation time.
- WHY?

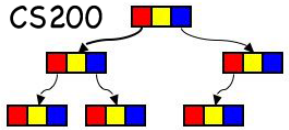
- Let's play with code for various animals: Zoo

# Abstract Class vs. Interface




- Abstract class: a special kind of class that **cannot be instantiated,** because it has **some** unimplemented (abstract) methods in it.
  - It allows only other classes to **inherit from** it, and make the derived class (more) concrete.
- Interface: is **NOT** a class.
  - An Interface has **NO** implementation at all inside.
    - Definitions of public methods without body.

# Abstract classes




- An abstract method has no body (i.e., no implementation).

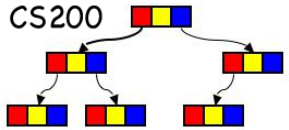
- Hence, an abstract class is incomplete and cannot be instantiated, but can be used as a base class.

```
abstract public class abstract-base-class-name {
    public abstract return-type method-name(params);
}
```

**Some subclass is required to override the abstract method and provide an implementation.**

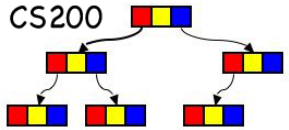
```
public class derived-class-name extends abstract-
base-class-name{
    public return-type method-name(params)
                { statements; }
}
```

# Abstract classes



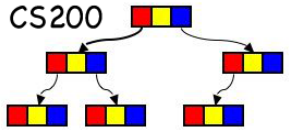

- When to use abstract classes
  - To represent entities that are insufficiently defined
  - Group together data/behavior that is useful for its subclasses

# Comparison-1



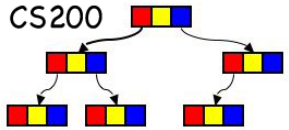

| Feature | Interface | Abstract Class |
|---|---|---|
| **Multiple inheritance** | A class may implement **several** interfaces | Only **one** |
| **Default implementation** | **Cannot** provide any code | **Can** provide complete, default code and/or just the details that have to be overridden. |
| **Access Modifier** | **Cannot have access modifiers** ( everything is assumed as public) | **Can** have it. |

# Comparison-2



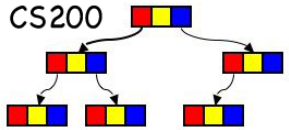

| Feature | Interface | Abstract Class |
|---|---|---|
| **Adding functionality (Versioning)** | For a new method, we have to **track down all the classes that implement** the interface and define implementations for that method | For a new method, we can provide **default implementation** and all the existing code might work properly. |
| **Instance variables** | **No instance variables** | **Instance variables** can be defined |

# Inheritance example



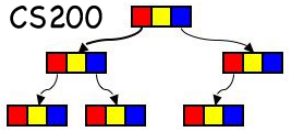

- You have been tasked with writing a program that handles pay for the employees of a non-profit organization.
- The organization has several types of employees on staff:
  - Full-time employees
  - Hourly workers
  - Volunteers
  - Executives

# Example




- Paying an employee:
  - Full-time employees – have a monthly pay
  - Hourly workers – hourly wages + hours worked
  - Volunteers – no pay
  - Executives – receive bonuses

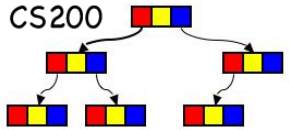
# Design




- All types of staff members need to have some basic functionality – capture that in a class called **StaffMember**

```
public class StaffMember {
    private String name;
    private String address;
    private String phone;

        public StaffMember (String name, String address,
                            String phone) {
        this.name = name;
        this.address = address;
        this.phone = phone;
    }
   // … getters and setters …
}
```

# Inheritance




- Creating a subclass, general syntax:

  `public class` ***<name>*** `extends` ***<superclass name>*** `{`

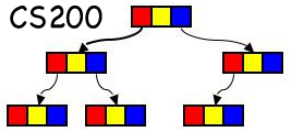
  - Example:

    `public class Employee` **`extends StaffMember{}`**

- By extending `StaffMember`, each `Employee` object now:
  - has `name, address, phone instance variables and get/setName(),get/setAddress(),get/setPhone() methods` automatically
  - can be treated as a `StaffMember` by any other code (seen later)

