CMSC 132: Object-Oriented Programming II

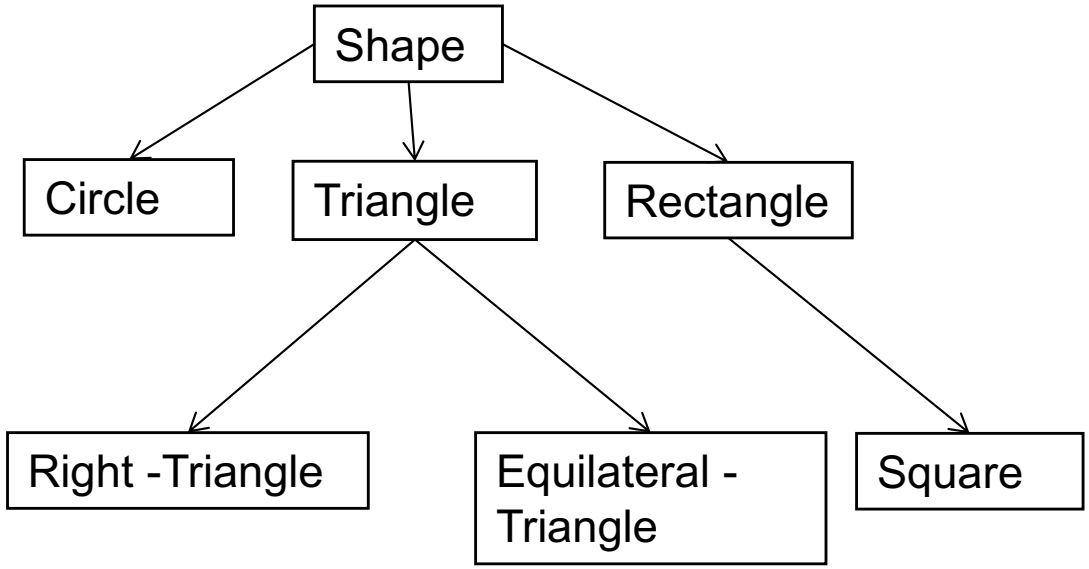
Inheritance

Inheritance

- Classes can be *derived* from other classes, thereby *inheriting* fields and methods from those classes.
- A class that is derived from another class is called a *subclass* (also a *derived class*, *extended class*, or *child class*).
- The class from which the subclass is derived is called a *superclass* (also a *base class* or a *parent class*).
- Derived (Child) class can be base (parent) class

