Inheritance

Introduction to Programming and Computational Problem Solving: Accelerated Pace

CSE 11

Lecture 12

Announcements

- Assignment 5 is due May 15, 11:59 PM
  - Upgrade beginning May 18, 12:01 AM
- Assignment 6 will be released May 15
  - Due May 22, 11:59 PM

Inheritance

- Suppose you define classes to model circles, rectangles, and triangles
- These classes have many common features
- What is the best way to design these classes so to avoid redundancy?
- Object-oriented programming allows you to define new classes from existing classes
- This is called *inheritance*

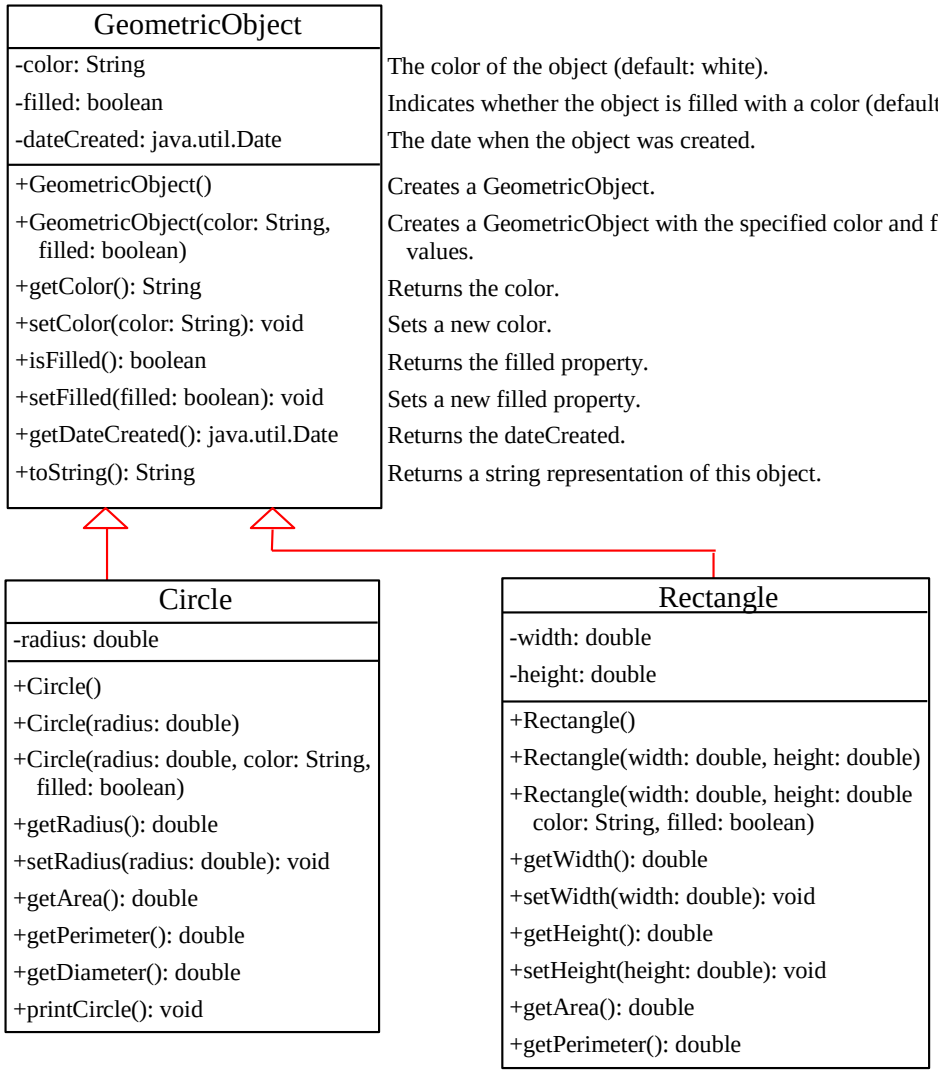
Superclasses and subclasses

- Inheritance enables you to define a general class (i.e., a *superclass*) and later extend it to more specialized classes (i.e., *subclasses*)
- A subclass inherits from a superclass
  - For example, both a circle and a rectangle are geometric objects
    - `GeometricObject` is a superclass
    - `Circle` is a subclass of `GeometricObject`
    - `Rectangle` is a subclass of `GeometricObject`
- Models **is-a** relationships
  - For example
    - Circle **is-a** GeometricObject
    - Rectangle **is-a** GeometricObject

Superclasses and subclasses

Superclass

Subclasses



Superclasses and subclasses

- A subclass *inherits* accessible data fields and methods from its superclass and may also add *new* data fields and methods
  - **A subclass is not a subset of its superclass**
    - A subclass usually contains *more* information and methods than its superclass
  - For example
    - A rectangle has a width and height
    - A circle has a radius
    - Both have a color