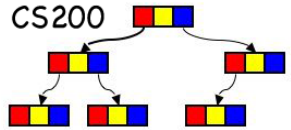
    (e.g. an `Employee` could be stored in a variable of type `StaffMember` or stored as an element of an array `StaffMember[]`)

# Inheritance




- **inheritance**: A way to create new classes based on existing classes, taking on their attributes/behavior.
  - a way to group related classes
  - a way to share code between classes
- A class *extends* another by absorbing its state and behavior.
  - **super-class**: The parent class that is being extended.
  - **sub-class**: The child class that extends the super-class and inherits its behavior.
    - The subclass receives a copy of every field and method from its super-class.
    - The subclass is **a more specific** type than its super-class (an **is-a** relationship)

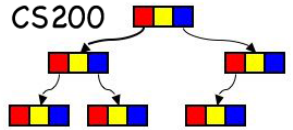
# Single Inheritance in Java




- Creating a subclass, general syntax:
  - `public class` ***<name>*** `extends` ***<superclass name>***
  - ***Can only extend a single class in Java!***

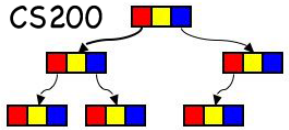
- Extends creates an is-A relationship
  - `class` ***<name>*** `is-A` ***<superclass name>***
  - ***This means that anywhere a <superclass variable> is used, a <subclass variable> may be used.***
  - Classes get all the instance variables/methods of their ancestors, **but cannot necessarily directly access them...**

# New access modifier - protected



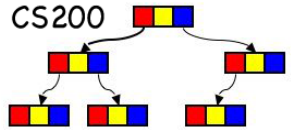

- public - can be seen/used by everyone
- **protected** – can be seen/used within class and any subclass.
- private - can only be seen/used by code in class (not in subclass!)

# Extends/protected/super




```
public class Employee extends StaffMember {
    protected String socialSecurityNumber;
    protected double payRate;

    public Employee (String name, String address,
       String phone, String socSecNumber, double rate){
       super(name, address, phone); //First line
       socialSecurityNumber = socSecNumber;
       payRate = rate;
    }
    public double pay(){
       return payRate;
    }
}
```

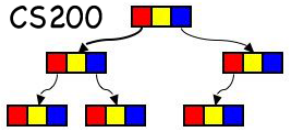
# StaffMember needs to change a bit




```
public class StaffMember {
    protected String name;
    protected String address;
    protected String phone;

    public StaffMember (String name, String address, String
    phone) {
        this.name = name;
        this.address = address;
        this.phone = phone;
    }
}
```

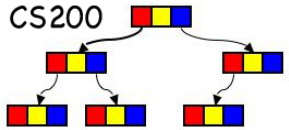
We need to know how staff members are to be paid, but we don't know how, so it's better to define StaffMember **abstract**

# Making StaffMember abstract




```
public abstract class StaffMember {
    protected String name;
    protected String address;
    protected String phone;

    public StaffMember (String name, String address, String
    phone) {
        this.name = name;
        this.address = address;
        this.phone = phone;
    }

    public abstract double pay();
}
```

# Overriding methods

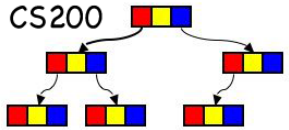



- **override**: To write a new version of a method in a subclass that replaces the super-class's version.
  - There is no special syntax for overriding.
    To override a super-class method, just write a new version of it in the subclass. This will replace the inherited version.

