Inheritance

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Instance Variables and Inheritance (1/3)

```
1  class Professor{
2    public String name;
3
4    public String get_name(){
5      return name;
6    }
7  }
8  class CSIEProfessor extends Professor{
9    public int office_number;
10   public int get_office_number(){
11     return office_number;
12   }
13 }
```

- `CSIEProfessor`: two instance variables;
  `Professor`: one instance variable

Instance Variables and Inheritance (2/3)

```
1  class Professor{
2    public String name;
3    public String get_name(){ return name;}
4  }
5  class CSIEProfessor extends Professor{
6    public String name; //?!
7    public int office_number;
8    public int get_office_number(){ return office_number;}
9    public String get_this_name(){ return name;}
10 }
11 /* CSIEProfessor HTLin = new CSIEProfessor();
12    Professor HTLin = new CSIEProfessor();
13    Professor HTLin = new Professor(); */
14 /* System.out.println(HTLin.get_name());
15    System.out.println(HTLin.get_this_name());
16    System.out.println(HTLin.name); */
```

- `CSIEProfessor`: three instance variables;
  `Professor`: one instance variable
- which name will we get?

Instance Variables and Inheritance (3/3)

```
1  class Professor{
2    public String p_name;
3    public String get_name(){ return p_name; }
4  }
5  class CSIEProfessor extends Professor{
6    public String c_name;
7    public int office_number;
8    public int get_office_number(){ return office_number;}
9    public String get_this_name(){ return c_name;}
10 }
```

- an (almost) equivalent view of what the compiler sees

Instance Variables and Inheritance: Key Point

- instance variable binding: determined at compile time
- same “name” can co-exist in a derived class, binding determined by compile-time type

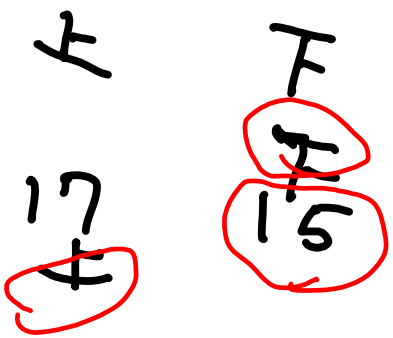
Instance Methods and Inheritance (1/2)

```
1  class Professor{
2    public void say_hello(){
3      System.out.println("Hello!");
4    }
5  }
6  class CSIEProfessor extends Professor{
7    public void play_BBS(){
8      System.out.println("Fun!");
9    }
10 }
```

- `CSIEProfessor`: two instance methods;
  `Professor`: one instance method

Instance Methods and Inheritance (2/2)

```
1  class Professor{
2    public void say_hello(){
3      System.out.println("Hello!");
4    }
5  }
6  class CSIEProfessor extends Professor{
7    public void say_hello(){
8      System.out.println("May the OOP course be with you!");
9    }
10 }
11 /* alternatives
12 CSIEProfessor HTLin = new CSIEProfessor();
13 Professor HTLin = new CSIEProfessor();
14 Professor HTLin = new Professor();
15 */
16 /* calls
17 HTLin.say_hello();
18 */
```



- which say_hello() will be called?

