Objects and Classes (Part 2)

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 10

Announcements

- Assignment 4 is due today, 11:59 PM
  - Upgrade beginning May 6, 12:01 AM
- Educational research study
  - May 5, weekly survey
- Midterm exam is May 8
- Assignments 2-4 upgrades due May 10

Object-oriented programming

- Object-oriented programming (OOP) involves programming using objects
- **This is the focus of CSE 8B**

Objects and classes

- An object represents an entity in the real world that can be distinctly identified
  - For example, a student, a desk, a circle, a button, and even a loan can all be viewed as objects
  - An object has a unique identity, state, and behaviors
- Classes are constructs that define objects of the same type

Objects and Java classes

- The state of an object consists of a set of data fields (also known as properties) with their current values
- The behavior of an object is defined by a set of methods
- A Java class uses variables to define data fields and methods to define behaviors

Instance data fields and methods vs static data fields methods

- **Instance** data fields and methods **can only be accessed using an object** (i.e., an instance of a class)
  - The syntax to access an **instance data field** is
    `objectReferenceVariable.variableName`
  - The syntax to invoke an **instance method** is
    `objectReferenceVariable.methodName(arguments)`
- **Static** data fields and methods (i.e., non-instance data fields and methods) can be accessed **without using an object** (i.e., they are not tied to a specific instance of a class)
  - The syntax to access a **static data field** is
    `ClassName.variableName`
  - The syntax to invoke a **static method** is
    `ClassName.methodName(arguments)`

Instance variables vs static variables

- An **instance** variable belongs to a specific instance of a class
- *A **static** variable is shared by all objects of the class*
  - Static variables are **shared** by all the instances of the class
  - Static constants are final variables **shared** by all the instances of the class

Static members

- In code using a class, the best practice is to *make invocations of static methods and access of static data fields* ***obvious***
- Use

```
ClassName.methodName(arguments)
ClassName.variableName
```

- Do **not** use

```
objectReferenceVariable.methodName(arguments)
objectReferenceVariable.variableName
```

The `static` modifier

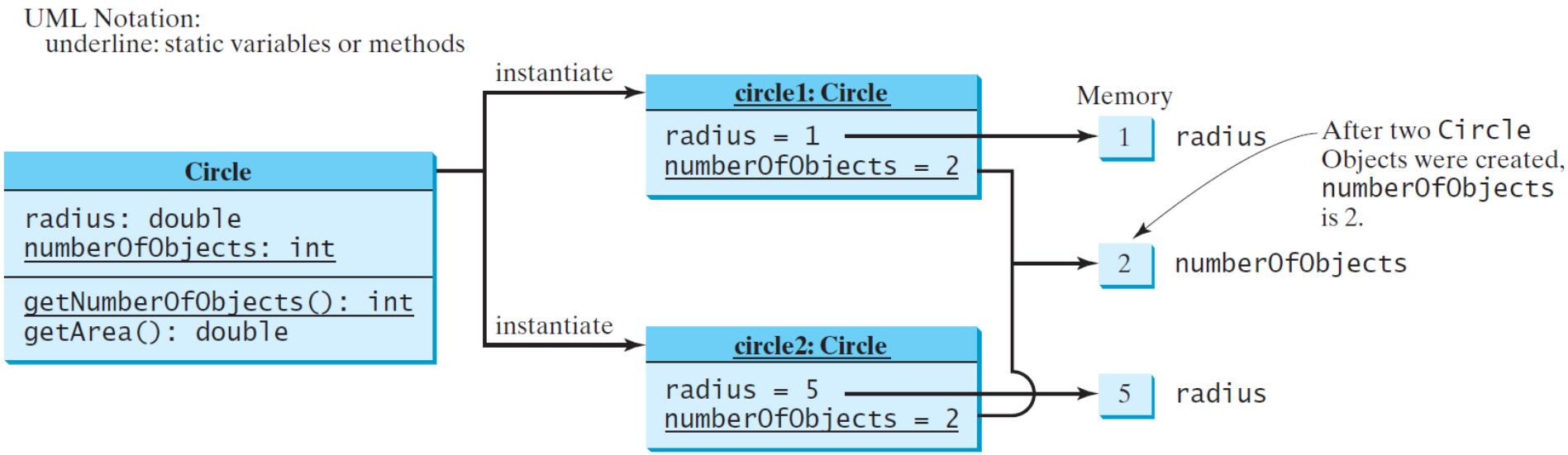
- To declare static variables, constants, and methods, use the `static` modifier
- `static` is a Java keyword