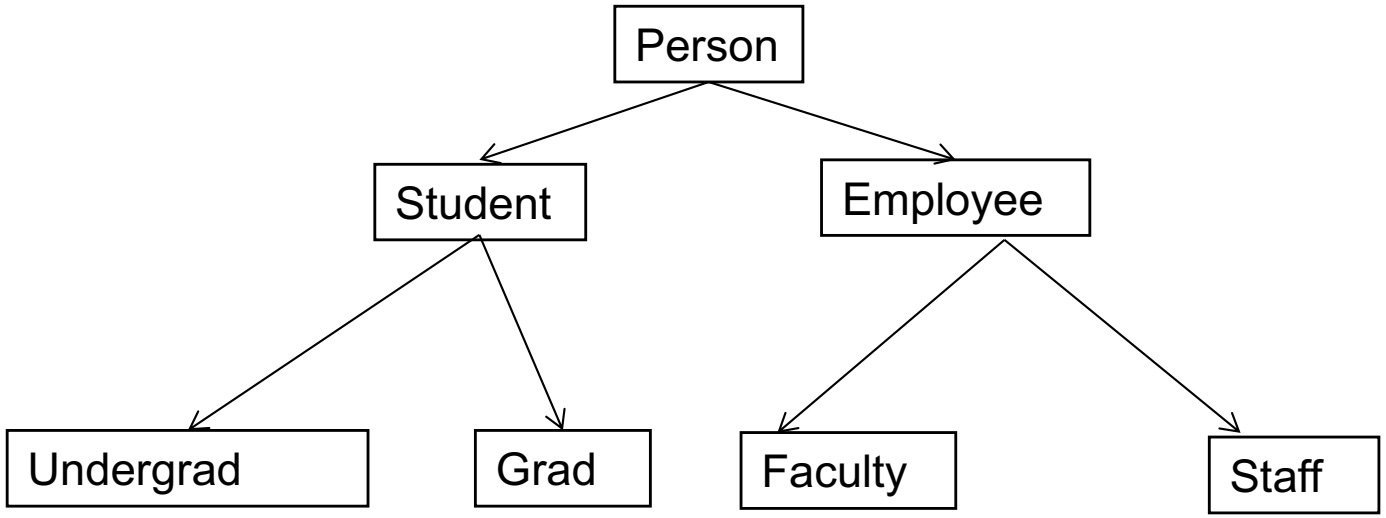
Inheritance

Motivation: In real life objects have a hierarchical structure:



Inheritance

- Define a general class
- Later, define specialized classes based on the general class
- These specialized classes inherit properties from the general class



Inheritance cont.

- What are some properties of a Person?
  - name, height, weight, age
- How about a Student?
  - ID, major, gpa
- Does a Student have a name, height, weight, and age?
  - Student inherits these properties from Person

is-a relationship

- This inheritance relationship is known as an is-a relationship

- A Grad student is a Student
- A Student is a Person.

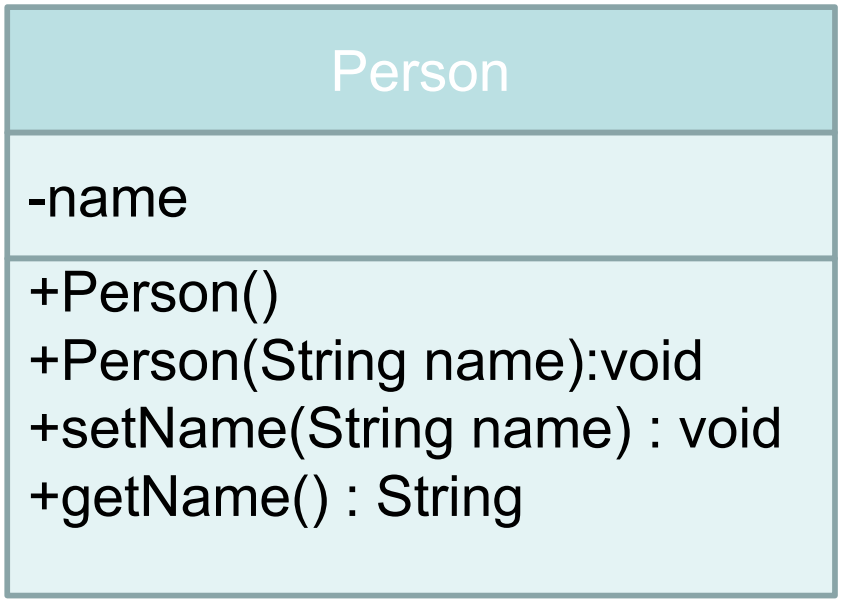
- Is a Person a Student? – Not necessarily!

Why inheritance is useful

- Enables you to define shared properties and actions once
- Derived classes can perform the same actions as base classes without having to redefine the actions
- If desired, the actions can be redefined – method overriding

