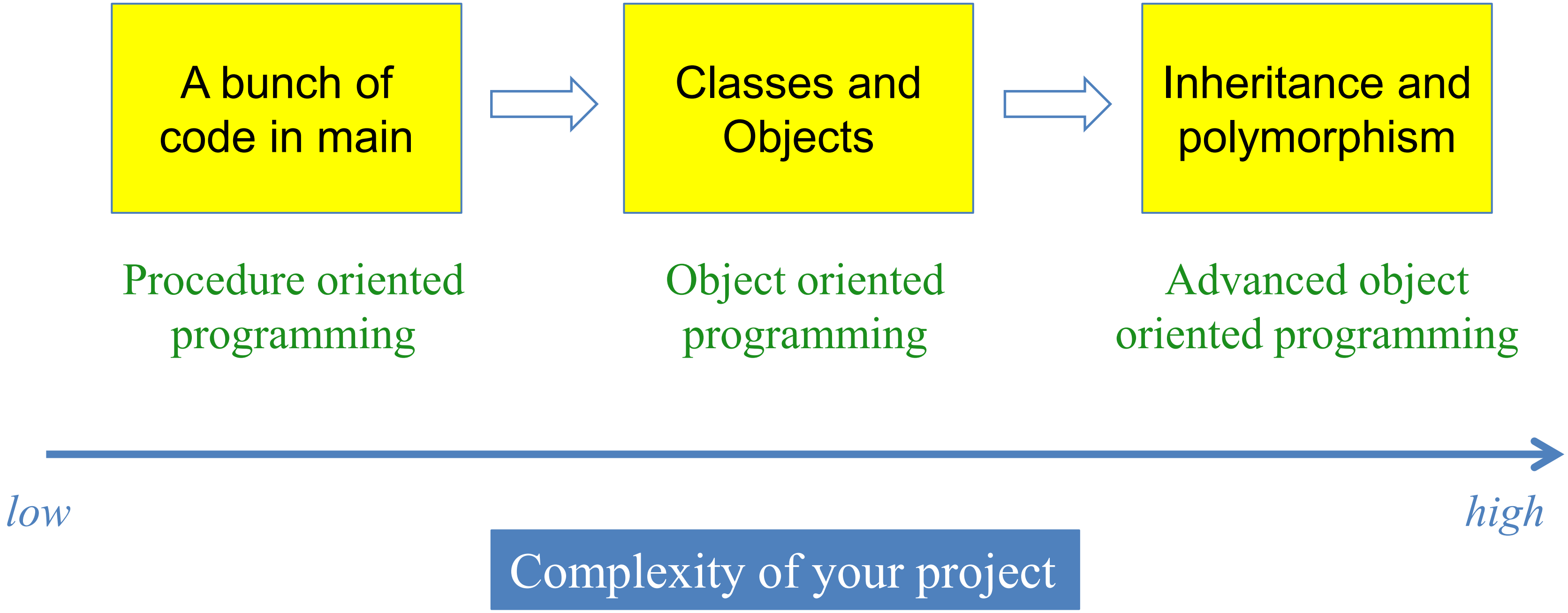
Lecture 3
Inheritance and Polymorphism

Department of Computer Science
Hofstra University

Lecture Goals

- Explain the value of inheritance
- Use UML Diagrams to display class hierarchies
- Explain an “is-a” relationship between classes
- Understand that object construction occurs from the inside out
- Explain the purpose and implementation of polymorphism
- Create methods which override from a superclass
- Use casting of objects to aid the compiler
- Describe abstract classes and interfaces and decide which one to use

General Motivation



A bunch of code in main

Classes and Objects

Inheritance and polymorphism

Procedure oriented programming

Object oriented programming

Advanced object oriented programming

low

high

Complexity of your project

Motivation for Inheritance

Fully written Person class

```
public class Person {
        private String name;
        // more code here
}
```

Potential Solution 1

```
public class Person
{
        private String name;
        private boolean student;
        public person(boolean s)
        {
                this.student = s;
        }
}
```

Potential Problem

Now needs to handle:

1. Students
2. Faculty

they behave differently

Now in every method, I can just do this:

```
if (student)
            // code for students
        else
            // code for faculty
```

Motivation for Inheritance (Contd.)

Fully written Person class

```
public class Person {
        private String name;
        // more code here
}
```

Potential Solution 1 - Problems

```
public class Person
{
        private String name;
        private boolean student;
        private boolean graduate;
        private boolean fulltime;
        // more code here
}
```

different students behave differently

Potential Problem

Now needs to handle:

1. Students
2. Faculty

they behave differently

Each method becomes:

```
~~if (student)~~
        ~~if (graduate && fulltime)~~
                ~~// some code~~
        ~~else if (!graduate)~~
                ~~// more code~~
```

Motivation for Inheritance (Contd.)

Fully written Person class

```
public class Person {
        private String name;
        // more code here
}
```

Potential Solution 2 - Problems

```
public class Student
{
        private String name;
        private String firstname;
        private String lastname;
}
```

```
// in main
~~Person persons[];~~
Student students[];
Faculty faculty[];
```

cannot use

this anymore

Potential Problem

Now needs to handle:

1. Students
2. Faculty

they behave differently

cannot just copy

tedious

potential mistake

```
public class Faculty
{
        private String name;
}
```

hard to keep common code consistent

no clean way single array of everyone for thing like sorting by join date

Motivation for Inheritance (Contd.)

- What do we want then?