Instance Methods and Inheritance: Key Point

instance method binding: dynamic, depending on run-time instance types

method overriding

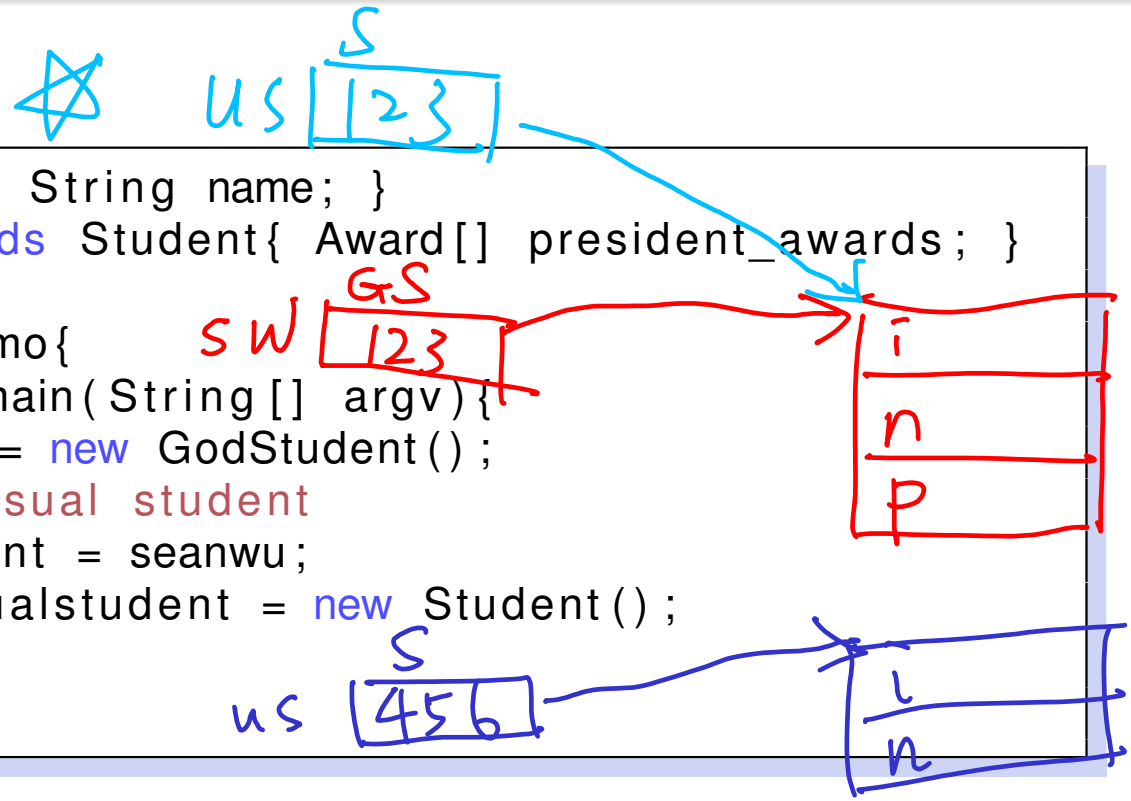
Reference Assignment and Inheritance (1/4)

```
1  class Student{ int ID; String name; }
2  class GodStudent extends Student{ Award[] president_awards; }
3
4  public class StudentDemo{
5    public static show_student_id(Student s){
6      System.out.println(s.ID);
7    }
8    public static void main(String[] argv){
9      GodStudent seanwu = new GodStudent();
10     show_student_id(seanwu);
11     Student CharlieL = new Student();
12     show_student_id(CharlieL);
13   }
14 }
```

- seanwu refers to an instance of GodStudent (for sure!)
- seanwu refers to an instance of Student as well
- one instance, many coherent types (in argument passing, return value, etc.)

Reference Assignment and Inheritance (2/4)

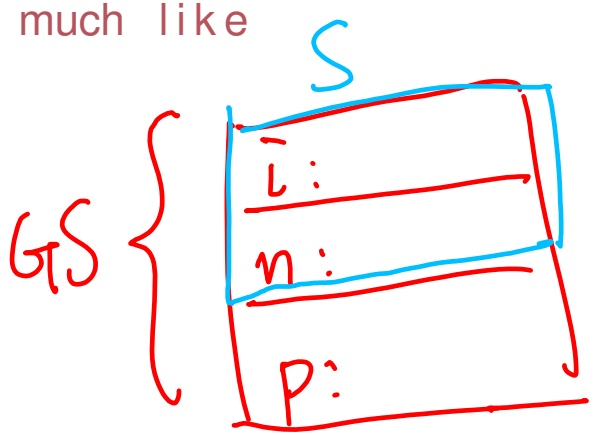
```
1  class Student{ int ID; String name; }
2  class GodStudent extends Student{ Award[] president_awards; }
3
4  public class StudentDemo{
5    public static void main(String[] argv){
6      GodStudent seanwu = new GodStudent();
7      //I want to be a usual student
8      Student usualstudent = seanwu;
9      Student anotherusualstudent = new Student();
10   }
11 }
```