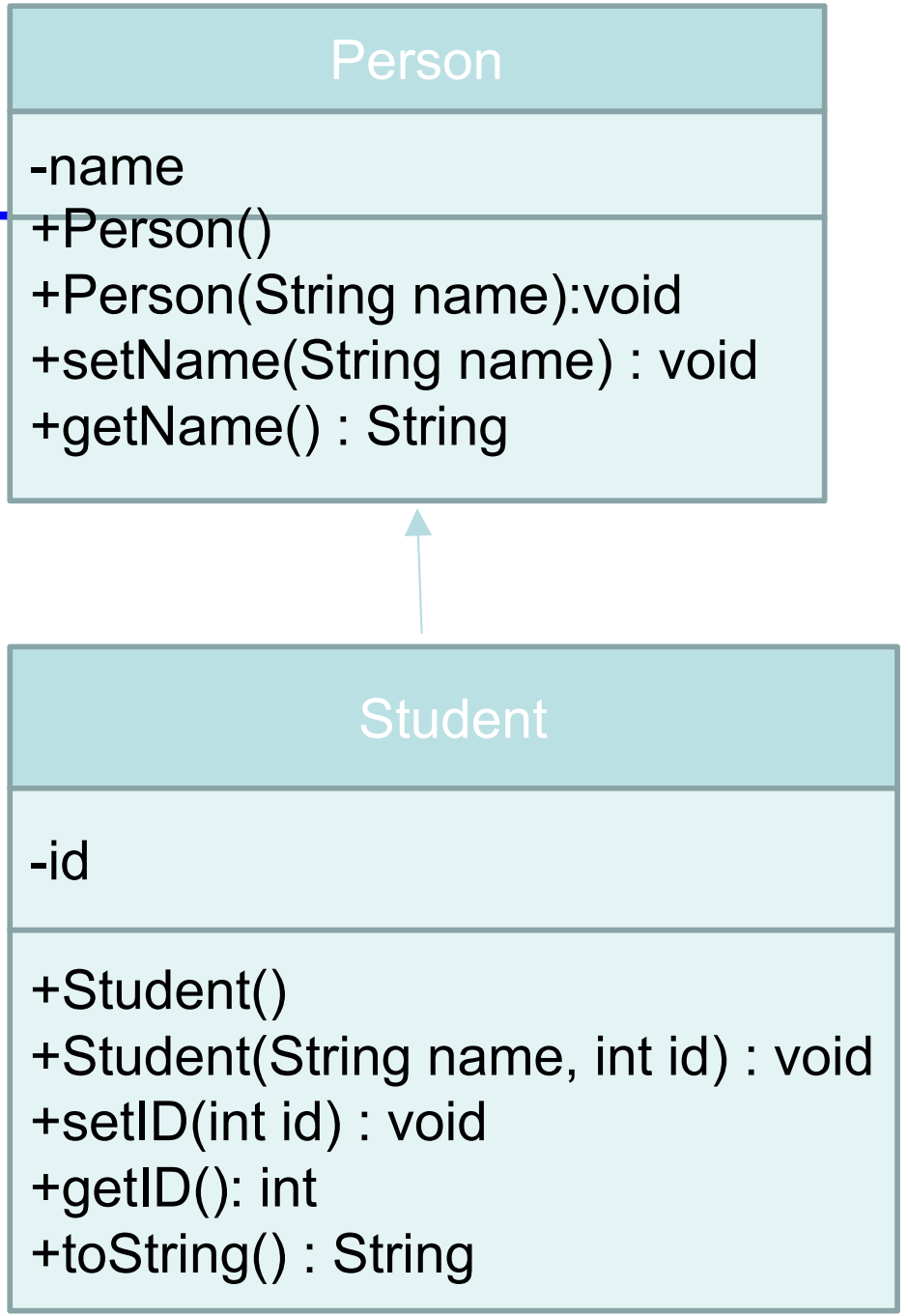
Person Class

```
public class Person {
    private String name;
    public Person(){
      name = "noname";
    }
    public Person(String name){
      this.name = name;
    }
    public void setName(String newName){
        name = newName;
    }
    public String getName(){
        return name;
    }
    @Override
    public String toString(){
        return "Name:"+name;
    }
}
```



Student Class

```
public class Student extends Person{
  private int id;
  public Student() {
    id = 0;
  }
  public Student(String name, int id) {
     super(name);
     this.id = id;
  }
  public void setID(int idNumber) {
     id = idNumber;
  }
  public int getID(){
      return id;
  }
  @Override
  public String toString(){
     return "Id:"+ id +"\tName:" +
                              getName();
  }
}
```