1. Keep common behavior in one class
2. Split different behavior into separate classes
3. Keep all of the objects in a single data structure

The answer is Inheritance

Details of Inheritance: Extend Keyword

common code

base/super class

```
public class Person {
        private String name;
        public getName() { return name; }
        // more code here
}
```

diverging code

derived/sub class

```
public class Student  extend Person  {
        ~~private String name;~~
        // more code here
}
```

“extend” means “inherit from”

diverging code

derived/sub class

```
public class Faculty   extend Person  {
        ~~private String name;~~
        // more code here
}
```

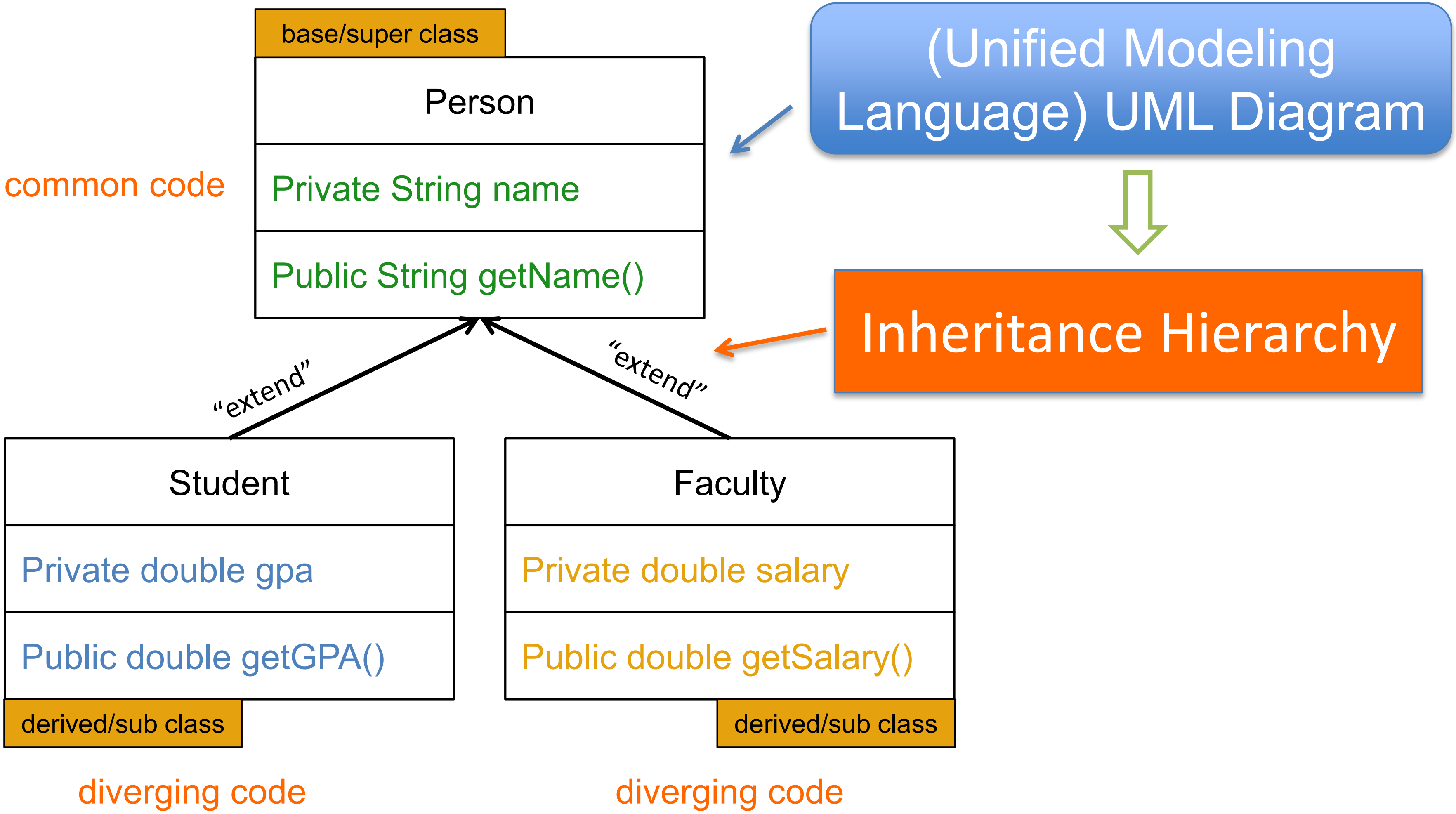
What is inherited?

- Public instance variables
- Public methods
- Private instance variables

Private variables can be accessed only through public methods!

Private methods cannot be inherited!

Illustrate Inheritance Hierarchy with UML Diagrams



base/super class

Person

Private String name

Public String getName()

common code

(Unified Modeling Language) UML Diagram

Inheritance Hierarchy

"extend"

"extend"

Student

Private double gpa

Public double getGPA()