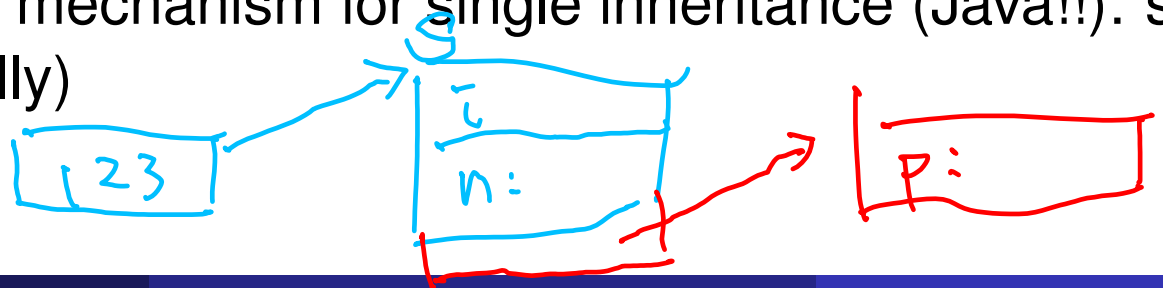
- if “copying assignment”, a copy of seanwu can be a usual student
- but “reference assignment” in Java, how can seanwu be usual?
- mechanism?

Reference Assignment and Inheritance (3/4)

```
1  class Student{ int ID; String name; }
2  //takes 4 + (8) bytes
3  class GodStudent extends Student{ Award[] president_awards; }
4  //takes 4 + (8) + (8) bytes
5
6  /** excluding some other information, much like
7  class GodStudent{
8    //first 4 + (8) bytes (for Student)
9    int ID;
10   String name;
11   //last (8) bytes (for GodStudent)
12   Award[] president_awards;
13 }//takes 4 + (8) + (8) bytes
14 **/
```



- one possible mechanism for single inheritance (Java!!): shared prefix (virtually)



Reference Assignment and Inheritance (4/4)

```
1  class Student{ int ID; String name; }
2  //class Student{ int 000; reference 004; }
3  class GodStudent extends Student{ Award[] president_awards; }
4  //class GodStudent{ int 000; reference 004; reference 012; }
```

- one possible mechanism: variable name $\Rightarrow$ a single number when class **loads**
- (after instance type check) objects can just safely access memory contents by numbers

Reference Assignment and Inheritance: Key Point

a simple run-time mechanism (shared prefix):
ancestor first, descendant last

Note, however, that *the Java virtual machine does not mandate any particular internal structure for objects.*

Constructor and Inheritance (1/3)

```
1  class Student{ int ID; String name;
2    Student(int ID, String name){this.ID = ID; this.name =
         name;}
3  }
4  class AwardStudent extends Student{
5    Award[] awards;
6    AwardStudent(int ID, String name, int nAward){
7      super(ID, name); //means invoke Student(ID, name);
8      awards = new Award[nAward];
9    }
10 }
```

- initialize the ancestor part **first**
- construct AwardStudent $\Rightarrow$ (i.e. calls) construct Student
- thus, the "Student" parts of the memory are initialized first, then the "AwardStudent" part

Constructor and Inheritance (2/3)

```
1  class Student{ int ID; String name;
2    Student(int ID, String name){this.ID = ID; this.name =
         name;}
3  }
4  class AwardStudent extends Student{
5    Award[] awards;
6    AwardStudent(int ID, String name, int nAward){
7      super(ID, name); //means invoke Student(ID, name);
8      //any utility function in Student can be used at this
           stage
9      awards = new Award[nAward];
10   }
11 }
```

- `super` goes first so that there is a valid "Student" object in the very beginning

Constructor and Inheritance (3/3)

```
1  class Student /* extends Object */ {
2    int ID; String name;
3    Student(int ID, String name){this.ID = ID; this.name =
         name;}
4    /*
5    Student(int ID, String name){
6      super(); //like Object();
7      this.ID = ID; this.name = name;
8    }
9    */
10 }
11 class AwardStudent extends Student{
12   Award[] awards;
13   AwardStudent(int ID, String name, int nAward){
14     //?
15   }
16 }
```

- `super()` automatically added if no explicit call in the beginning

A Fallback: Constructor Calls

```
1  class Record{
2    String name; int score;
3    Record(int init_score){score = init_score;}
4    Record(){ Record(40);}
5  }
6  public class RecordDemo{
7    public static void main(String[] arg){
8      Record r1 = new Record(60);
9      Record r2 = new Record();
10     System.out.println(r1.score);
11     System.out.println(r2.score);
12   }
13 }
```

- there is a bug above
- one constructor can only call one other constructor (via this or super)

Constructor and Inheritance: Key Point

calls ancestor constructor first
(and thus ancestor forms first)

Private Variables and Inheritance (1/1)

```
1  class Parent{
2    private int hidden_money;
3    public void show_hidden_money_amount(){ }
4  }
5  class Child extends Parent{
6    void spend_money(){
7      //(1) can hidden_money be spent here?
8      //(2) can show_hidden_money_amount() be called here?
9    }
10 }
```

- (1) not directly (2) yes
- does Child have a hidden_money slot in the memory?
  - yes, to make show_hidden_money_amount() work!