Superclasses and subclasses

- A **superclass** is also called a *parent class* or *base class*
- A **subclass** is also called a *child class*, *extended class*, or *derived class*
  - A child class inherits from a parent class
  - A subclass extends a superclass
  - A derived class derives from a base class

Superclasses and subclasses

- Remember, a class defines a type
- A type defined by a subclass is called a *subtype*, and a type defined by its superclass is called a *supertype*
  - For example
    - `Circle` is a subtype of `GeometricObject`, and `GeometricObject` is a supertype for `Circle`

Inheritance

- The keyword `extends` tells the compiler that the (sub)class extends another (super)class
- A Java class may inherit directly from only one superclass
  - This restriction is known as *single inheritance*
  - Some other programming languages allow classes to inherit from one or more classes
    - This is known as *multiple inheritance*

`extends` keyword

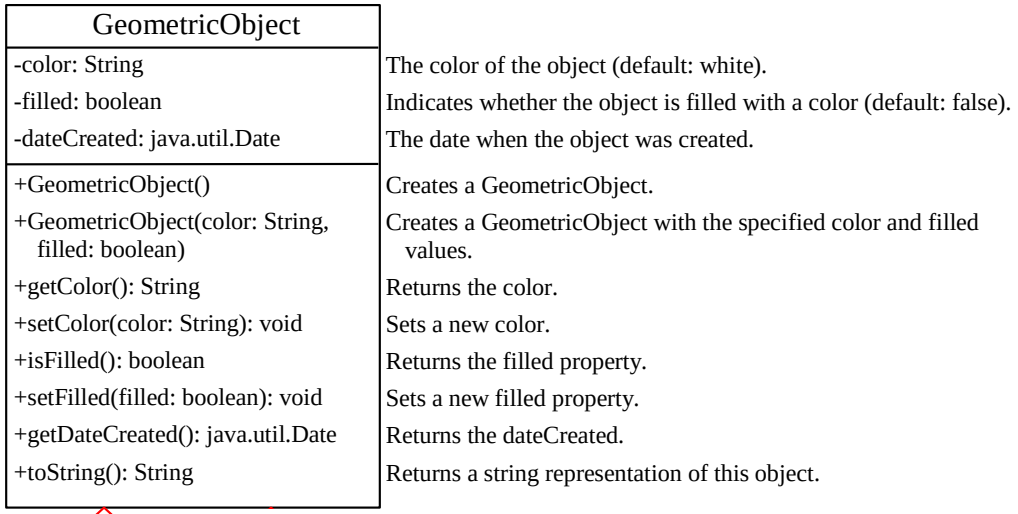
- The keyword `extends` tells the compiler that the (sub)class extends another (super)class
- For example
  - The `Circle` class extends the `GeometricObject` class using the syntax

```
public class Circle extends GeometricObject
```

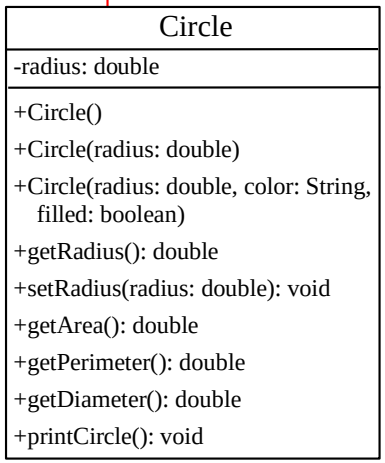
  - The `Circle` class inherits the **accessible** data fields and methods of `GeometricObject`

Circle extends GeometricObject

Superclass



Subclass




```
public class Circle extends GeometricObject {
  private double radius;

  public Circle() {
  }

  public Circle(double radius) {
    this.radius = radius;
  }
```