derived/sub class

diverging code

Faculty

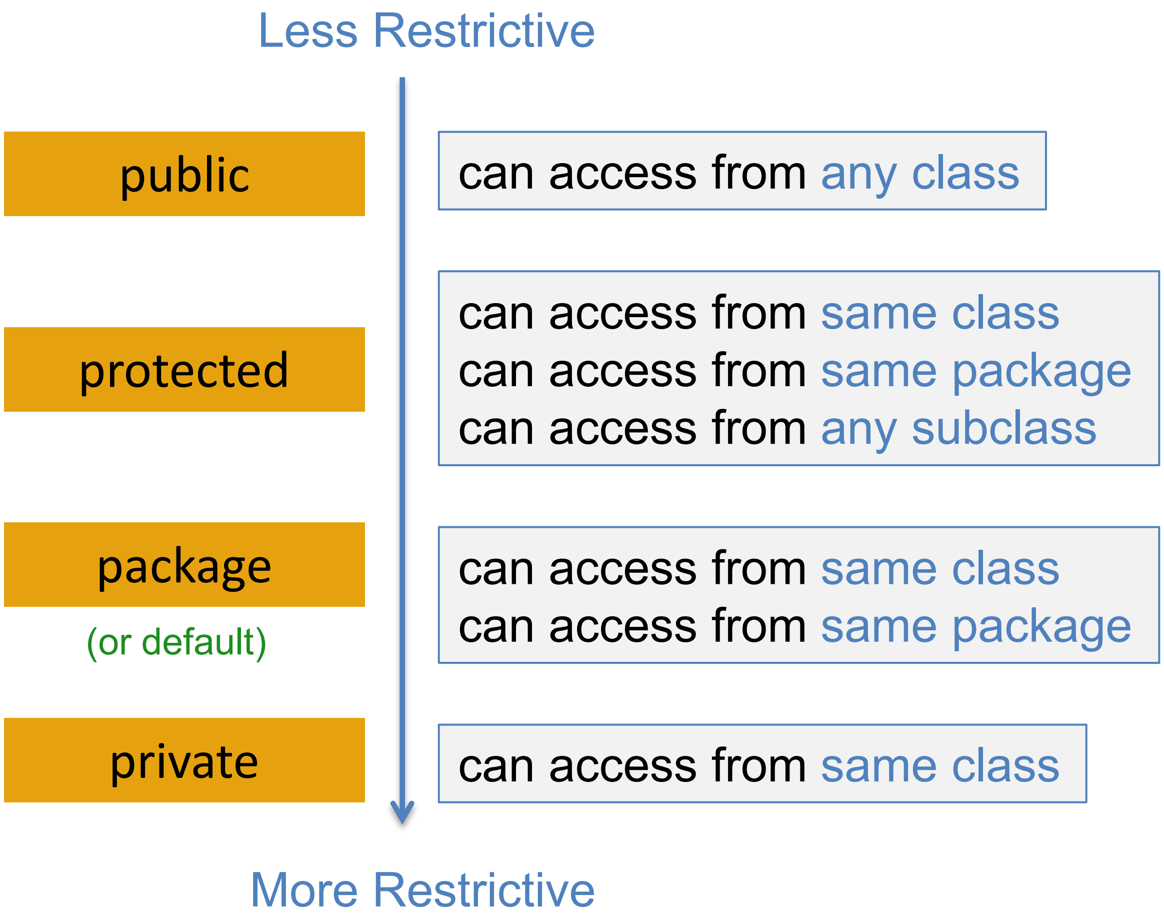
Private double salary

Public double getSalary()

derived/sub class

diverging code

Definitions of Visibility Modifiers



Less Restrictive

public	can access from any class
protected	can access from same class can access from same package can access from any subclass
package (or default)	can access from same class can access from same package
private	can access from same class

More Restrictive

<u>Definition</u>: A **package** is a grouping of related classes. It makes classes easier to find and use, to avoid naming conflicts, and to control access

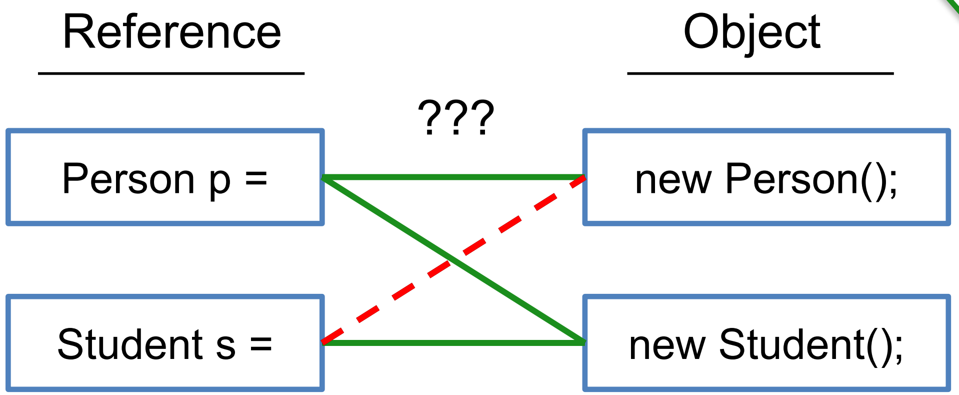
Lose access by any subclass

Rule of thumb: Make member variables private (and methods either public or private)

“Is-a” Relationship Between Reference and Object Type

- What do we want then?

1. Keep common behavior in one class
2. Split different behavior into separate classes
3. Keep all of the objects in a single data structure



the code compiles and works just fine

```
// in main
Person[] p = new Person[3];
p[0] = new Person();
p[1] = new Student();
p[2] = new Faculty();
```

A Person array CAN store Student and Faculty objects

Person p = new Person(); ✓

Student s = new Student(); ✓

Person p = new Student(); ✓

Student s = new Person(); ✗

A Person “is-a” Person

A Student “is-a” Student

A Student “is-a” Person

You can assign an object of a more specific subclass (Student) to a reference of a more abstract base class (Person), but not vice versa.

Some Practices

```
public class Person {
        private String name;
        public String getName() {return name;}
}
```

```
public class Student extends Person {
        private int id;
        public int getID() {return id;}
}
```

```
public class Faculty extends Person {
        private String id;
        public String getID() {return id;}
}
```

```
Student s = new Student();
Person p = new Person();
Person q = new Person();
Faculty f = new Faculty();
Object o = new Faculty();
```