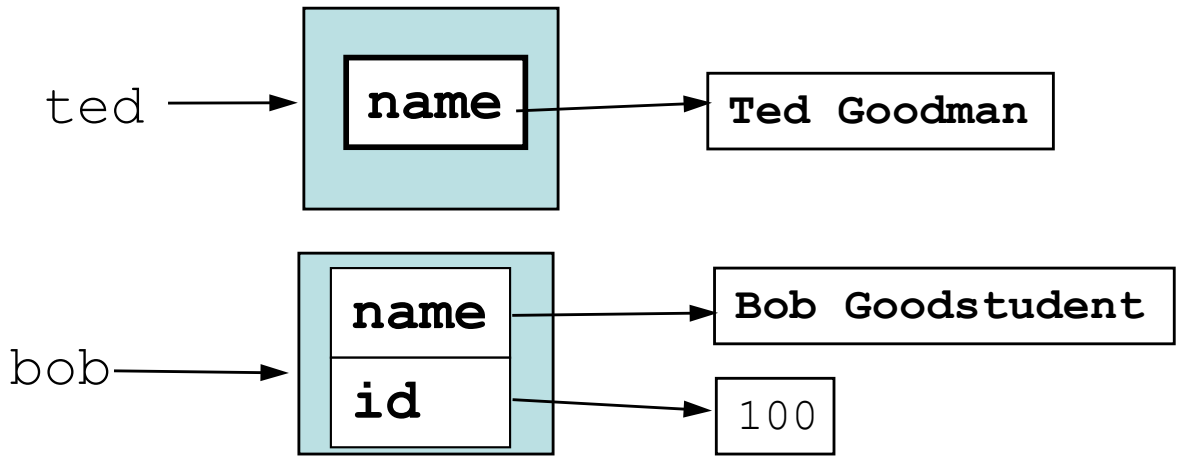
Dissecting the Student Class

- **Extends**: To specify that Student is a **derived class** (subclass) of Person we add the descriptor "extends" to the class definition:
  - **public class Student extends Person { … }**
- Notice that a Student class
  - Inherits everything from the Person class
  - A Student IS-A Person (wherever a Person is needed, we can use a Student).
- **super( )**: When initializing a new Student object, we need to initialize its **base class** (or **superclass**). This is done by calling **super(…)**. For example, **super(name)** invokes the constructor **Person(name)**
  - super(…) must be the **first statement** of your constructor
  - If you **do not** call super( ), Java will automatically invoke the base class's **default constructor**
  - What if the base class's default constructor is **undefined**? **Error**
  - You must use "**super(…)**", not "**Person(…)**".

Memory Layout and Initialization Order

- When you create a new derived class object:
  - Java allocates space for **both** the **base class** instance variables and the **derived class** variables
  - Java initializes the **base class variables first**, and then initializes the derived class variables
- **Example**:

```
Person ted = new Person( "Ted Goodman");
Student bob = new Student( "Bob Goodstudent", 100);
```



Inheritance

- **Inheritance:** Since Student is derived from Person, a Student object can invoke any of the Person methods, it **inherits** them

```
Student bob = new Student( "Bob Goodstudent", 100);
String bobsName = bob.getName( ) );
bob.setName( "Robert Goodstudent" );
System.out.println( "Bob's new info: " + bob.toString( ) );
```

- **A Student "is a" Person**:
  - By inheritance a Student object is also a Person object. We can use a Student reference anywhere that a Person reference is needed

```
Person robert = bob;                    // Okay: A Student is a Person
```

  - We cannot reverse this. (A Person need not be a Student.)

```
Student bob2 = robert; // Error! Cannot convert Person to Student
```

Overriding Methods

- **New Methods**: A derived class can define **entirely new** instance variables and new methods (e.g. gpa and getGpa())
- **Overriding**: A derived class can also **redefine existing** methods

```
public class Person {
  …
  public String toString() { … }
}
public class Student extends Person {
    …
    public String toString() { … }
}
Student bob = new Student( "Bob Goodstudent", 100);
System.out.println("Bob's info: " + bob);
```

The derived class can redefine this method.

Since bob is of type Student, this invokes the Student toString( )

Overriding and Overloading

- Don't confuse method **overriding** with method **overloading**.

  Overriding: occurs when a derived class defines a method with the **same name** and **parameters** as the base class.

  Overloading: occurs when two or more methods have the **same name**, but have **different parameters** (different signature).

  Example:

```
public class Person {
    public void setName(String n) { name = n; }
    …
}
public class Faculty extends Person {
    public void setName(String n) {
        super.setName("The Evil Professor " + n);
    }
    public void setName(String first, String last) {
        super.setName(first + " " + last);
    }
}
```

The base class defines a method setName( )

Overriding: Same name and parameters; different definition.

Overloading: Same name, but different parameters.