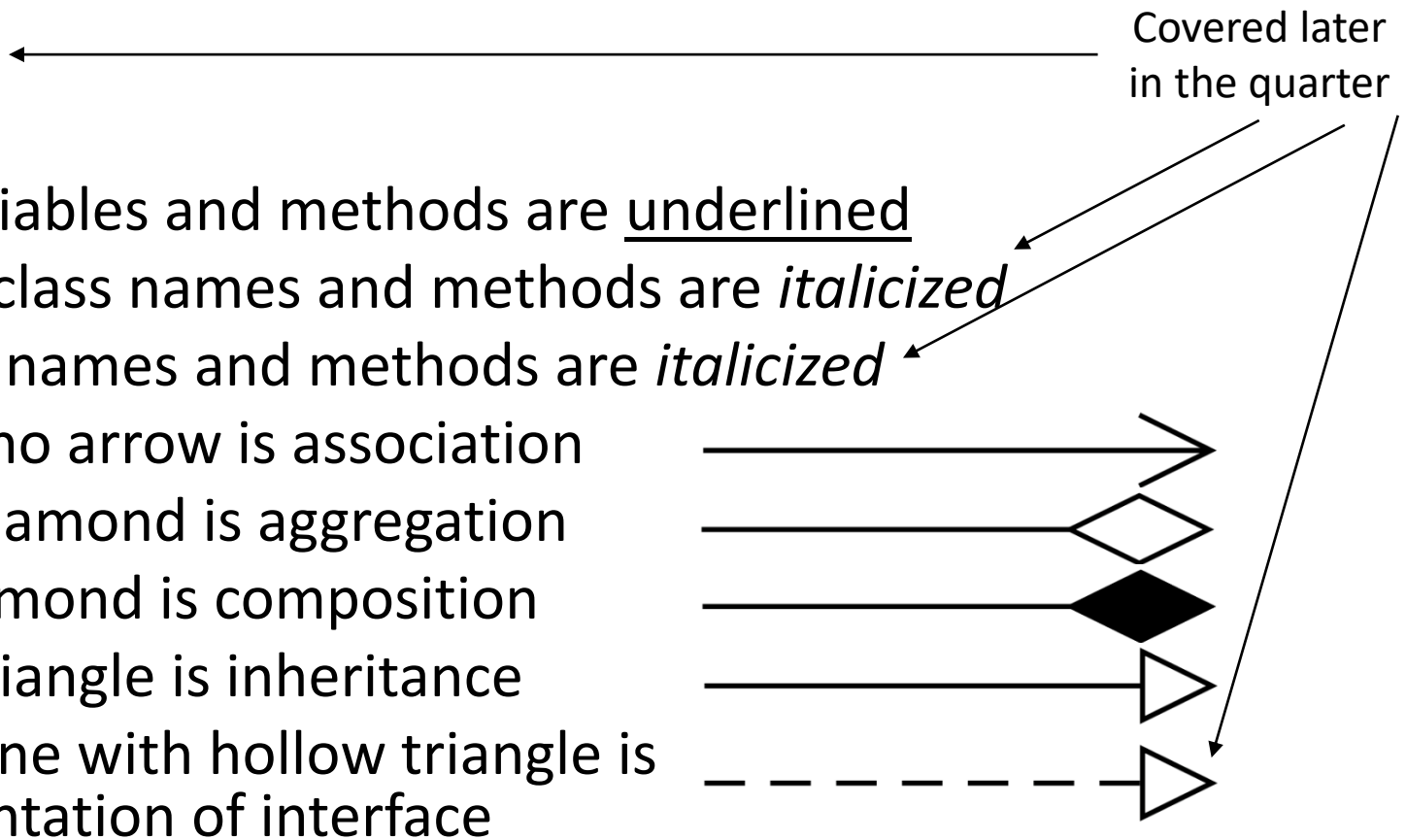
Unified Modeling Language (UML)