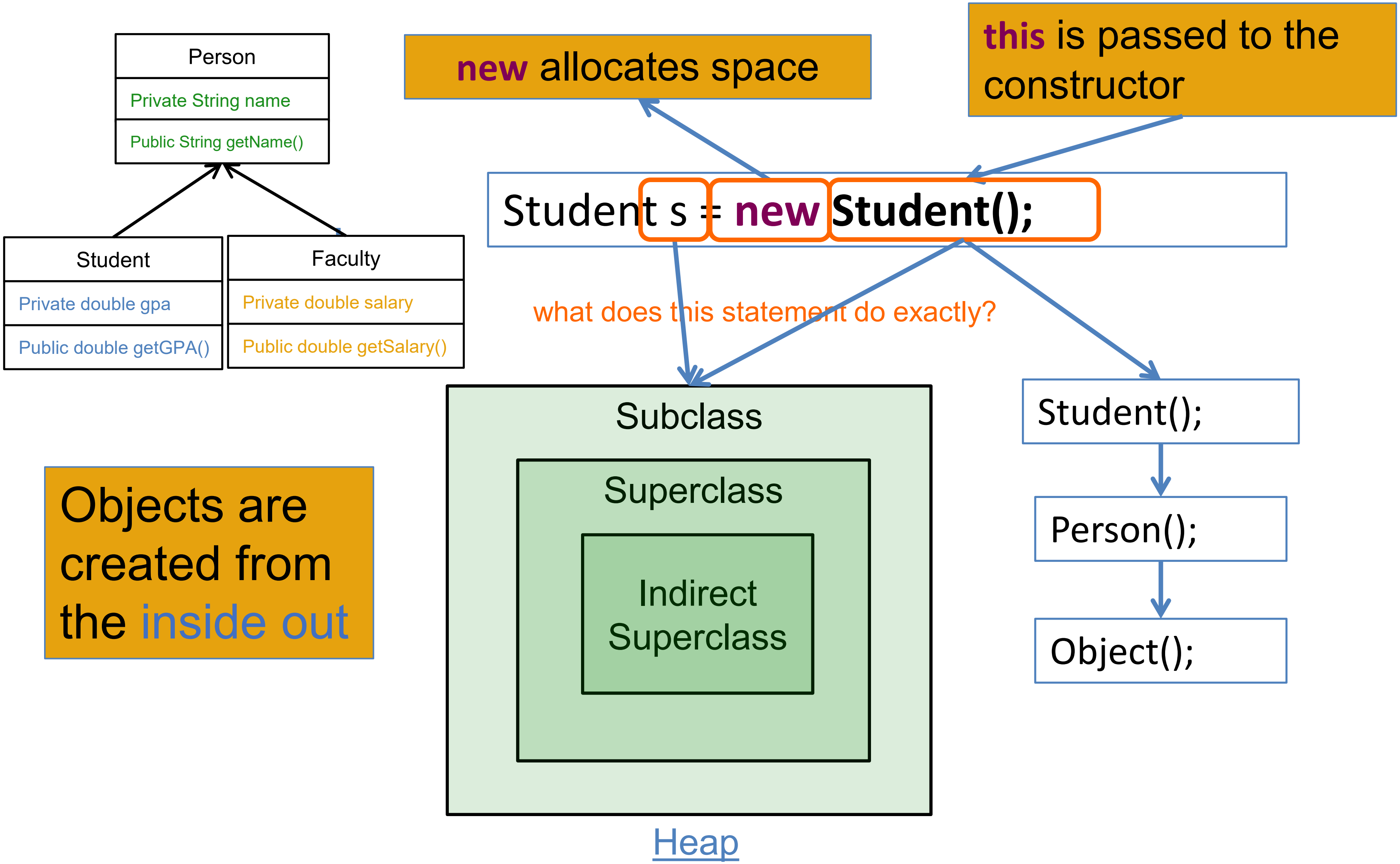
Which of the following lines of code, when executed in sequence, will cause an error?

```
String n = s.getName();    ✓
p = s;                     ✓
int m = p.getID();         ✗
f = q;                     ✗
o = s;                     ✓
```

```
int m = ((Student)p).getID();
```

do casting and compiler would trust you

Revisit Object Construction with Inheritance



Person

Private String name

Public String getName()

Student

Private double gpa

Public double getGPA()

Faculty

Private double salary

Public double getSalary()

new allocates space

this is passed to the constructor

Student s = **new** **Student();**

what does this statement do exactly?

Subclass

Superclass

Indirect Superclass

Heap

Student();

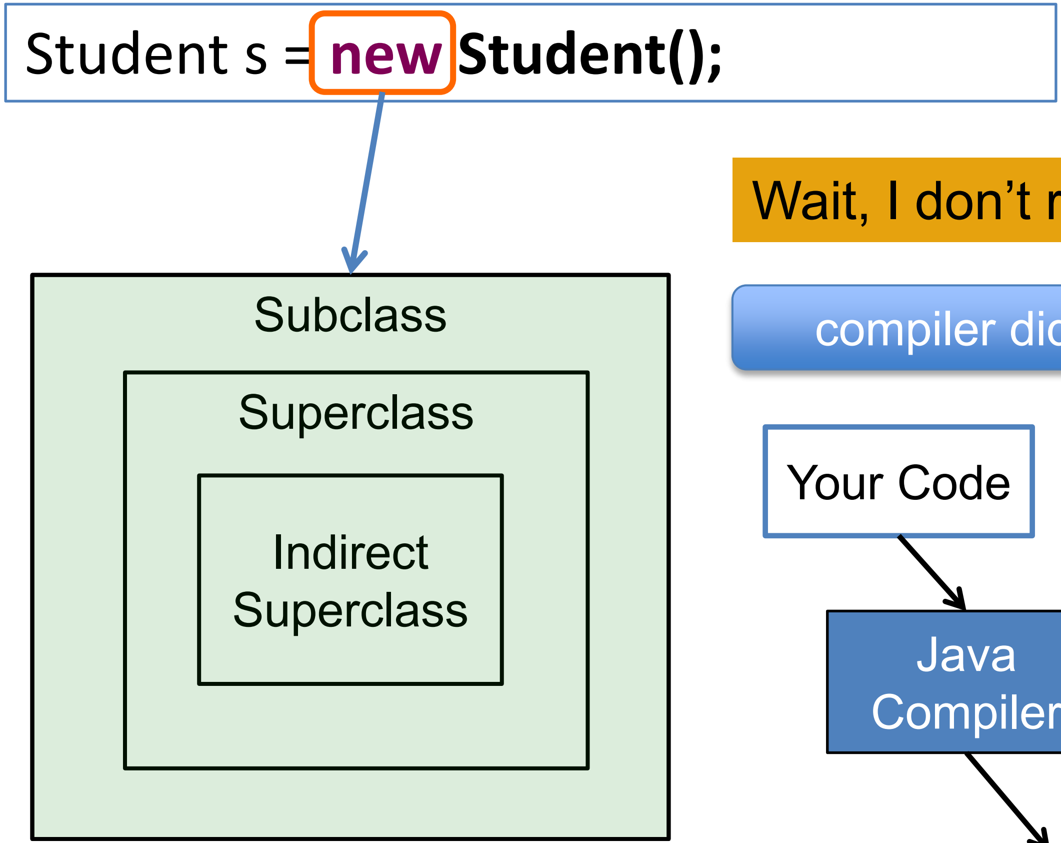
Person();

Object();