Quiz 1: Output of following program

```
class Test {
  int i;
}
class Main {
  public static void main(String args[]){
     Test t;
     System.out.println(t.i);
 }
}
```

A. 0
B. garbage value
C. compiler error
D. runtime error

Quiz 1: Output of following program

```
class Test {
  int i;
}
class Main {
  public static void main(String args[]){
     Test t;
     System.out.println(t.i);
 }
}
```

A. 0
B. garbage value
C. compiler error: variable not initialized
D. runtime error

Quiz 2: Output of following program

```
class Test {
  int i;
}
class Main {
  public static void main(String args[]){
     Test t = null;
     System.out.println(t.i);
 }
}
```

A. 0
B. garbage value
C. compiler error
D. runtime error

Quiz 2: Output of following program

```
class Test {
  int i;
}
class Main {
  public static void main(String args[]){
     Test t = null;
     System.out.println(t.i);
 }
}
```

A. 0
B. garbage value
C. compiler error
D. runtime error: Null pointer exception

Quiz 3: Output of following program

```
class Base{
    void display() {System.out.print("Base ");}
}
class Child extends Base{
   void display(){System.out.print("Child ");}
}
Base b= new Base();
Child c =  new Child ();
Base ref = b;
ref.display();
ref = c;
ref.display();
```

A. Compilation error
B. Base Child
C. Child Base
D. Runtime error

Quiz 3: Output of following program

```
class Base{
    void display() {System.out.print("Base ");}
}
class Child extends Base{
   void display(){System.out.print("Child ");}
}
Base b= new Base();
Child c =  new Child ();
Base ref = b;
ref.display();
ref = c;
ref.display();
```

A. Compilation error
B. Base Child
C. Child Base
D. Runtime error

Quiz 4: Output of following program

```
class Test{
  int a = 1;
  int b = 2;
  Test func(Test obj){
    Test obj3 = new Test();
    obj3 = obj;
    obj3.a = obj.a++ + ++obj.b;
    obj.b = obj.b;
    return obj3;
  }
  main(){
    Test obj1 = new Test();
    Test obj2 = obj1.func(obj1);
    System.out.print(obj1.a + ","+  obj1.b+",");
    System.out.print(obj2.a + "," + obj2.b+",");

    }
}
```

A. 1,2,4,3,
B. 4,3 4,3
C. Error

Quiz 4: Output of following program

```
class Test{
  int a = 1;
  int b = 2;
  Test func(Test obj){
    Test x = new Test();
    x = obj;
    x.a = obj.a++ + ++obj.b;
    obj.b = obj.b;
    return x;
  }
  main(){
    Test obj1 = new Test();
    Test obj2 = obj1.func(obj1);
    System.out.print(obj1.a + ","+  obj1.b+",");
    System.out.print(obj2.a + "," + obj2.b+",");
    }
}
```

A. 1,2,4,3,
B. 4,3 4,3
C. Error

Overriding Variables: Shadowing

- **We can override methods, can we override instance variables too?**
- **Answer**: Yes, it is possible, but **not recommended**
  - Overriding an instance variable is called **shadowing**, because it makes the base instance variables of the base class inaccessible. (We can still access it explicitly using **super.varName**).

```
public class Person {
  String name;
  // …
  Staff's name
}
```

```
public class Staff
  extends Person {
    String name;
    // …  name refers to
}
```

  - This can be **confusing** to readers, since they may not have noticed that you redefined name. Better to just pick a new variable name

Shadowing example

```
class Base {
 public int x;
 public Base(){x = 10;}
 public void foo(){return x);}
}
```

```
class Derived extends Base {
 public int x;
 public Derived(){ x = 20;}
 public void foo(){return (x + "\t" + super.x);}
}
```

```
Derived d = new Derived();
d.foo();
```

Shadowing example

```
class Base {
 public int x;
 public Base(){x = 10;}
 public void foo(){return x);}
}
```

```
class Derived extends Base {
 public int x;
 public Derived(){ x = 20;}
 public void foo(){return (x + "\t" + super.x);}
}
```

```
Derived d = new Derived();
Base b = d;
b.foo();
```