The `static` modifier

```
public class Circle {
  double radius; // The radius of the circle
  static int numberOfObjects = 0; // The number of objects created

  // Construct a circle of radius 1
  Circle() {
    radius = 1;
    numberOfObjects++;
  }

  // Construct a circle with a specified radius
  Circle(double newRadius)
  {
    radius = newRadius;
    numberOfObjects++;
  }

  // Return numberOfObjects
  static int getNumberOfObjects() {
    return numberOfObjects;
  }
```

The `static` modifier

```
Circle circle1 = new Circle();
Circle circle2 = new Circle(5);
```



Limitations of static methods

- An **instance** method can
  - Invoke an **instance or static** method
  - Access an **instance or static** data field
- A **static** method can
  - Invoke a **static** method
  - Access a **static** data field
- A **static** method **cannot**
  - Invoke an **instance** method
  - Access an **instance** data field

Static methods

- If a member method or data field is independent of any specific instance, then make it static
- Do not require those using your class to create instance unless it is absolutely necessary

Visibility modifiers

- Visibility modifiers can be used to specify the visibility of a class and its members
- By **default**, the class, variable, or method can be accessed by any class **in the same *package***
- Packages can be used to organize classes
  - For example, classes C1 and C2 are placed in package p1, and class C3 is placed in package p2

```
package p1;

class C1 {
```

```
package p1;

public class C2 {
```

```
package p2;

public class C3 {
```

Visibility modifiers

- There is **no restriction** on accessing data fields and methods from **inside** the class
- A **visibility modifier** specifies how data fields and methods in a class can be accessed from **outside** the class

Visibility modifiers

`public`

- The class, data, or method is visible to **any class in any package**

`private`

- Modifier **cannot** be applied to a class, only its members
- The data or methods can be accessed **only by the declaring class**

`protected`

- Used in inheritance (covered later in the quarter)

Packages and classes

- The **default** modifier (i.e., no modifier) on a class restricts access to **within a package**
- The **`public`** modifier enables **unrestricted** access

Compile multiple `.java` files in the same directory using `javac *.java`

These are three different files (each class is in its own file)

```
package p1;

class C1 {
  ...
}
```

```
package p1;

public class C2 {
  can access C1
}
```

```
package p2;

public class C3 {
  cannot access C1;
  can access C2;
}
```

package p1

package p2

Packages, classes, and members

- The **`private`** modifier restricts access to **within a class**
- The **default** modifier (i.e., no modifier) restricts access to **within a package**
- The **`public`** modifier enables **unrestricted** access

```
package p1;

public class C1 {
  public int x;
  int y;
  private int z;

  public void m1() {
  }
  void m2() {
  }
  private void m3() {
  }
}
```

```
package p1;

public class C2 {
  void aMethod() {
    C1 o = new C1();
    can access o.x;
    can access o.y;
    cannot access o.z;

    can invoke o.m1();
    can invoke o.m2();
    cannot invoke o.m3();
  }
}
```

```
package p2;

public class C3 {
  void aMethod() {
    C1 o = new C1();
    can access o.x;
    cannot access o.y;
    cannot access o.z;

    can invoke o.m1();
    cannot invoke o.m2();
    cannot invoke o.m3();
  }
}
```