Objects are created from the inside out

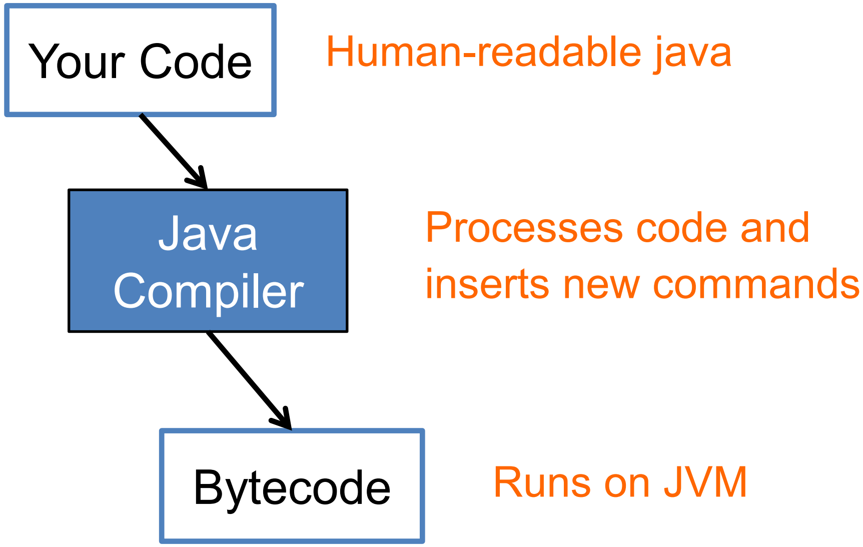
Object Construction with Compiler Support

```
Student s = new Student();
```

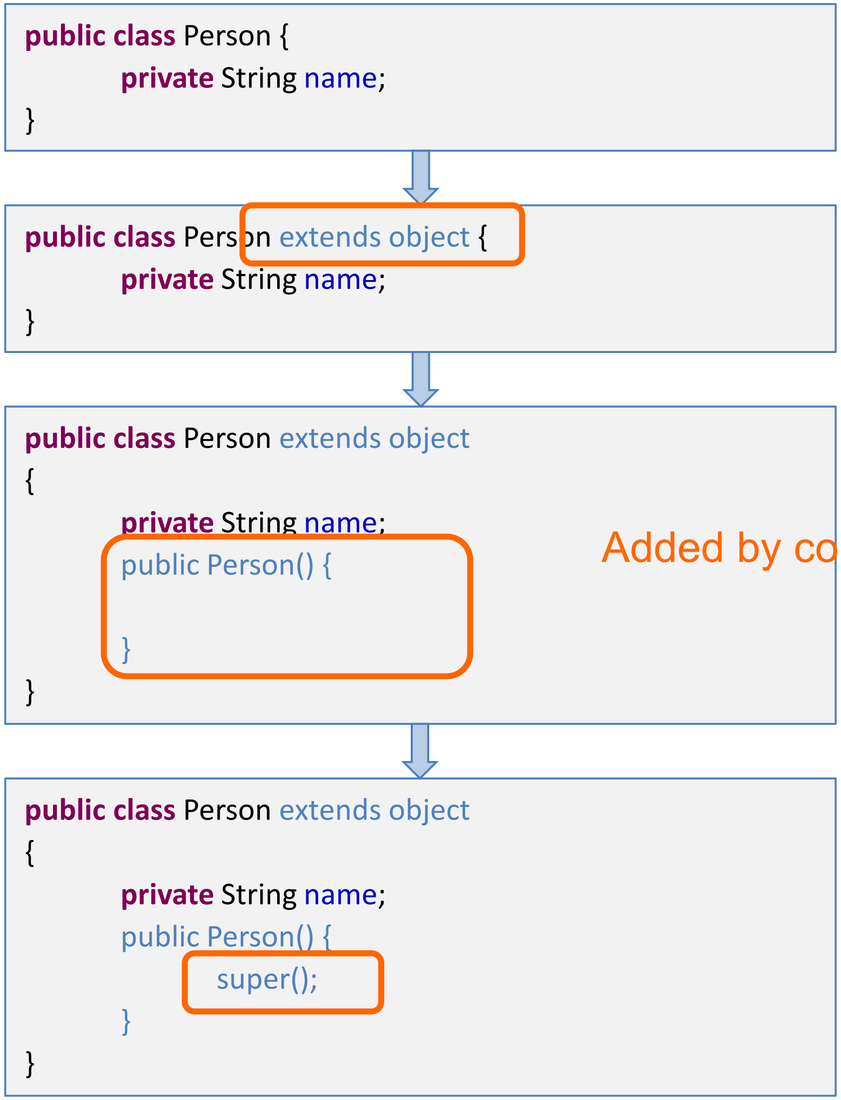


Wait, I don't remember extending Object...

compiler did that for you!



Compiler’s Rules



```
public class Person {
        private String name;
}
```

```
public class Person extends object {
        private String name;
}
```

```
public class Person extends object
{
        private String name;
        public Person() {

        }
}
```

Added by compiler

```
public class Person extends object
{
        private String name;
        public Person() {
                super();
        }
}
```

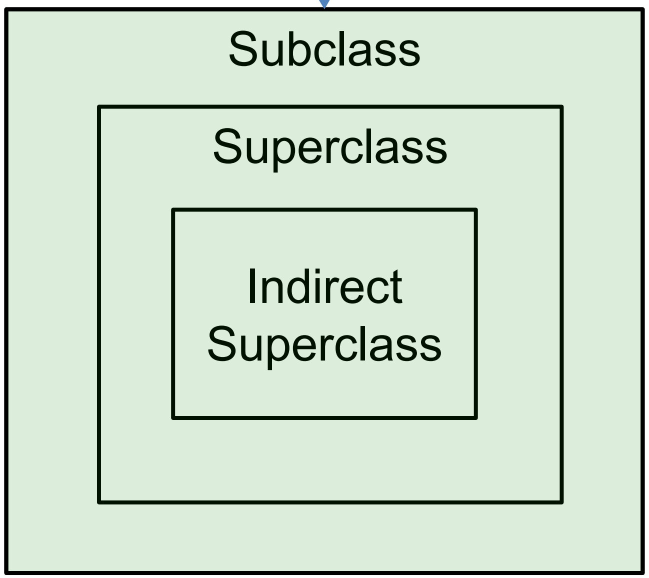
Rule #1 - No superclass?
Compiler inserts: extends Object

Rule #2 - No constructor?
Java gives you one for you.