Shadowing example

```
class Base {
 public int x;
 public Base(){x = 10;}
 public void foo(){return x);}
}
```

```
class Derived extends Base {
 public int x;
 public Derived(){ x = 20;}
 public void foo(){return (x + "\t" + super.x);}
}
```

```
Derived d = new Derived();
Base b = d;
d.x;
b.x;
```

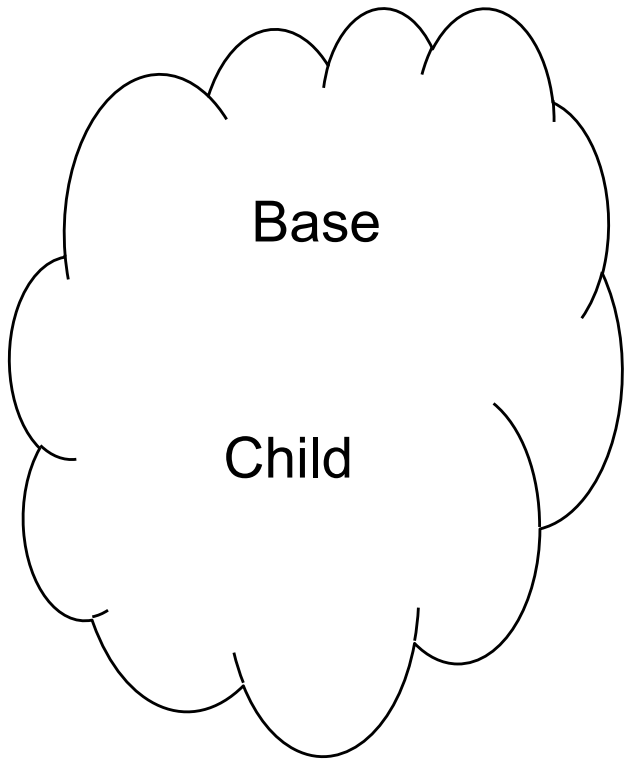
super and this

- **super**: refers to the base class object
  - We can invoke any base class constructor using **super(…)**.
  - We can access data and methods in the base class (Person) through **super**. E.g., toString( ) and equals( ) invoke the corresponding methods from the Person base class, using **super.toString( )** and **super.equals( )**.
- **this**: refers to the current object
  - We can refer to our own data and methods using "**this.**" but this usually is not needed
  - We can invoke any of our own constructors using **this(…)**. As with the super constructor, this can only be done **within a constructor**, and must be the **first statement** of the constructor. Example:

```
public Fraction(int n) {
    this(n,1);
}
```

Memory Layout

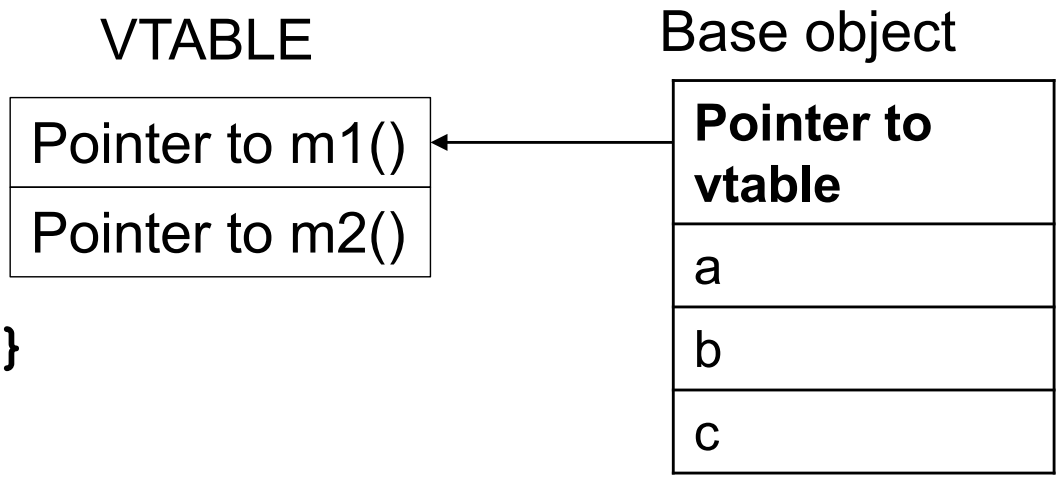
```
class Base{
  private int a;
  protected int b;
  protected int c;
  protected void m1(){}
  public void m2(){}
}

class Child extends Base{
  private int d;
  public void m1(){}
  public void m3(){}
}
```



The Java Virtual Machine does not mandate any particular internal structure for objects.