+ public

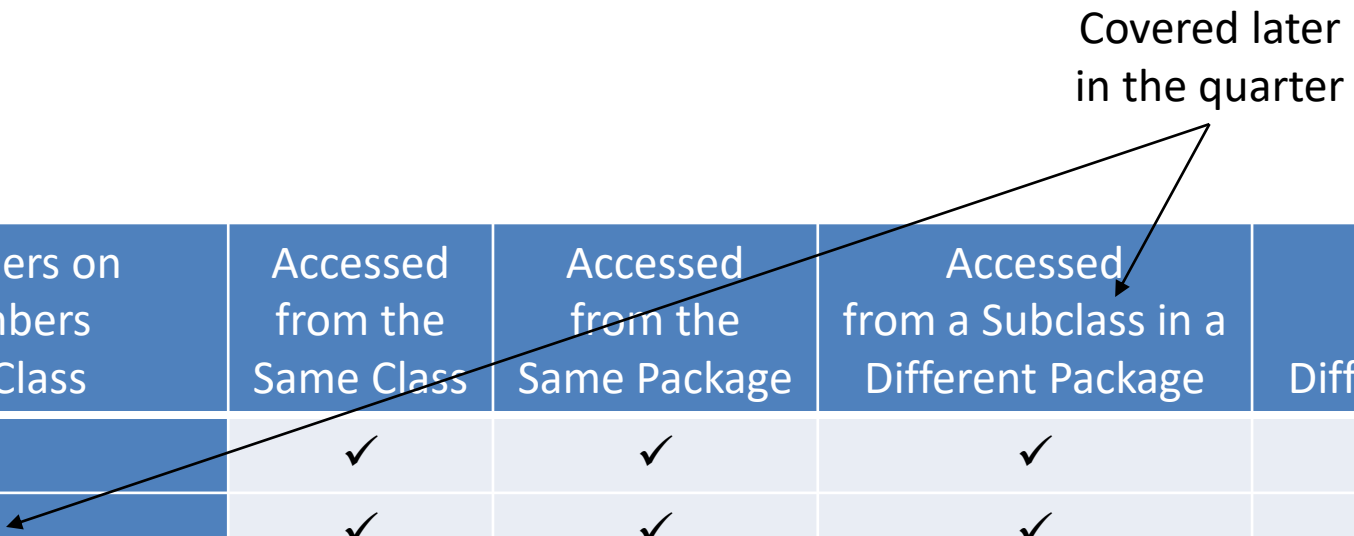
protected

- private

- Static variables and methods are <u>underlined</u>
- Abstract class names and methods are *italicized*
- Interface names and methods are *italicized*
- Open or no arrow is association
- Hollow diamond is aggregation
- Filled diamond is composition
- Hollow triangle is inheritance
- Dashed line with hollow triangle is implementation of interface



Methods and data fields visibility



Modifiers on Members in a Class	Accessed from the Same Class	Accessed from the Same Package	Accessed from a Subclass in a Different Package	Accessed from a Different Package
Public	✓	✓	✓	✓
Protected	✓	✓	✓	
Default (no modifier)	✓	✓		
Private	✓			

Methods and data fields visibility

- **Private members cannot be accessed outside of a class, including one of its subclasses**
  - Use accessor (getter) and mutator (setter) methods

```
public class Circle extends GeometricObject {
  private double radius;

  public Circle() {
  }

  public Circle(double radius) {
    this.radius = radius;
  }

  public Circle(double radius, String color, boolean filled) {
    this.radius = radius;
    setColor(color);
    setFilled(filled);
  }
```

Superclass constructors and the `super` keyword

- Remember, a constructor is used to construct an instance of a class
- Unlike properties and methods, **a superclass's constructors are not inherited in the subclass**
- They can only be invoked from the subclasses' constructors, using the keyword `super`
- **If the keyword `super` is not explicitly used, the superclass's no-arg constructor is automatically invoked**

Superclass constructors and the super keyword

- For example, replace this

```
public class Circle extends GeometricObject {
  private double radius;

  public Circle(double radius, String color, boolean filled) {
    this.radius = radius;
    setColor(color);
    setFilled(filled);
  }
```

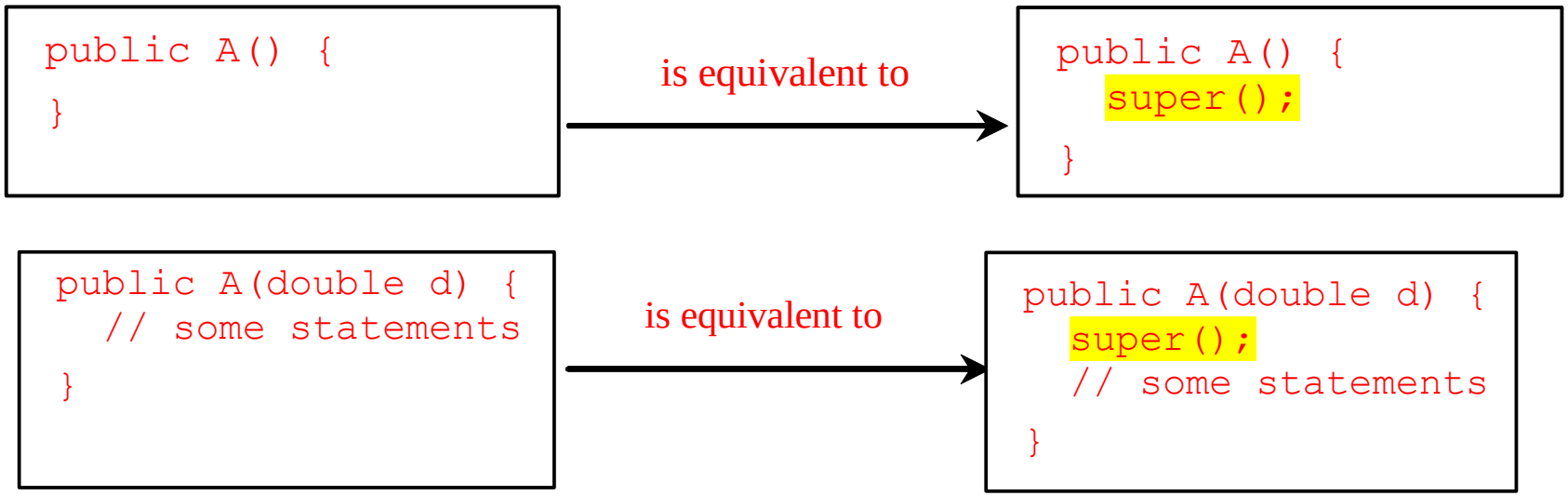
with this

```
public class Circle extends GeometricObject {
  private double radius;

  public Circle(double radius, String color, boolean filled) {
    super(color, filled);
    this.radius = radius;
  }
```