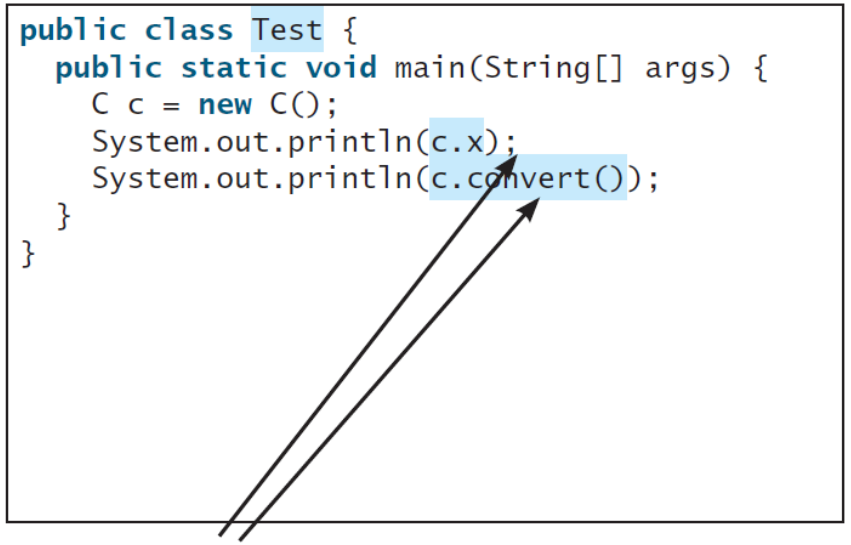
Visibility of own members

- There is **no restriction** on accessing data fields and methods from **inside** the class
- However, an object cannot access its **private** members **outside** the class

```
public class C {
  private boolean x;

  public static void main(String[] args) {
    C c = new C();
    System.out.println(c.x);
    System.out.println(c.convert());
  }

  private int convert() {
    return x ? 1 : -1;
  }
}
```

(a) This is okay because object `c` is used inside the class `C`.

```
public class Test {
  public static void main(String[] args) {
    C c = new C();
    System.out.println(c.x);
    System.out.println(c.convert());
  }
}
```

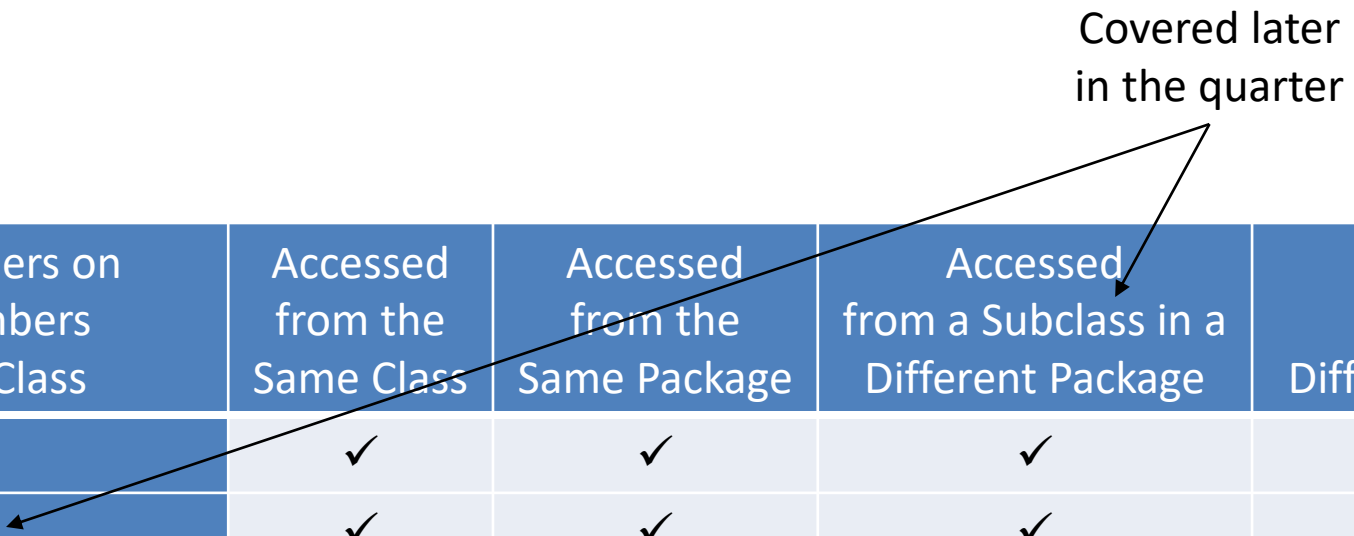


(b) This is wrong because `x` and `convert` are private in class `C`.