  - Example:

```
public class Hourly extends Employee {
    // overrides the pay method in Employee class
    public double pay () {
      double payment = payRate * hoursWorked;
      hoursWorked = 0;
      return payment;
  }
```

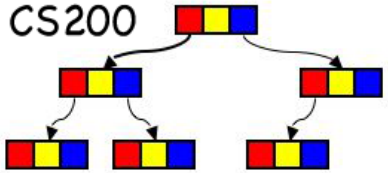
# Calling overridden methods




- The new method often relies on the overridden one. A subclass can call an overridden method with the `super` keyword.
- Calling an overridden method, syntax:

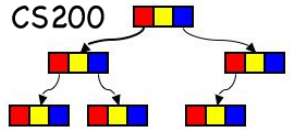
`super.`***<method name>*** `(` ***<parameter(s)>*** `)`

```
public class Executive extends Employee {
  public double pay() {
    double payment = super.pay() + bonus;
    bonus = 0;  // one time bonus
    return payment;
  }
```




# Inheritance and Polymorphism

# Constructors




- Constructors are not inherited.
  - Default constructor:

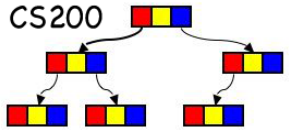
```
public Employee(){
    super();      // calls StaffMember() constructor
}
```

  - Constructor needs to call super-class constructors explicitly:

```
public Employee (String name, String address, String phone,
                 String socSecNumber, double rate) {
  super (name, address, phone);
  socialSecurityNumber = socSecNumber;
  payRate = rate;
}
```

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

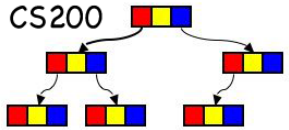
# Everything is an Object




- Every class in Java implicitly extends the Java `Object` class.
- Therefore every Java class inherits all the methods of the class `Object`, such as
  - `equals(Object other)`
  - `toString()`
- Often we want to override the standard implementation

What is the difference between overloading and overriding?

# The equals method




- You might think that the following is a valid implementation of the `equals` method:

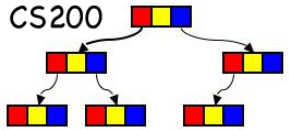
```
public boolean equals(Object other) {
    if (name.equals(other.name)) {
        return true;
    } else {
        return false;
    }
}
```

However, it does not compile.

```
StaffMember.java:36: cannot find symbol
symbol  : variable name
location: class java.lang.Object
```

- **Why?** Because an Object does not have a name instance variable.

# Type casting

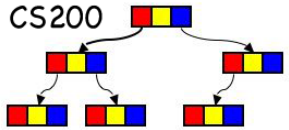



- The object that is passed to `equals` can be cast from `Object` into your class's type.
  - Example:

```
public boolean equals(Object o) {
    StaffMember other = (StaffMember) o;
    return name.equals(other.name);
}
```

- Type-casting with objects behaves differently than casting primitive values.
  - We are really casting a **reference of type `Object`** into a **reference of type `StaffMember`**.
  - We're **promising** the compiler that `o` refers to a `StaffMember` object, and thus has an instance variable `name`.

# instanceof




We can use a keyword operator `instanceof` to ask whether a variable refers to an object of a given type.

- The `instanceof` operator, general syntax:

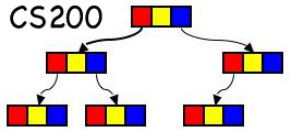
  ***<variable>*** `instanceof` ***<type>***

- The above is a `boolean` expression that can be used as the test in an `if` statement.

- Examples:

```
String s = "hello";
StaffMember p = new StaffMember(…);
if(s instanceof String) ...
if(p instanceof String) ...
```

# Our final version of equals

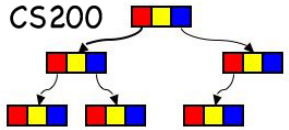



This version of the `equals` method allows us to correctly compare `StaffMember` objects with any type of object:

```
// Returns whether o refers to a StaffMember
// object with the same name

public boolean equals(Object o) {
    if (o instanceof StaffMember) {
        StaffMember other = (StaffMember) o;
        return name.equals(other.name);
    } else {
        return false;
    }
}
```

**even though we just checked that o is a StaffMember, we still have to cast it!**

# instanceof




- In our payroll example, Employee extends StaffMember. Consider the following snippet of code:

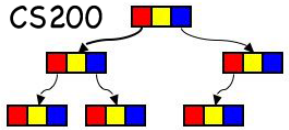
```
Employee employee = new Employee(…);
Boolean result = (employee instanceof StaffMember);
```

What will be the value of result?

a) true
b) false

Let's check out the Staff code

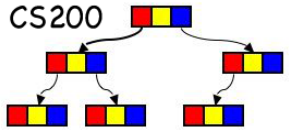
# Binding: which method is called?