Invoking the superclass constructor using super must be the first statement in the subclass's constructor

Superclass constructors and the `super` keyword

- If the keyword `super` is not explicitly used, the superclass's no-arg constructor is automatically invoked (as the **first** statement in the constructor)

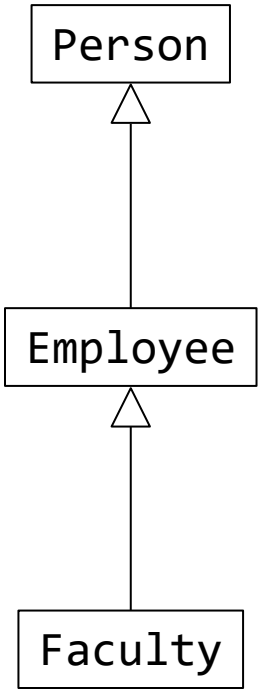


Constructor chaining

- Constructing an instance of a class invokes **all** the superclasses' constructors along the inheritance chain
- This is known as *constructor chaining*

Constructor chaining

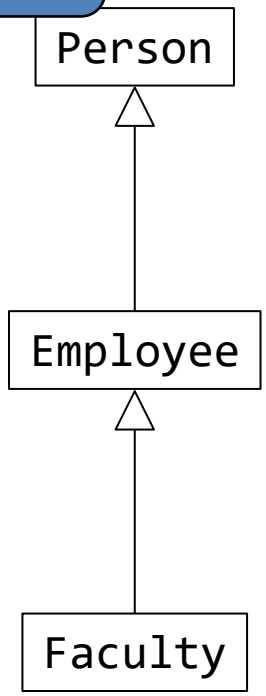
```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee’s overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

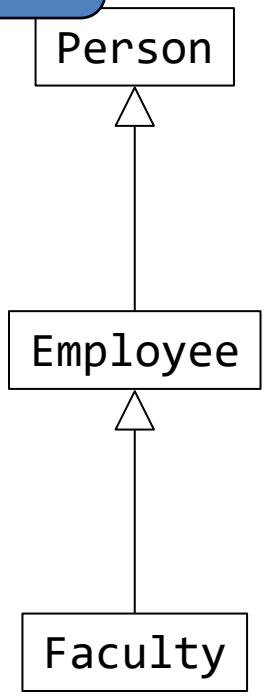
1. Start from the main method



Trace code

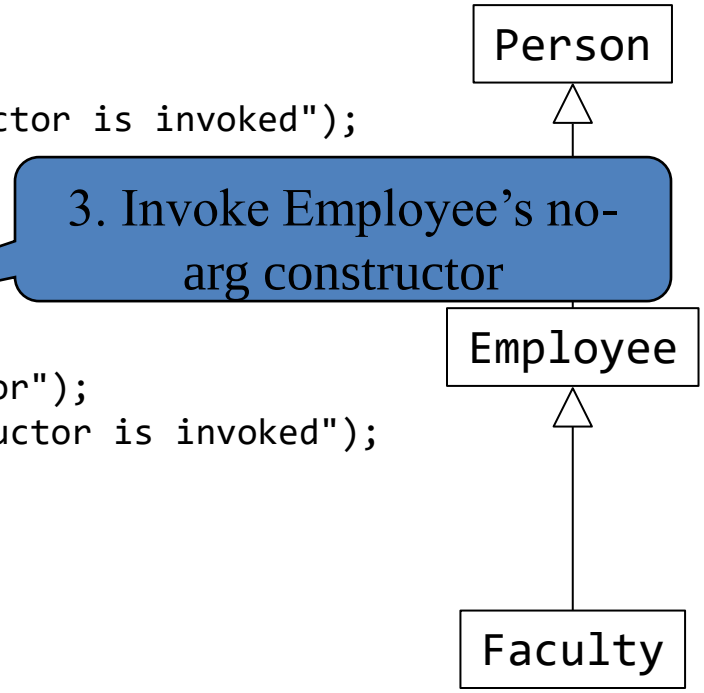
```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```