Constructors

- Use public constructors in most cases
- Use a private constructor if you want to prohibit users from creating an instance of a class
  - For example, in `java.lang.Math`, the constructor `Math()` is private

Methods and data fields visibility



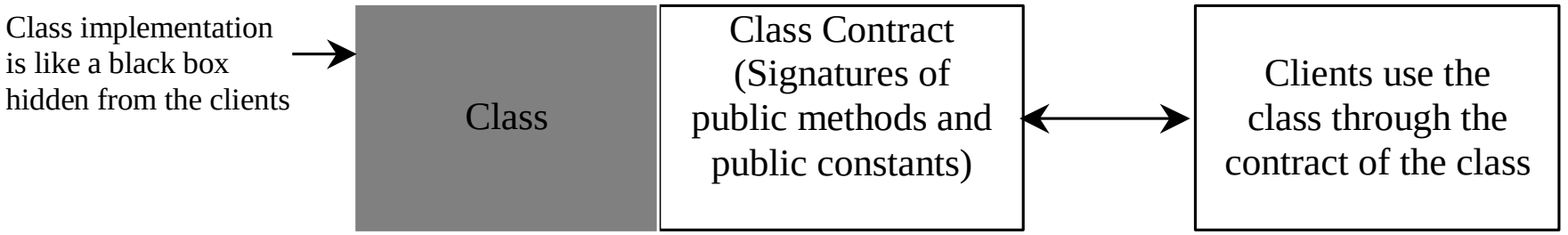
Modifiers on Members in a Class	Accessed from the Same Class	Accessed from the Same Package	Accessed from a Subclass in a Different Package	Accessed from a Different Package
Public	✓	✓	✓	✓
Protected	✓	✓	✓	
Default (no modifier)	✓	✓		
Private	✓			

Data field encapsulation

- It is a best practice to **declare all data fields private**
- Protects data
  - From being set to an arbitrary value mistakenly (i.e., tampering) outside of the class
- Makes class easier to maintain
  - Modify the implementation inside the class without modifying all existing code currently using the class outside of the class

Object-oriented programming: class abstraction and encapsulation

- *Class abstraction* means to separate class implementation from the use of the class
- The creator of the class provides a description of the class and lets the user know how the class can be used
  - The *class contract*
- The user of the class does not need to know how the class is implemented
- The detail of implementation is encapsulated and hidden from the user
  - *Class encapsultion*
  - A class is called an *abstract data type* (ADT)