Private Variables and Inheritance: Key Point

private variables are still “inherited” in memory,
but not “visible” to the subclass because of encapsulation

Private Methods and Inheritance (1/1)

```
1  class Parent{
2    private int hidden_money;
3    private void buy_liquor(){ }
4    public void show_hidden_money_amount(){ }
5  }
6  class Child extends Parent{
7    void buy(){
8      //can buy_liquor() be called here?
9    }
10 }
```

- no, because cannot see
- private methods effectively not inherited

Private Methods and Inheritance: Key Point

private methods effectively not inherited because not "visible" to the subclass

More on Access Permissions (1/2)

```
1  package generation.old;
2  class Parent{
3    private int hidden_money;
4    public void show_hidden_money_amount(){ }
5    /* default */ void middle_age_issues();
6    /* default */ void cross_gen_issues();
7  }
8  //different file, Child.java
9  package generation.new;
10 class Child extends Parent{
11 }
```

- in Child, can hidden_money be accessed? no.
- can show_hidden_money_amount be accessed? yes.
- can middle_age_issues be accessed? no.
- can cross_gen_issues be accessed? no.
  —what if we want “yes”?

More on Access Permissions (2/2)

```
1  package generation.old;
2  public class Parent{
3    private int hidden_money;
4    public void show_hidden_money_amount(){ }
5    /* default */ void middle_age_issues();
6    protected void cross_gen_issues();
7  }
8  //different file, Child.java
9  package generation.young;
10 class Child extends Parent{
11 }
```

- can cross_gen_issues be accessed? no.
  —what if we want “yes”?
- `protected`: accessible to Child (sub-classes) and Friend (same-package-classes)

More on Access Permissions: Key Point

1. `public`: accessible to everyone
2. `protected`: accessible to sub-classes and same-package-classes
3. `(default)`: accessible to same-package-classes
4. `private`: accessible within my class definitions

class

1. 3

instance

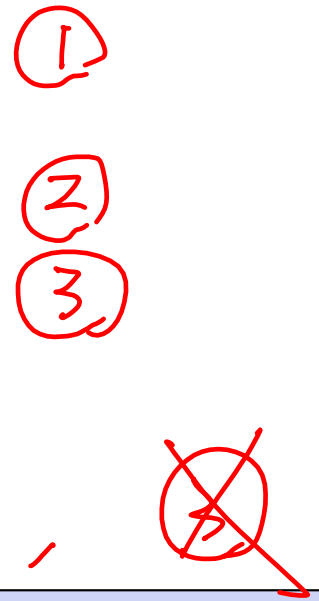
1 2 3 4

static

1 2 3 4

Permissions and Method Overriding (1/1)

```
1  public class Parent{
2    protected void method(){ }
3  }
4  class Child extends Parent{
5    public void method(){ } //?
6    private void method(){ } //?
7  }
8
9  //bottom line
10 Parent var = new Child();
11 var.method();
```



- need last two lines to work for things same-package as Parent
- need last two lines to reflect overriding (calling Child's)
- Child: same or more open than Parent

Permissions and Method Overriding: Key Points

Child: same or more open than Parent

More on `super` (1/1)

```
1  class Student{
2    int ID; String name;
3    void study_for_midterm(){
4      System.out.println("I am studying for midterm.");
5    }
6  }
7  class AwardStudent extends Student{
8    Award[] president_awards;
9    void study_for_midterm(){
10     for(int i = 0; i < 10; i++)
11       super.study_for_midterm();
12   }
13 }
```

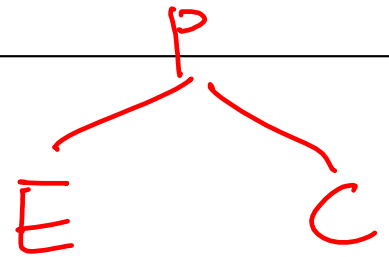
- `super`: much like `(ParentName)this` (but NOT the same)