2. Invoke Faculty constructor



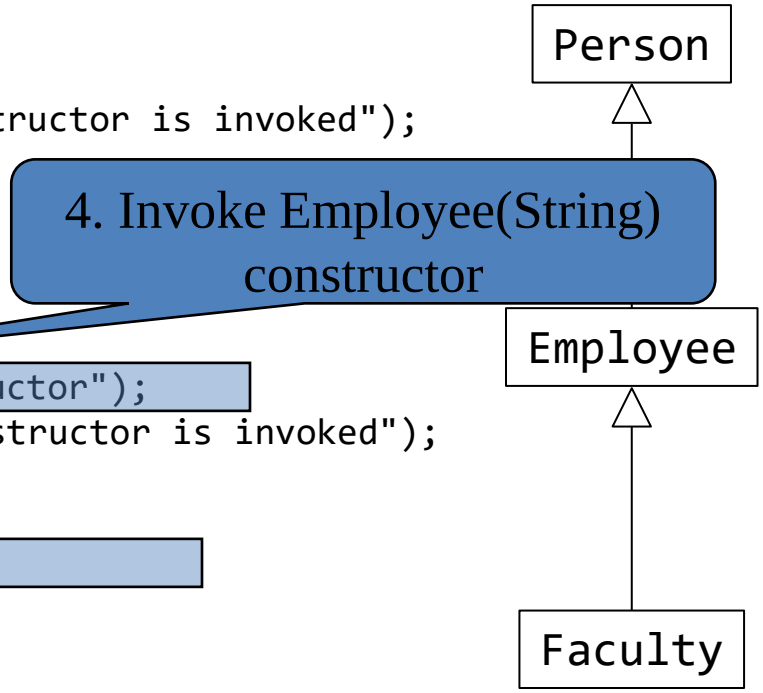
Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



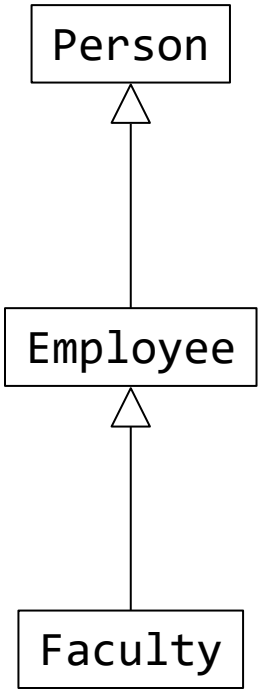
Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



Trace code

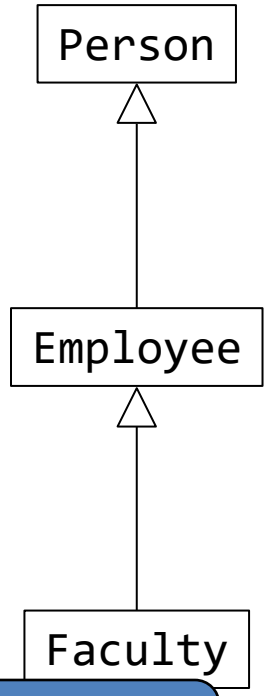
```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



5. Invoke Person() constructor

Trace code

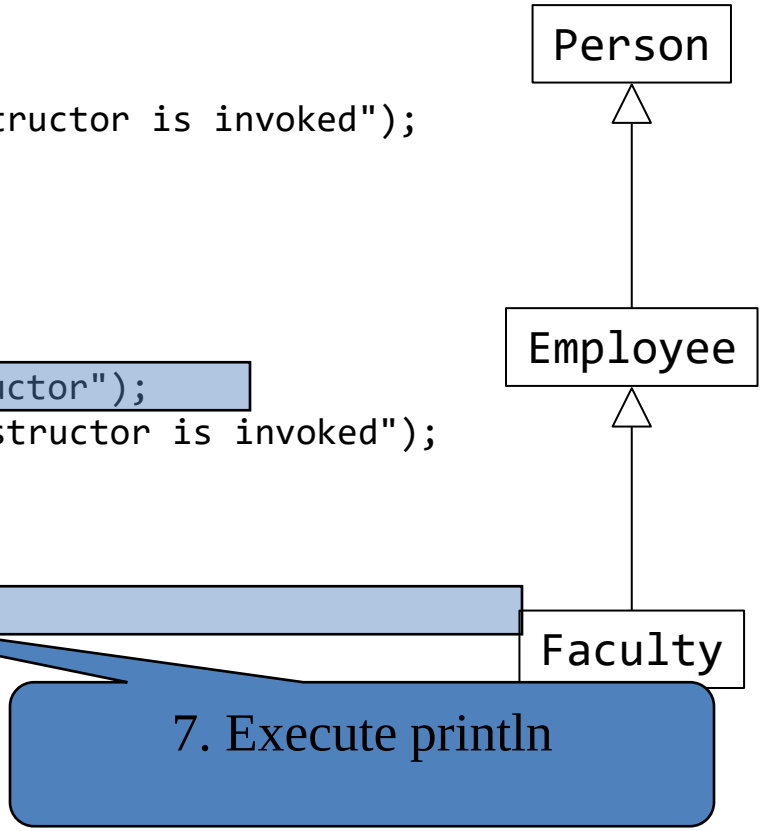
```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