Accessor and mutator

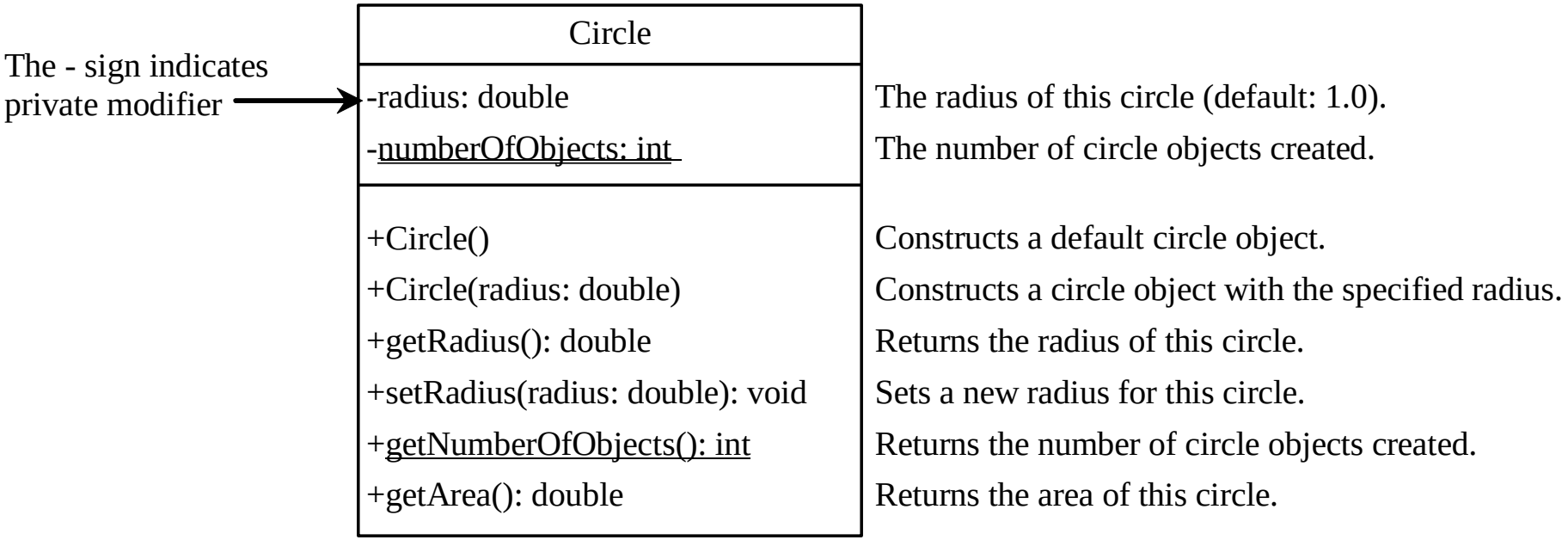
- Accessor
  - Provide a *getter* method to read a private data field
  - Use syntax

```
public returnType getPropertyName()
public boolean isPropertyName()
```

- Mutator
  - Provide a *setter* method to modify a private data field
  - Use syntax

```
public void setPropertyName(datatype propertyValue)
```