More on `super`: Key Point

`this`: a Sub-type reference variable pointing to the object itself
`super`: a Base-type reference variable pointing to the object itself
same reference value, different type
`super.super`: no

Inheritance (1/5)

```
1  class Professor{ }
2  class CSIEProfessor extends Professor{ }
3  class EEProfessor extends Professor{ }
4
5  class Demo{
6    public static void main(String[] argv){
7      CSIEProfessor HTLin = new CSIEProfessor();
8      System.out.println(HTLin.getClass());
9      System.out.println(HTLin instanceof CSIEProfessor);
10     System.out.println(HTLin instanceof Professor);
11     System.out.println(HTLin instanceof EEProfessor);
12   }
13 }
```



class CSIEProfessor
true
true
~~false~~
hahaha

- HTLin is an instance of CSIEProfessor
- HTLin is an instance of Professor (because CSIEProfessor is a type of Professor)
- HTLin is **not** an instance of EE Professor [the compiler knows]

Inheritance (2/5)

```
1  class Professor{ }
2  class CSIEProfessor extends Professor{ }
3  class EEProfessor extends Professor{ }
4
5  class Demo{
6    public static void main(String[] argv){
7      Professor HTLin = new CSIEProfessor();
8      System.out.println(HTLin.getClass());
9      System.out.println(HTLin instanceof CSIEProfessor);
10     System.out.println(HTLin instanceof Professor);
11     System.out.println(HTLin instanceof EEProfessor);
12   }
13 }
```

- HTLin is an instance of CSIEProfessor
- HTLin is an instance of Professor
- HTLin is **not** an instance of EE Professor [not easily determined at compile-time, but can be checked at run-time]

Inheritance (3/5)

```
1   class Professor{ }
2   class CSIEProfessor extends Professor{ }
3   class EEProfessor extends Professor{ }
4
5   class Demo{
6     public static void main(String[] argv){
7       Professor HTLin = new CSIEProfessor();
8       int score = 100;
9       System.out.println(HTLin.getClass());
10      System.out.println(score.getClass());
11      System.out.println(HTLin instanceof java.lang.Object);
12      System.out.println(score instanceof java.lang.Object);
13    }
14  }
```

hahaha

true

hahaha

- every valid object is an instance of java.lang.Object
- primitive type is not an instance of anything [easily determined at compile-time]

Inheritance (4/5)

```
1  class Professor{ }
2  class CSIEProfessor extends Professor{ }
3  class EEProfessor extends Professor{ }
4
5  class Demo{
6    public static void main(String[] argv){
7      Professor[] parr = new CSIEProfessor[3];
8      System.out.println(parr.getClass());
9      System.out.println(parr instanceof Object);
10     System.out.println(parr instanceof Object[]);
11     System.out.println(parr instanceof Professor[]);
12     System.out.println(parr instanceof CSIEProfessor[]);
13     System.out.println(parr instanceof EEProfessor[]);
14   }
15 }
```

T F H
23 3 2
22 1 1
25 1 0
27 1 0
1 27 2

- every object array is an instance of Object[]
- Object[] is a reference type
- every reference type “extends” Object
- every object array is an instance of Object

Inheritance (5/5)

```
1  class Demo{
2    public static void main(String[] argv){
3      int[] oarr = new int[3];
4      System.out.println(oarr.getClass());
5      System.out.println(oarr instanceof Object);
6      System.out.println(oarr instanceof Object[]);
7      System.out.println(oarr instanceof double[]);
8      System.out.println(oarr instanceof short[]);
9      System.out.println(oarr instanceof int[]);
10   }
11 }
```

T F It
20 1 0
13 0 5
0 12 7
1 6 7
many

- a int array is an instance of int[]
- int[] is a reference type
- every reference type “extends” Object
- every object array is an instance of Object

Inheritance: Key Point

- compile-time detectable: only siblings (int sibling of Object, EEProfessor sibling of CSIEProfessor, etc.)
- run-time detectable: other instances (or null)

```
1  CSIEProfessor SomeOne = new CSIEProfessor();
2  Professor p;
3  p = SomeOne; //note: reference assignment
4  if (p instanceof CSIEProfessor && p != null){
5    CSIEProfessor pCSIE = (CSIEProfessor)p;
6    //...
7  }
8  /* instanceof is not really used very often;
9     but useful in enhancing understanding. */
```

Java Type Hierarchy