6. Execute println

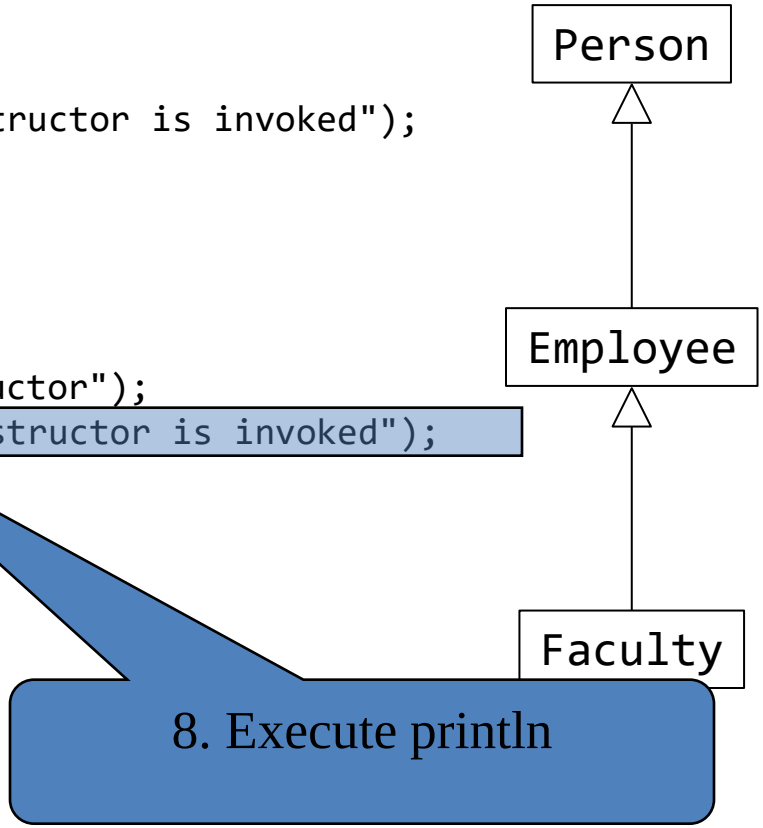
Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



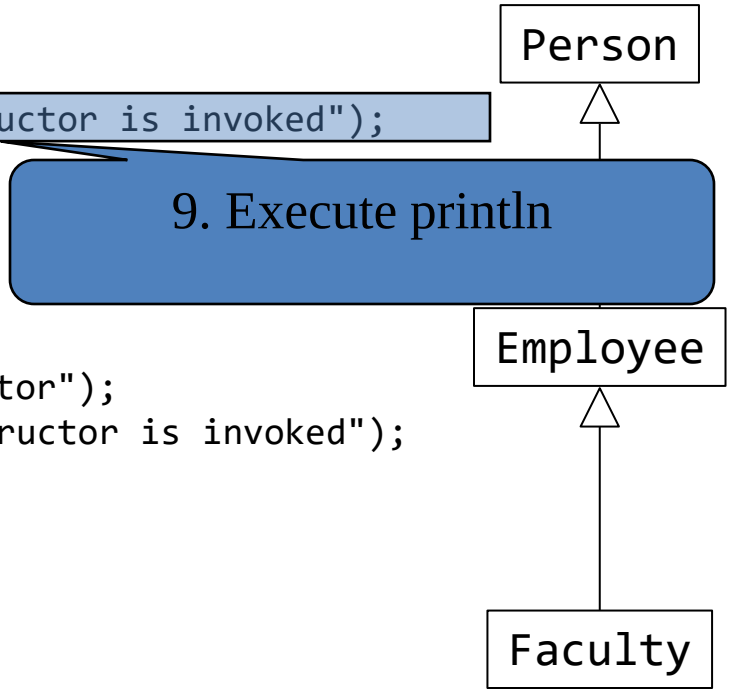
Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



Trace code

```
public class Faculty extends Employee {
  public static void main(String[] args) {
    new Faculty();
  }

  public Faculty() {
    System.out.println("(4) Faculty's no-arg constructor is invoked");
  }
}

class Employee extends Person {
  public Employee() {
    this("(2) Invoke Employee's overloaded constructor");
    System.out.println("(3) Employee's no-arg constructor is invoked");
  }

  public Employee(String s) {
    System.out.println(s);
  }
}

class Person {
  public Person() {
    System.out.println("(1) Person's no-arg constructor is invoked");
  }
}
```