Data encapsulation

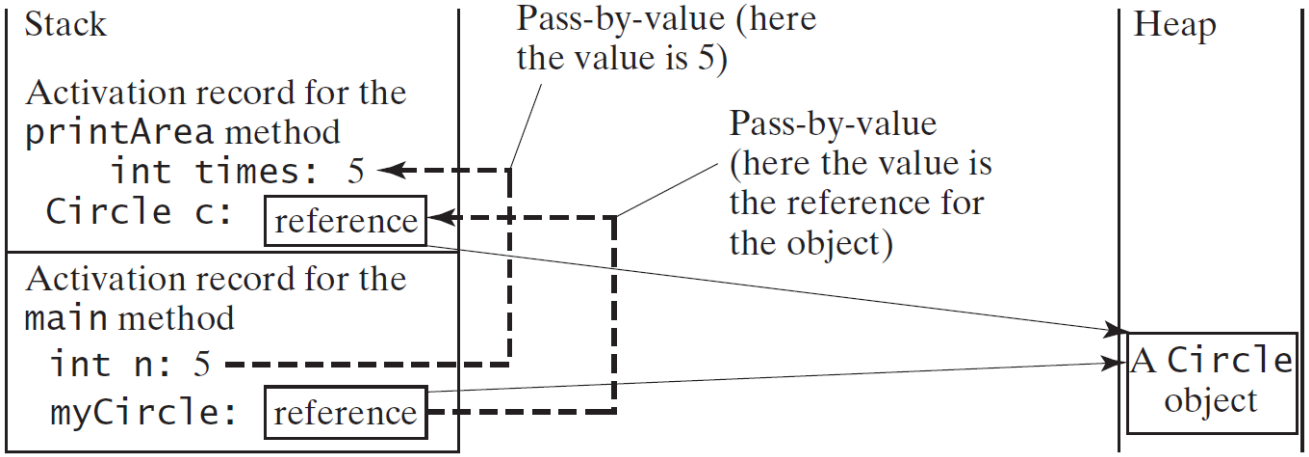


Pass by value

- Remember, Java uses **pass by value** to pass arguments to a method
- For a parameter of a **primitive type**, the **actual value** is passed
  - Changing the value of the local parameter inside the method **does not affect** the value of the variable outside the method
- For a parameter of an **array or object type**, the **reference value** is passed
  - Any changes to the array that occur inside the method body **will affect** the original array or object that was passed as the argument

Passing objects to methods

```
public static void main(String[] args) {
  Circle myCircle = new Circle(1);
  int n = 5;
  printAreas(myCircle, n);
}

public static void printAreas(Circle c, int times) {
  System.out.println("Radius \t\tArea");
  while (times >= 1) {
    System.out.println(c.getRadius() + "\t\t" + c.getArea());
    c.setRadius(c.getRadius() + 1);
    times--;
  }
}
```



Arrays of objects

- An array can hold objects as well as primitive type values
- An array of objects is actually an array of reference variables

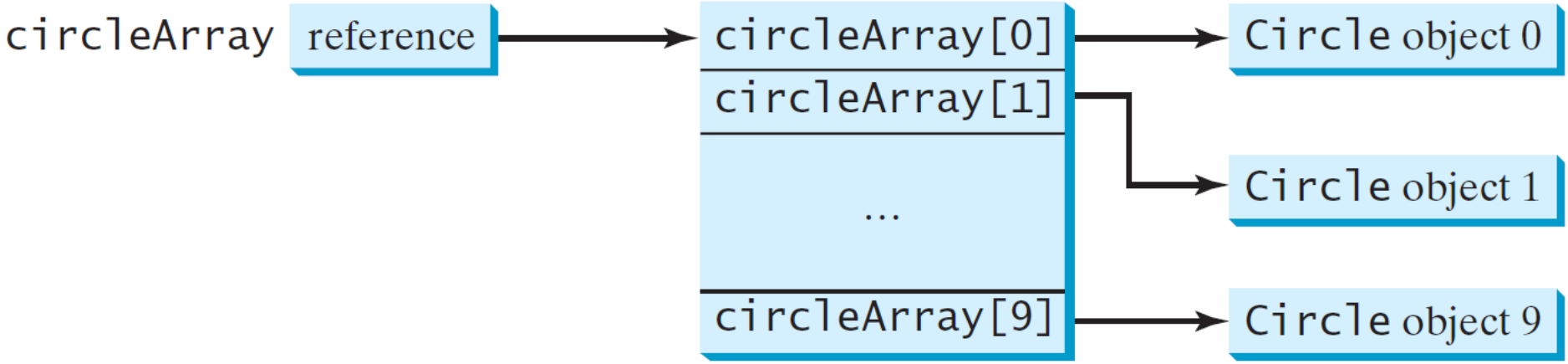
Arrays of objects

- Create an array **and** each object in it
- When creating an array using `new`, each element in the array is a reference variable with a default value of `null`

```
Circle[] circleArray = new Circle[10];
for (int i = 0; i < circleArray.length; i++)
{
  circleArray[i] = new Circle();
}
```

Arrays of objects

- Invoking `circleArray[1].getArea()` involves two levels of referencing
  - `circleArray` references to the entire array
  - `circleArray[1]` references to a Circle object