Rule #3 - 1st Line must be:
this(args$_{\text{opt}}$) Same class constructor call
or
super(args$_{\text{opt}}$) Base class constructor call
Otherwise, Java inserts:
“super();”

Object Construction with Compiler Support (Contd.)

```
Student s = new Student();
```



Has super class:
1st rule doesn't apply

```
public class Student extends Person
{
}
```

```
public class Student extends Person
{
          public Student() {
                    super();
          }
}
```

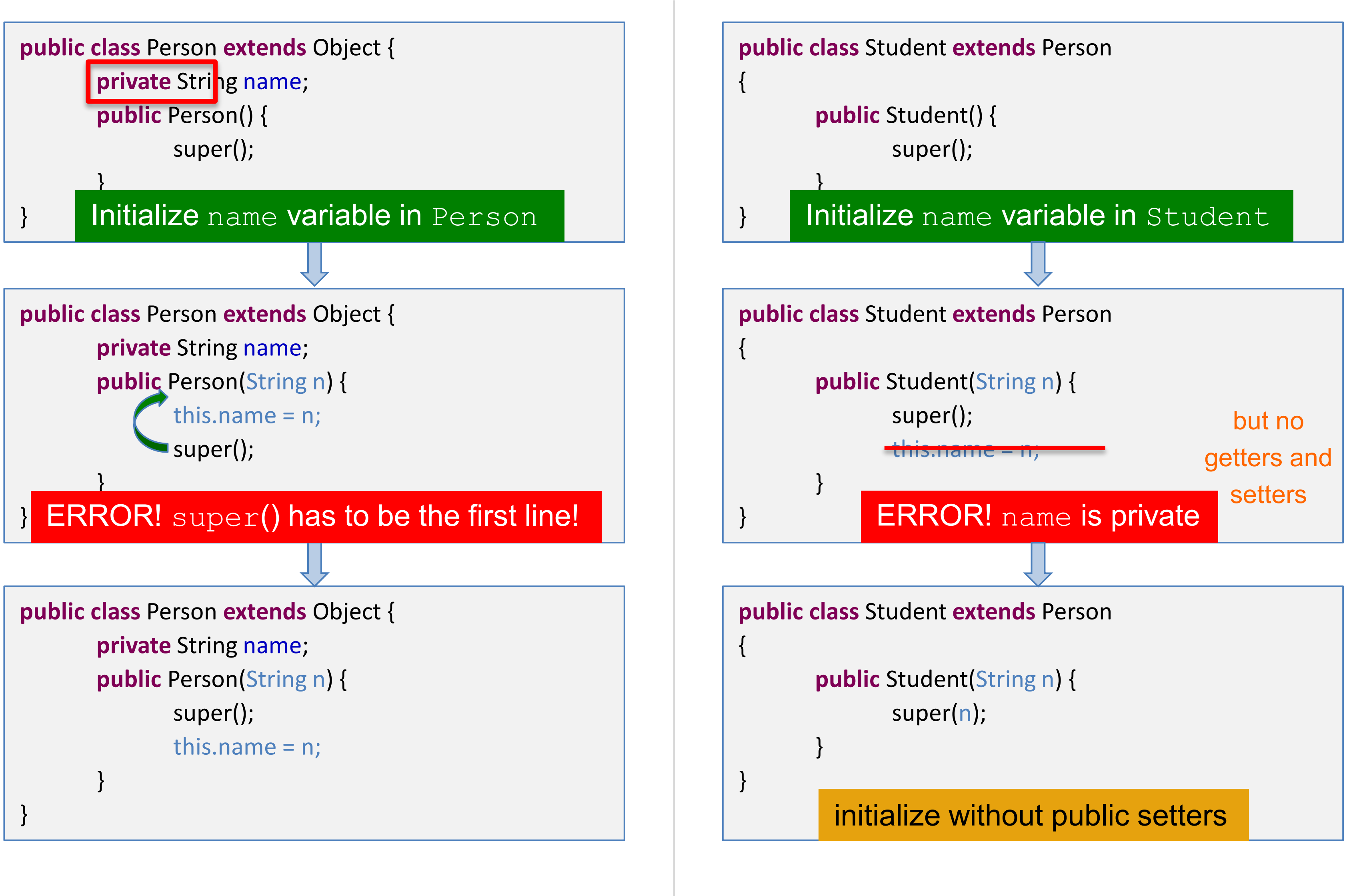
Has no constructor:
2nd rule DOES apply

Needs to call super's
default constructor:
3rd rule DOES apply

But how do we initialize name ?

Compiler ensures object construction occurs from the inside out

Variable Initialization in a Class Hierarchy



```
public class Person extends Object {
        private String name;
        public Person() {
                super();
        }
}
```

Initialize name variable in Person

```
public class Person extends Object {
        private String name;
        public Person(String n) {
                this.name = n;
                super();
        }
}
```

ERROR! super() has to be the first line!

```
public class Person extends Object {
        private String name;
        public Person(String n) {
                super();
                this.name = n;
        }
}
```

```
public class Student extends Person
{
        public Student() {
                super();
        }
}
```

Initialize name variable in Student

```
public class Student extends Person
{
        public Student(String n) {
                super();
                ~~this.name = n;~~
        }
}
```

but no getters and setters

ERROR! name is private

```
public class Student extends Person
{
        public Student(String n) {
                super(n);
        }
}
```

initialize without public setters

Variable Initialization in a Class Hierarchy (Contd.)

```
public class Student extends Person
{
        public Student(String n) {
                super(n);
        }
}
```

Add a no-arg constructor

```
public class Student extends Person
{
        public Student(String n) {
                super(n);
        }
        public Student() {
                super(“Student”);
        }
}
```

should not jump to the super class if there is same class constructor

```
public class Student extends Person
{
        public Student(String n) {
                super(n);
        }
        public Student() {
                this(“Student”);
        }
}
```

Use super class constructor

Use our same class constructor

Some Practices

```
public class Person {
        private String name;
        public Person(String n) {
                this.name = n;
                System.out.print("#1 ");
        }
}
```

```
public class Student extends Person {
        public Student() {
                this("Student");
                System.out.print("#2 ");
        }
        public Student(String n) {
                super(n);
                System.out.print("#3 ");
        }
}
```

Suppose you call:

Student s = new Student();

What is the order of statements printed?