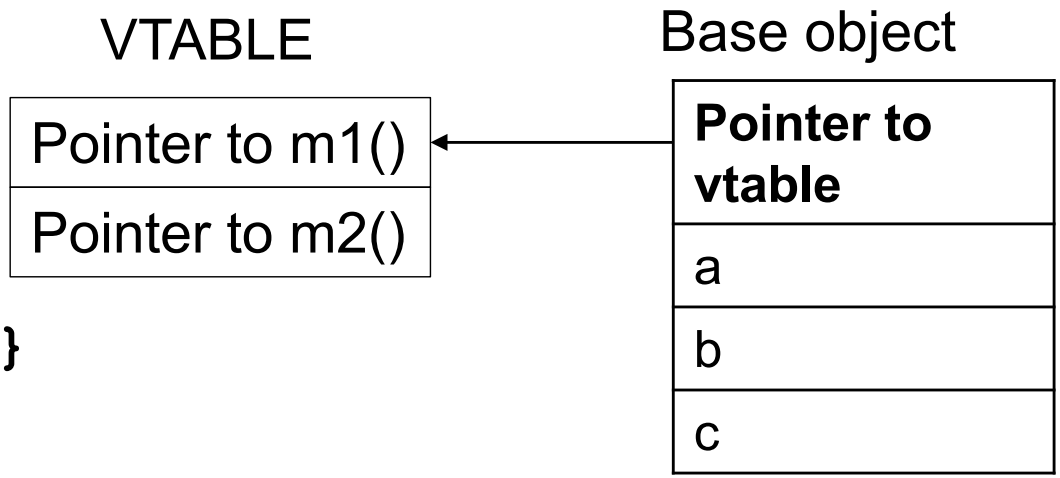
Memory Layout

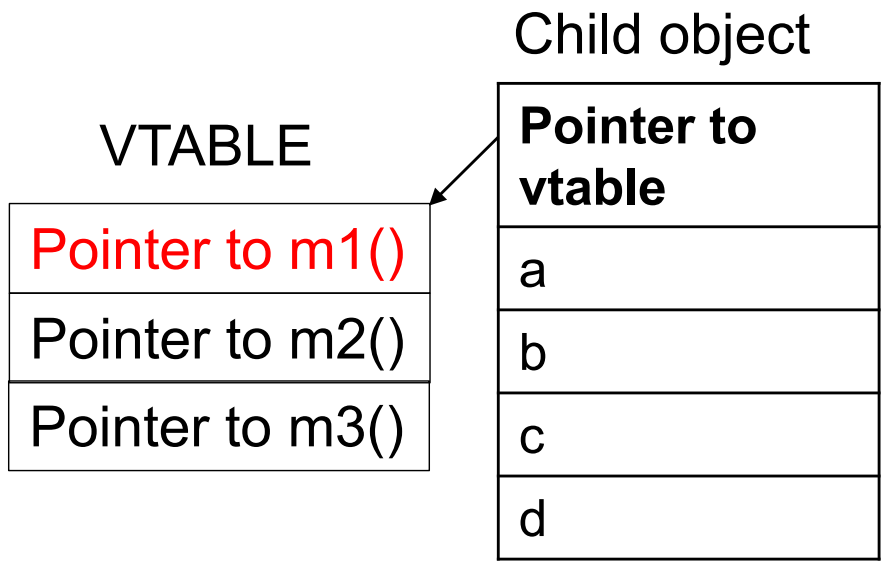
```
class Base{
  private int a;
  protected int b;
  protected int c;
  protected void m1(){}
  public void m2(){}
}

class Child extends Base{
  private int d;
  public void m1(){}
  public void m3(){}
}
```