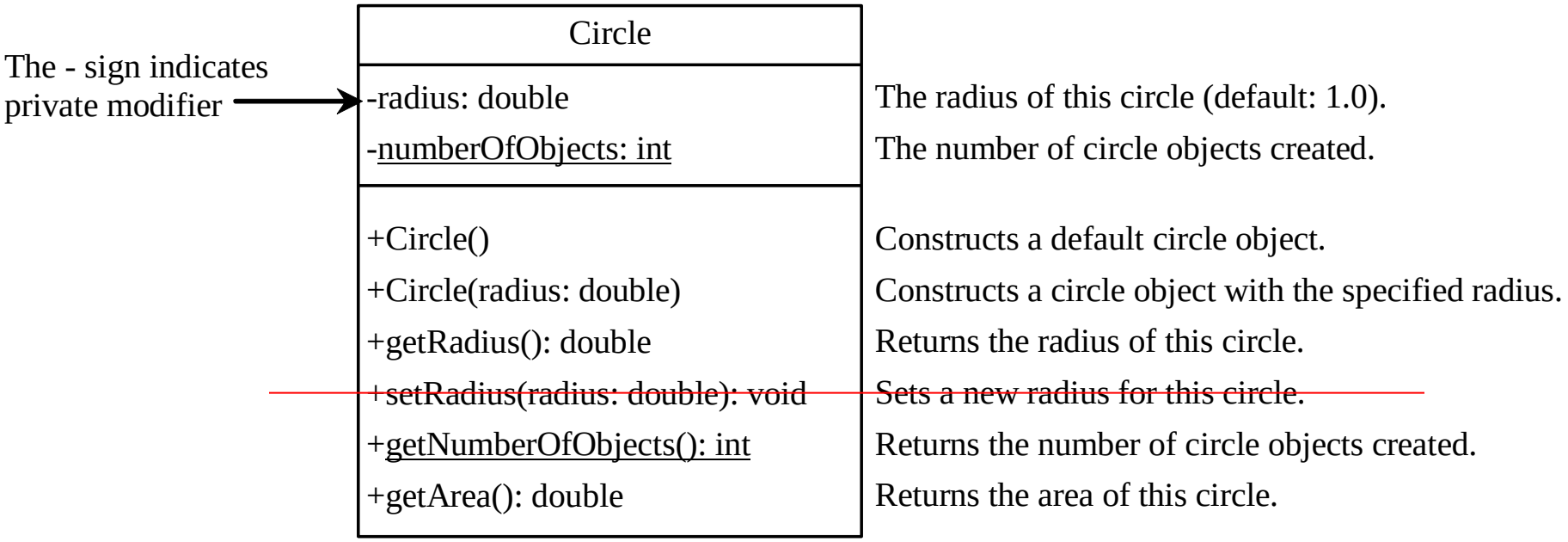


Immutable objects and classes

- Occasionally, it is desirable to create an object whose contents **cannot** be changed once the object has been created
- Such an object is called an **immutable object** and its class is called an **immutable class**

Immutable objects and classes

- For example, deleting the `setRadius` method in the `Circle` class would make it an immutable class because radius is private and cannot be changed without a mutator (i.e., set) method



Immutable objects and classes

```
public class Student {
  private int id;
  private BirthDate birthDate;

  public Student(int ssn,
      int year, int month, int day) {
    id = ssn;
    birthDate = new BirthDate(year, month, day);
  }

  public int getId() {
    return id;
  }

  public BirthDate getBirthDate() {
    return birthDate;
  }
}
```

```
public class BirthDate {
  private int year;
  private int month;
  private int day;

  public BirthDate(int newYear,
      int newMonth, int newDay) {
    year = newYear;
    month = newMonth;
    day = newDay;
  }

  public void setYear(int newYear) {
    year = newYear;
  }
}
```

```
public class Test {
  public static void main(String[] args) {
    Student student = new Student(111223333, 1970, 5, 3);
    BirthDate date = student.getBirthDate();
    date.setYear(2010); // Now the student birth year is changed!
  }
}
```

Warning: a class with all private data fields and without mutators is not necessarily immutable

Immutable class

- Requirements of an immutable class
  - **All data fields** must be **private**
  - There **cannot be any mutator methods** for data fields
  - **No accessor methods can return** a reference to a data field that is **mutable**