A. #1 #2 #3

[✓ B. #1 #3 #2]

C. #3 #2 #1

D. #3 #1 #2

E. None of the above

#1 #3 #2

Some Practices Con’t

```
public class Person {
        private String name;
        public Person(String n) {
                this.name = n;
                System.out.print("#1 ");
        }
}
```

```
public class Student extends Person {
        public Student() {
                this("Student");
                System.out.print("#2 ");
        }
        public Student(String n) {
                super(n);
                System.out.print("#3 ");
        }
}
```

Suppose you call:

Student s = new Student(“Tom");

What is the order of statements printed?

#1 #3

Suppose you call:

Student s = new Person(“Tom");

What is the order of statements printed?

Compile time error (ref. Slide 11.)

Some Practices (Contd.)

```
public class Person {
        private String name;
        public Person(String n) {
                super();
                this.name = n;
        }
        public void setName(String n) {
                this.name = n;
        }
}
```

```
public class Student extends Person {
        public Student() {
                this.setName(“Student”);
        }
}
```

Super()

Suppose you call:

Student s = new Student();

What will be the name variable for this object?

A. “student”

B. “Undefined”

C. null

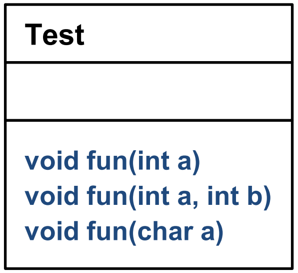
[✓ D. Compile Error]

E. Runtime Error

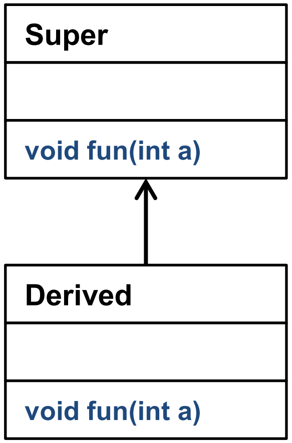
ERROR: Implicit super constructor Person() is undefined. Must explicitly invoke another constructor

Method Overriding

- **Overloading**: **Same class** has same method name with **different** parameters
- **Overriding**: **Subclass** has same method name with the **same parameters** as the superclass



Overloading



Overriding

- What do we want then?

1. Keep common behavior in one class
2. Split different behavior into separate classes
3. Keep all of the objects in a single data structure

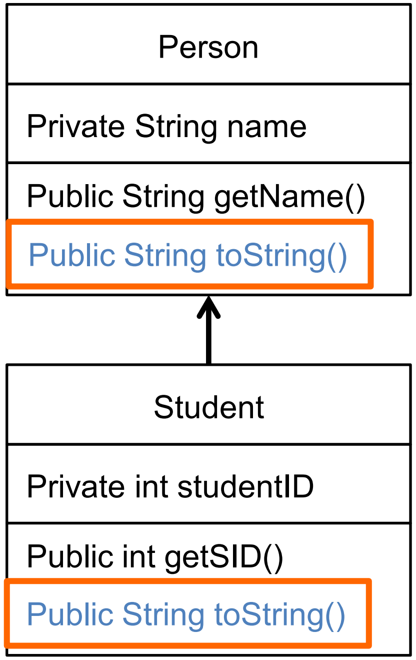
A `private` method cannot be overridden since it is not visible from any other class. When we use `final` specifier with a method, the method cannot be overridden in any of the inheriting classes. Since private methods are inaccessible, they are implicitly final in Java.

An Example: Object Class

String	toString() Returns a string representation of the object.

All java classes can override it

Override Object’s `toString`() method for `Person` class



Override Object’s `toString`() method for `Student` class

```
public class Person {
        private String name;
        // more code here
        public String toString() {
                return this.getName();
        }
        public static void main(String[] args) {
                Person p = new Person("Tim");
                System.out.println(p.~~toString()~~);
        }
}
```

```
$ Tim
```

`println` automatically calls `toString`()

```
public class Student extends Person{
        private int studentID;
        // more code here
        public String toString() {
                return this.getSID() + “: ” +
                    ~~this.getName()~~;
        }
        public static void main(String[] args) {
                Student s = new Student("Cara", 1234);
                System.out.println(s);
        }
}
```

```
$ 1234: Cara
```

what if `Person` changes?

Introduce to Polymorphism

```
Person s = new Student("Cara", 1234);
System.out.println(s);
```

```
$ 1234: Cara
```

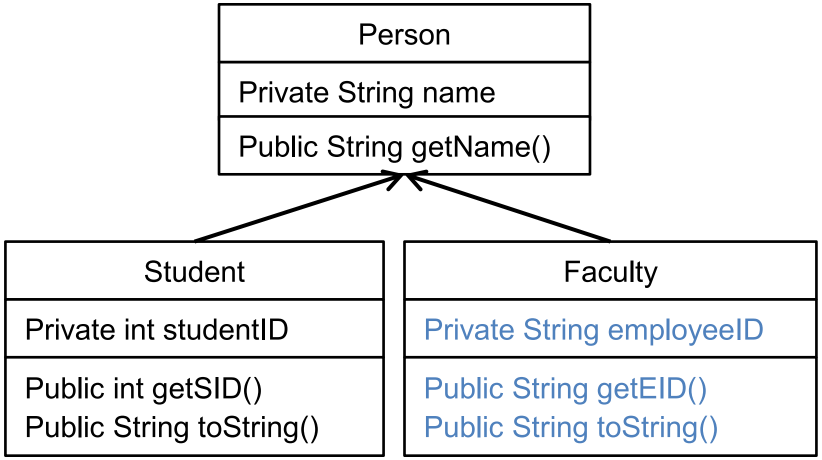
✓

```
$ Cara
```

✗

The dynamic (or actual) type of the object is Student, so its `toString()` method will be called.

For superclass reference to subclass object, the actually called method depends on the dynamic type. This is referred as **Polymorphism**.