Memory Layout

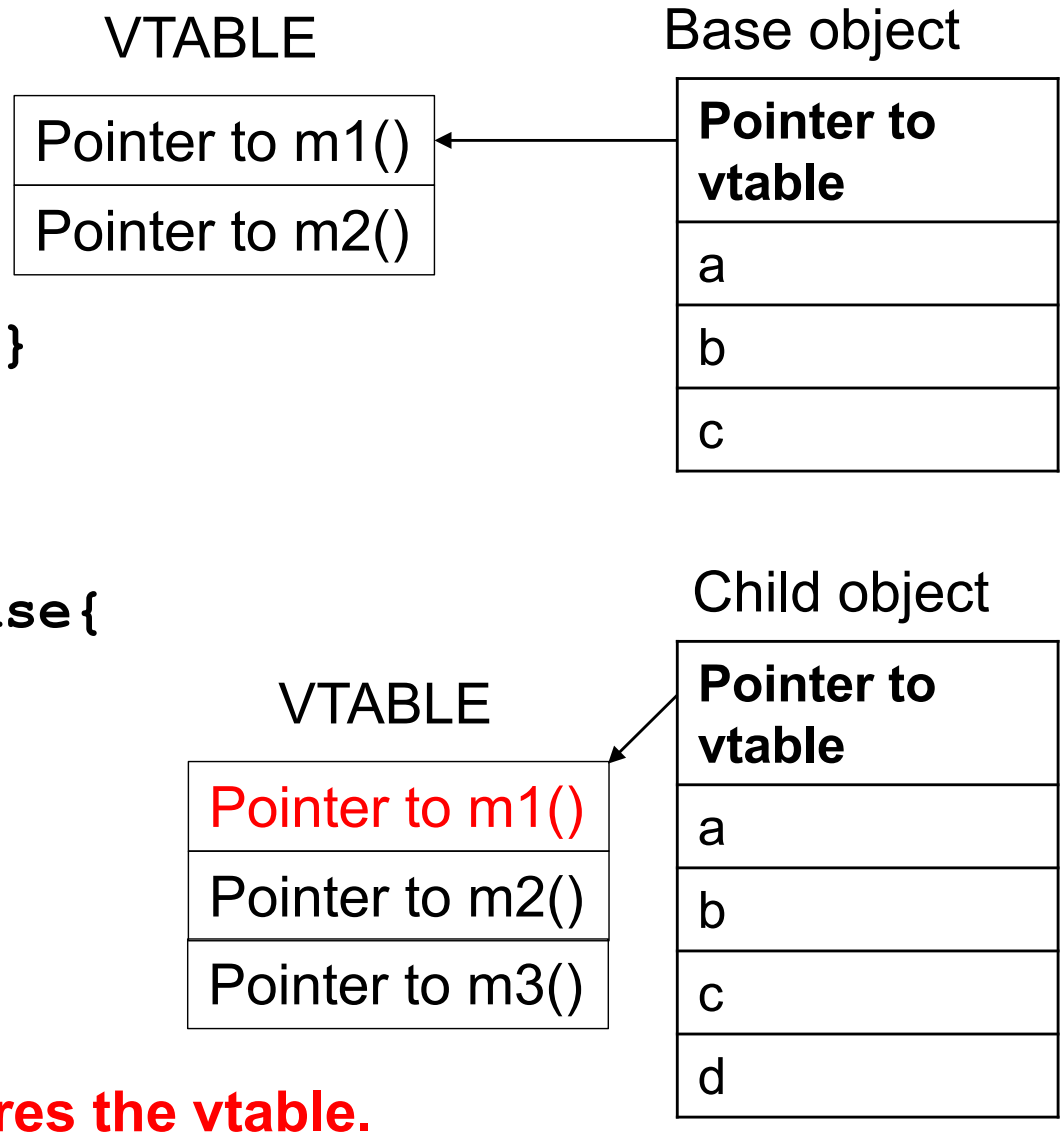
```
class Base{
  private int a;
  protected int b;
  protected int c;
  protected void m1(){}
  public void m2(){}
}

class Child extends Base{
  private int d;
  public void m1(){}
  public void m3(){}
}
```





Memory Layout

```
class Base{
  private int a;
  protected int b;
  protected int c;
  protected void m1(){}
  public void m2(){}
}

class Child extends Base{
  private int d;
  public void m1(){}
  public void m3(){}
}
```



Each class has one vtable.

All objects of the this class shares the vtable.