Scope of variables revisited

- The scope of **class variables** (instance and static data fields) is the entire class
  - They can be declared anywhere inside a class
    - Best practice is to **declare them at the beginning of the class**
  - They have default values
- The scope of a **local variable** starts from its declaration and continues to the end of the block that contains the variable
  - Java assigns no default value to a local variable inside a method
  - A local variable must be initialized explicitly before it can be used

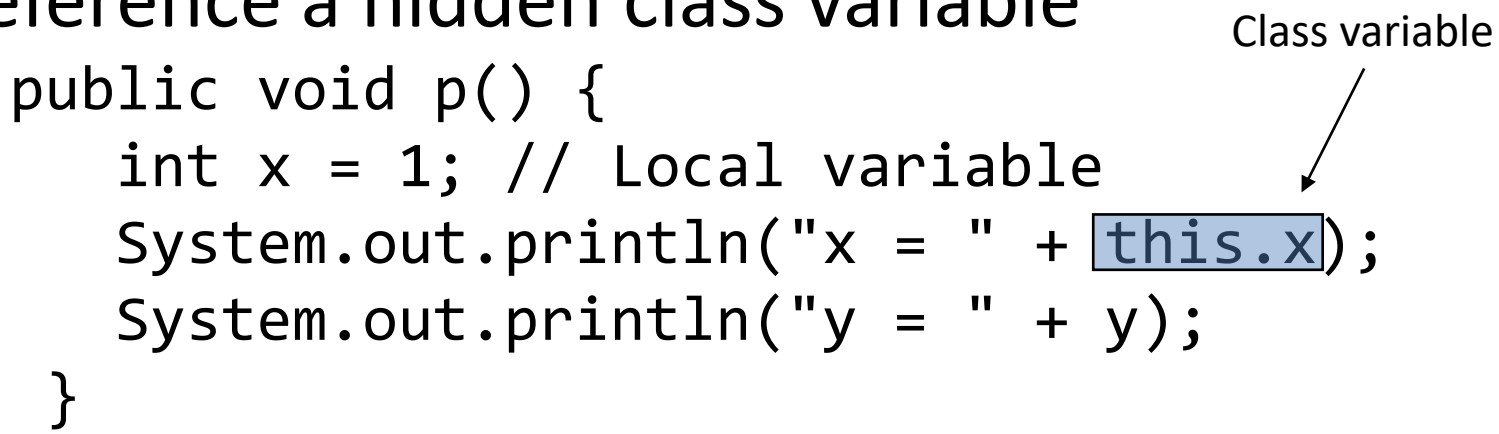
Scope of variables revisited

- If a local variable has the same name as a class variable, then **the local variable takes precedence** (i.e., the class variable is *hidden*)

```
public class F {
  private int x = 0; // Class variable
  private int y = 0;

  public F() {
  }

  public void p() {
    int x = 1; // Local variable
    System.out.println("x = " + x); // Uses local variable
    System.out.println("y = " + y);
  }
}
```

`this` reference

- The `this` keyword 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 variable



Use `this` to reference data fields

- For a hidden **static variable**, use `ClassName.staticVariable`
- Best practice is to **use the data field name as the parameter name in the setter method or a constructor**

```
public class F {
  private int i = 5;
  private static double k = 0;

  void setI(int i) {
    this.i = i;
  }

  static void setK(double k) {
    F.k = k;
  }
}
```

Class variable

Class static variable

```
Suppose that f1 and f2 are two objects of F.
F f1 = new F();
F f2 = new F();

Invoking f1.setI(10) is to execute
   this.i = 10, where this refers f1

Invoking f2.setI(45) is to execute
   this.i = 45, where this refers f2
```

`this` reference

- The `this` keyword is the name of a reference that refers to an object itself
- We just used the `this` keyword is to reference a hidden class variable
- It can also be used **inside a constructor** *to invoke another constructor of the same class*

```
public class Circle {
  private double radius;

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

  public Circle() {
    this(1.0);
  }
```

this must be explicitly used to reference the data field radius of the object being constructed

this is used to invoke another constructor

`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
      ```

Next Lecture

- Object-oriented thinking