Person

Private String name

Public String getName()

Student

Private int studentID

Public int getSID()
Public String toString()

Faculty

Private String employeeID

Public String getEID()
Public String toString()

```
Person p[] = new Person[3];
p[0] = new Person( "Tim" );
p[1] = new Student( "Cara", 1234 );
p[2] = new Faculty( "Mia", "ABCD" );
for(int i = 0; i < p.length; i++)
{
  System.out.println(p[i]);
}
```

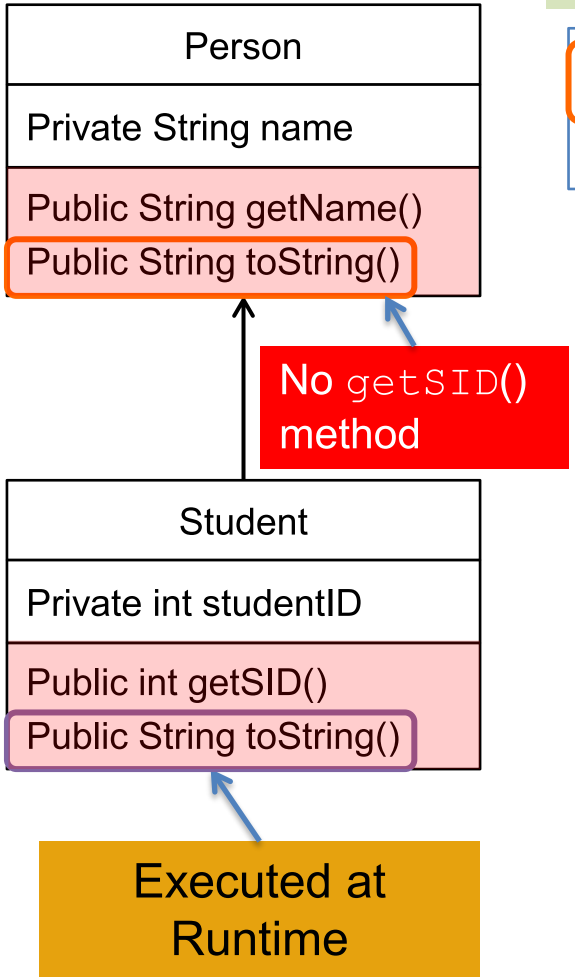
```
$ Tim
$ 1234: Cara
$ ABCD: Mia
```

Polymorphism allow us to keep all of our objects in one big collection, and then call appropriate methods on every element

Java Polymorphism Fully Explained In 7 Minutes
https://www.youtube.com/watch?v=jhDUxynEQRI

Polymorphism Implementation: Compile Time and Run Time Rules

Think like a compiler, act like a runtime environment.



1. compiler interprets the code → 2. the runtime environment executes the interpreted code

```
Person s = new Student("Cara", 1234);
s.toString();
```

String toString()

Method Signature

Compile Time Rules:

- Compiler ONLY knows reference type
- Can only look in reference type class for method
- Outputs a method signature

Run Time Rules:

- Follow exact runtime type of object to find method
- Must match compile time method signature to appropriate method in actual actual object's class

```
Person s = new Student("Cara", 1234);
s.getSID();
```

Compile Time Error!

needs explicit casting

Use Casting of Objects to Aid the Compiler

Two types of casting:

- Automatic type promotion (like `int` to `double`)

  Superclass superRef = new Subclass();

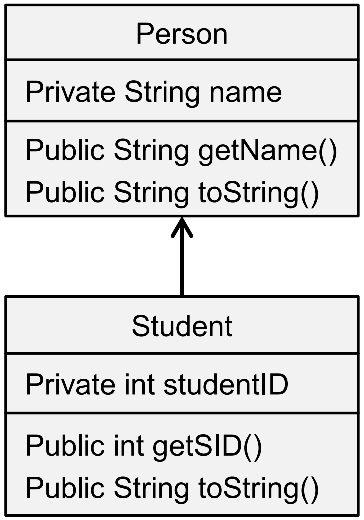
  Widening

- Explicit casting (like `double` to `int`)

  Subclass ref = (Subclass)superRef;

  Narrowing

BE CAREFUL:
Compiler trusts you


Person

Private String name

Public String getName()
Public String toString()

Student

Private int studentID

Public int getSID()
Public String toString()

Person s = new Student("Cara", 1234);

~~s.getSID();~~

((Student)s).getSID();

This works

```
Person s = new Person(”Tim”);
((Student)s).getSID();
```

break the trust

Runtime Error!
java.lang.ClassCastException: From Person to Student

Runtime type check - `instanceof`

- Provides runtime check of **is-a** relationship

```
if(s instanceof Student )
{
        // only executes if s is-a
        // Student at runtime
        ((Student)s).getSID();
}
```

Abstract Classes and Interfaces

- `Person` - Campus Accounts
  - "Person" objects no longer make sense
  - Add method "monthlyStatement"
- How do we:
  - Force subclasses to have this method
  - Stop having actual Person objects
  - Keep having Person references
  - ~~Retain common Person code~~

Implementation vs. Interface

Abstract classes offer inheritance of both!

- **Implementation**: instance variables and methods which define common behavior
- **Interface**: method signatures which define required behaviors

What if we just want to inherit the Interface?

Abstract classes!

Then use an Interface!

- Can make any class abstract with keyword:

```
public abstract class Person {
```

- Class **must** be abstract if any methods are:

```
public abstract void monthlyStatement(){
```

Interfaces only define required methods. Classes can inherit from multiple Interfaces

Abstract Classes and Methods in Java Explained in 7 Minutes
https://www.youtube.com/watch?v=HvPlEJ3LHgE

Abstract Classes and Interfaces (Contd.)

```
// Defined in java.lang.Comparable
package java.lang;
public interface Comparable<E> {
// Compare this object's name to o's name
// Return < 0, 0, > 0 if this object compares
//   less than, equal to, greater than o.
 public abstract int compareTo(E o);
}
```

```
public class Person implements Comparable<Person> {
        private String name;
        // more code here
        @Override
        public int compareTo(Person o) {
                return this.getName().compareTo(o.getName());
}
```

Abstract class or Interface?

- If you just want to define a required method:

  `Interface`

- If you want to define potentially required methods AND common behavior:

  `Abstract class`