- Assume 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");
    }
}
```

# Example

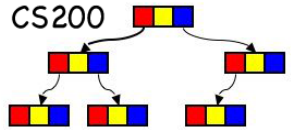



```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

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

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

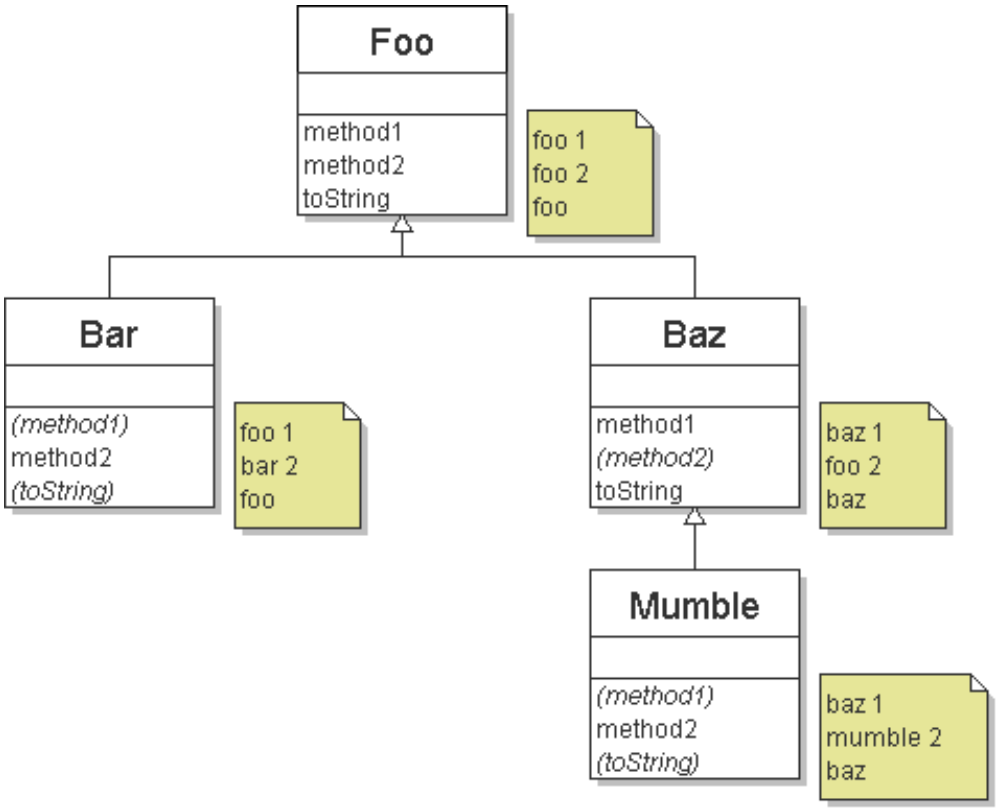
- The output of the following client code?

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

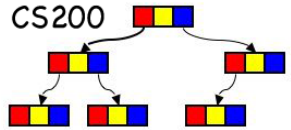
# Describing inheritance and binding




- UML diagram: Subclasses point to their super-class
- List methods (inherited methods in parenthesis)
- Method called is the **nearest in the hierarchy going up the tree**
  - This is a dynamic (run time) phenomenon called **dynamic binding**