Default constructor

- Remember, a class may be defined without constructors
- In this case, a no-arg constructor with an empty body is *implicitly* defined in the class
- This constructor, called a *default constructor*, is provided automatically *only if no constructors are explicitly defined in the class*
- **Best practice is to provide (if possible) a no-arg constructor for every class to make the class easy to extend and avoid compile-time errors during constructor chaining**

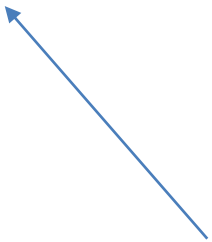
Defining a subclass

- A subclass inherits from a superclass
- You can also
  - Add new properties
  - Add new methods
  - Override the methods of the superclass

Add new methods

- For example
  - Add `printCircle()` method in the `Circle` class

```
public void printCircle() {
  System.out.println("The circle is created " +
    getDateCreated() + " and the radius is " + radius);
}
```



Call superclass method

Override the methods of the superclass

- A subclass inherits methods from a superclass
- Sometimes it is necessary for the subclass to modify the implementation of a method defined in the superclass
- This is referred to as *method overriding*

Override the methods of the superclass

- To override a method, the method must be defined in the subclass using **the same signature** as in its superclass, and **same or subtype of the overridden method's return type**
- A best practice to avoid mistakes is to use a special Java syntax, called *override annotation*
  - Annotated method is required to override a method in its superclass
    - If it does not, then there will be a compile-time error

```
public class Circle extends GeometricObject {
  // Other methods are omitted

  @Override
  public String toString() {
    return super.toString() + "\nradius is " + radius;
  }
}
```

Overriding vs overloading

- Overridden methods
  - Have the same signature
  - Are in different classes related by inheritance
- Overloaded methods
  - Have the same name, but different parameter lists
  - Can be either
    - In the same class
    - In different classes related by inheritance

Overriding vs overloading

```
public class Test {
  public static void main(String[] args) {
    A a = new A();
    a.p(10);
    a.p(10.0);
  }
}

class B {
  public void p(double i) {
    System.out.println(i * 2);
  }
}

class A extends B {
  // This method overrides the method in B
  public void p(double i) {
    System.out.println(i);
  }
}
```

```
public class Test {
  public static void main(String[] args) {
    A a = new A();
    a.p(10);
    a.p(10.0);
  }
}

class B {
  public void p(double i) {
    System.out.println(i * 2);
  }
}

class A extends B {
  // This method overloads the method in B
  public void p(int i) {
    System.out.println(i);
  }
}
```

Remember to use @Override annotation
(not shown so lines align)

Private methods of the superclass

- An instance method can be overridden only if it is accessible
- As such, **a private method cannot be overridden** because it is not accessible outside its own class
- **If a method defined in a subclass is private in its superclass, then the two methods are completely unrelated**

Static methods of the superclass

- Like an instance method, a static method can be inherited
- However, **a static method cannot be overridden**
- **If a static method defined in the superclass is redefined in a subclass, the method defined in the superclass is hidden**

`this` and `super` keywords

- Similar to using `this` to reference the calling object, the keyword `super` refers to the superclass of the class which `super` appears
- The keyword `this` is the name of a reference that refers to an object itself
  - One common use of the `this` keyword is to reference a hidden *class* member
- The keyword `super` refers to the superclass of the class in which `super` appears
  - One common use of the `super` keyword is to reference a hidden *superclass* member

`this` keyword

- The keyword `this` refers to an object itself
- The keyword `this` can be used to
  - Call another constructor of the same class
    - Syntax

      ```
      this(arguments);
      ```
  - Reference a hidden class variable
    - Syntax

      ```
      this.variableName
      ```

super keyword

- The keyword super refers to the superclass of the class in which super appears
- The keyword super can be used to
  - Call a superclass constructor
    - Syntax

      ```
      super(arguments);
      ```
  - Call a superclass method
    - Syntax

      ```
      super.methodName(arguments);
      ```

The `Object` class and its methods

- Every class in Java is descended from the `java.lang.Object` class
- If no inheritance is specified when a class is defined, the superclass of the class is `Object`

```
public class Circle {
   ...
}
```

Equivalent

```
public class Circle extends Object {
   ...
}
```

The toString() method in Object

- The toString() method returns a string representation of the object
- The default implementation returns a string consisting of a class name of which the object is an instance, the at sign (@), and a number representing this object
- For example

```
Loan loan = new Loan();
System.out.println(loan.toString());
```

  - The code displays something like Loan@15037e5
  - This message is not very helpful or informative
  - Usually, you should override the toString method so that it returns a digestible string representation of the object

Next Lecture

- Polymorphism