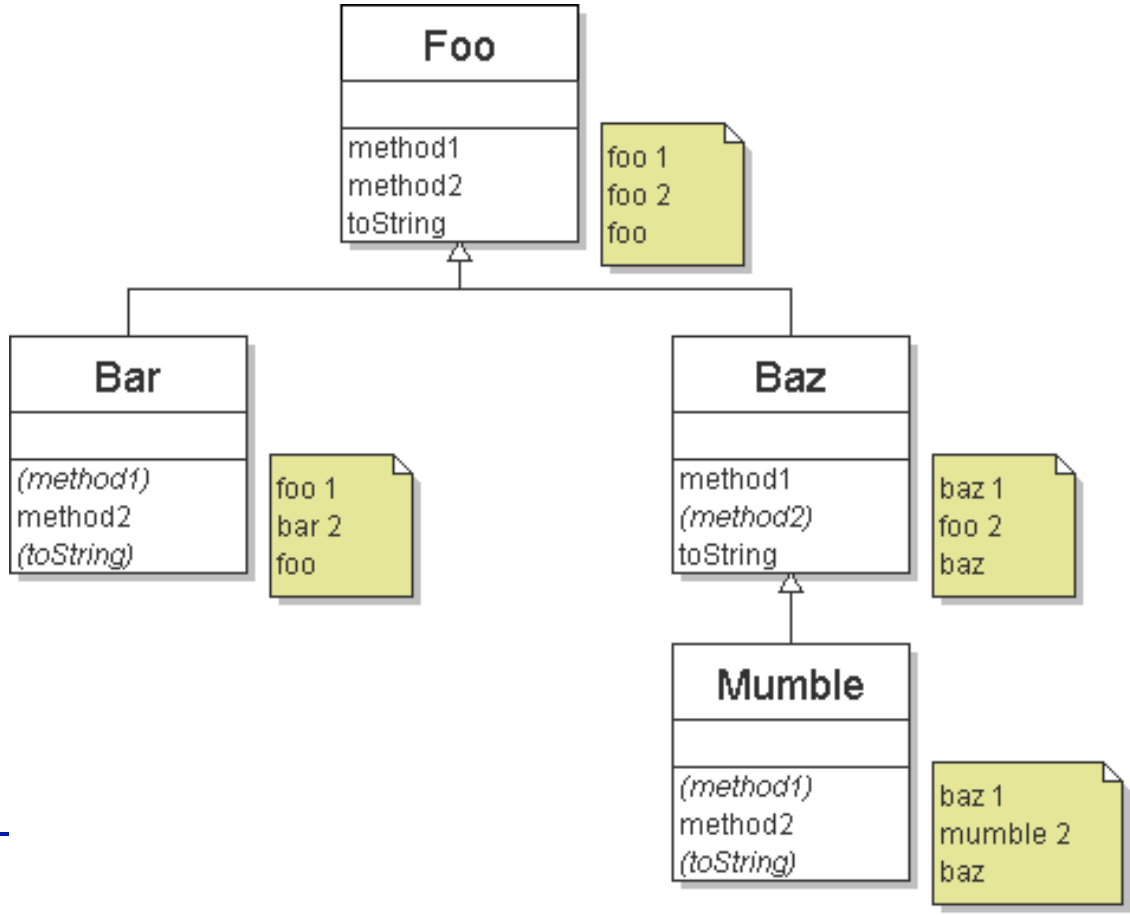
# Example (solved)



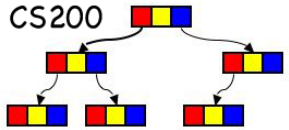

```
Foo[] a = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < a.length; i++) {
    System.out.println(a[i]);
    a[i].method1();
    a[i].method2();
    System.out.println()
}
```

Output?

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1

mumble 2
foo
foo 1
foo 2
```



# Polymorphism



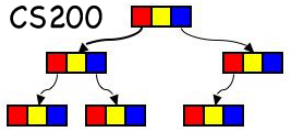

- It's legal for a variable of a super-class to refer to an object of one of its subclasses.

  Example:

```
staffList = new StaffMember[6];
staffList[0] = new Executive("Sam", "123 Main Line",
      "555-0469", "123-45-6789", 2423.07);
staffList[1] = new Employee("Carla", "456 Off Line",
      "555-0101", "987-65-4321", 1246.15);
staffList[2] = new Employee("Woody", "789 Off Rocker",
      "555-0000", "010-20-3040", 1169.23);
((Executive)staffList[0]).awardBonus (500.00);
```

Arrays of a super-class type can store any subtype as elements.

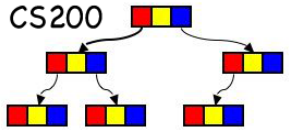
# Conversion and casting




- When a primitive type is used to store a value of another type (e.g. an `int` in a `double` variable) conversion takes place, i.e. the bit representation changes from e.g., int to double.

- When a subclass is stored in a superclass no conversion occurs, as these are both references!

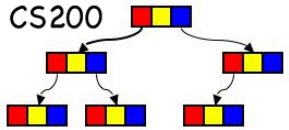
# Polymorphism defined




- **Polymorphism**: the ability for the same code to be used with several different types of objects and behave differently depending on the actual type of object used. Polymorphism is based on dynamic binding.
- Example:

```
for (int count=0; count < staffList.length; count++)
{
    amount = staffList[count].pay();  // polymorphic
}
```

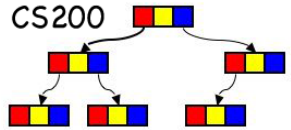
# Polymorphism and parameters




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

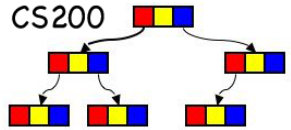
```
public class EmployeeMain {
    public static void main(String[] args) {
        Executive lisa = new Executive(…);
        Volunteer steve = new Volunteer(…);
        payEmployee(lisa);
        payEmployee(steve);
    }

    public static void payEmployee(StaffMember s) {
        System.out.println("salary = " + s.pay());
    }

}
```

# Notes about polymorphism



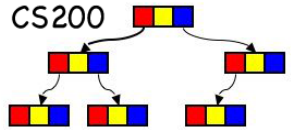

- The program doesn't know which pay method to call until it's actually running. This has many names: late binding, dynamic binding, virtual binding, and dynamic dispatch.
- You can only call methods known to the super-class, unless you explicitly cast.
- You can assign a sub-class object to a super class variables
- You **cannot** assign a super-class object to a sub-class variable
- **WHY? Which is more specific (sub or super?)**

# Inheritance: FAQ



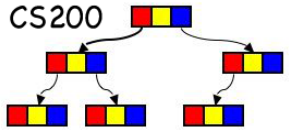

- How can a subclass call a method or a constructor defined in a super-class?
  - Use super() or super.method()
  - Can you call super.super.method()? **NO**
- Does Java support multiple inheritance?
  - No. Use interfaces instead
- What restrictions are placed on method overriding?
  - Same name, argument list, and return type. May not throw exceptions that are not thrown by the overridden method, or limit the access to the method
- Does a class automatically call the constructors of its super-class?
  - No. Need to call them explicitly

# this and super in constructors




- `this(...)` calls a constructor of the same class.
- `super(...)` calls a constructor of the super-class.
- Both need to be the first action in a constructor.

# Generics



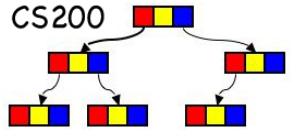

- Generics are used to build classes with a parameterized (element) type, e.g.

```
public class Thing<T>{
  private T data;
  public Thing(T input) {
     data = input;
  }
}
```

- We can now instantiate a particular Thing as follows:

```
Thing<String> stringThing =
      new Thing<String>(" a string ");
```

# Element types in Container Classes




- We have met generics in container classes such as ArrayList and List. E.g., ArrayLists are defined as:

  **Class ArrayList<E>**

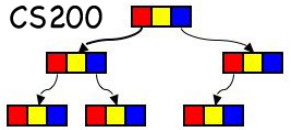
  - See java API
- Generics use type specifiers to, well, specify the type of the elements of the container, e.g., List<Integer> contains Integer objects.

```
List <Integer> integerList =
                        new List<Integer>();
```

- We can put an interface in the type specifier, e.g.,

  **ArrayList<Comparable>**

# Extending the type specifier




- Suppose we want to specify that objects of type Thing are Comparable. They could be e.g. Strings or Integers. We can express this as follows:

```
public class Thing<T extends Comparable<T>>{
   …
}
```

- let's check out some code …

***We will use generics in P4s BST and BSTNode classes***