Objects and Classes (Part 2)

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 7

Announcements

- Assignment 3 is due Oct 20, 11:59 PM
- Quiz 3 is Oct 22
- Assignment 4 will be released Oct 20
  - Due Oct 27, 11:59 PM
- Educational research study
  - Oct 22, weekly survey
- Reading
  - Liang
    - Chapter 9

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
- 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 methods vs static methods

- An instance method can only be invoked from an object (i.e., a specific instance of a class)
  - The syntax to invoke an instance method is

    ```
    objectReferenceVariable.methodName(arguments)
    ```
- A static method (i.e., a non-instance method) can be invoked without using an object (i.e., they are not tied to a specific class instance)
  - 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.variable
```

- Do not use

```
objectReferenceVariable.methodName(arguments)
objectReferenceVariable.variable
```

The `static` modifier

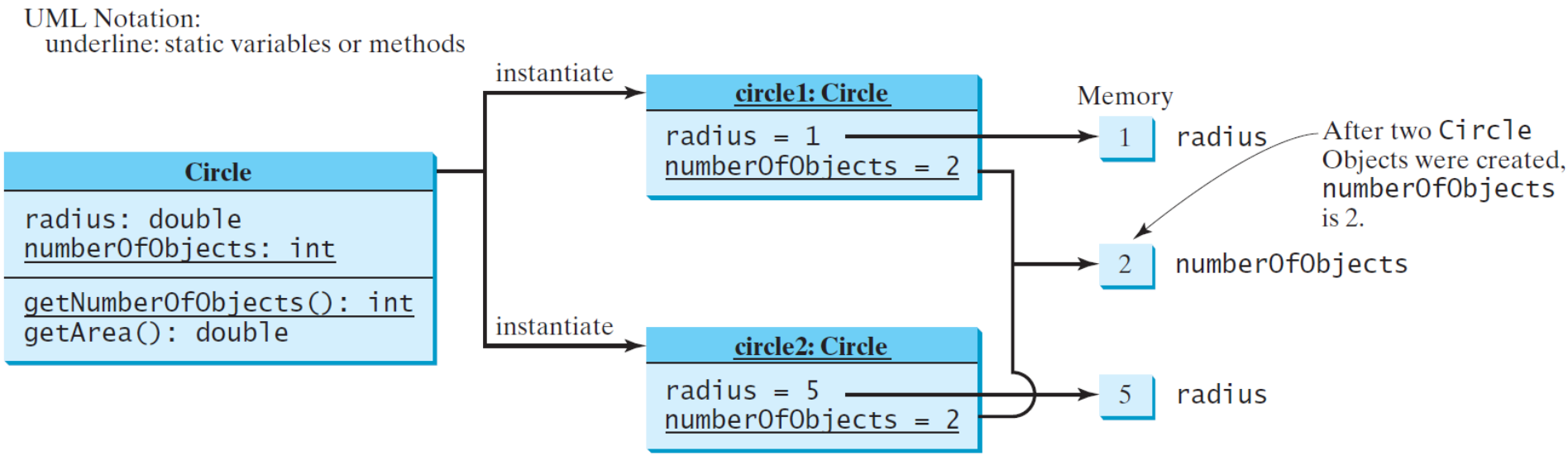
- To declare static variables, constants, and methods, use the `static` modifier
- `static` is a Java keyword

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 access instance members**

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 next week)

Packages and classes

- The default modifier on a class restricts access to within a package, and the public modifier enables unrestricted access

```
package p1;

class C1 {
  ...
}
```

```
package p1;

public class C2 {
  can access C1
}
```

```
package p2;

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

Packages, classes, and members

- The private modifier restricts access to within a class, the default modifier restricts access to within a package, and 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();
  }
}
```

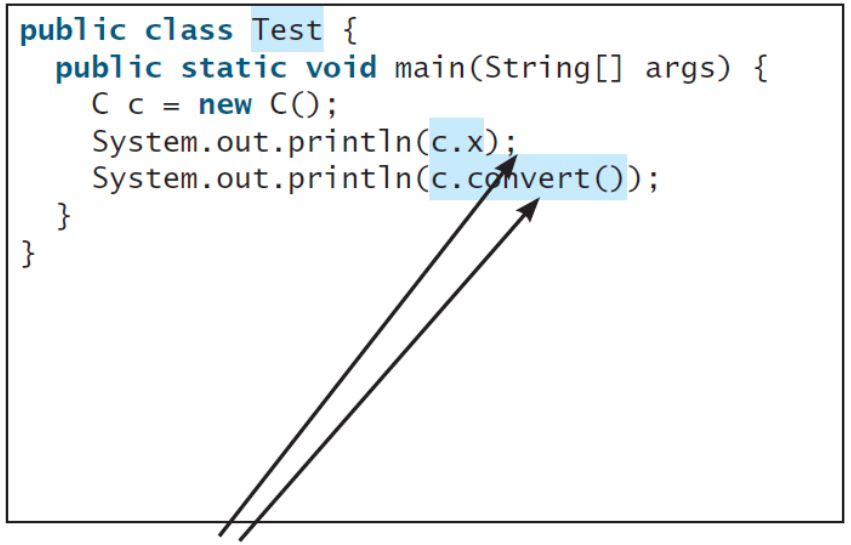
Visibility of own members

- 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 is 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

Accessor and mutator

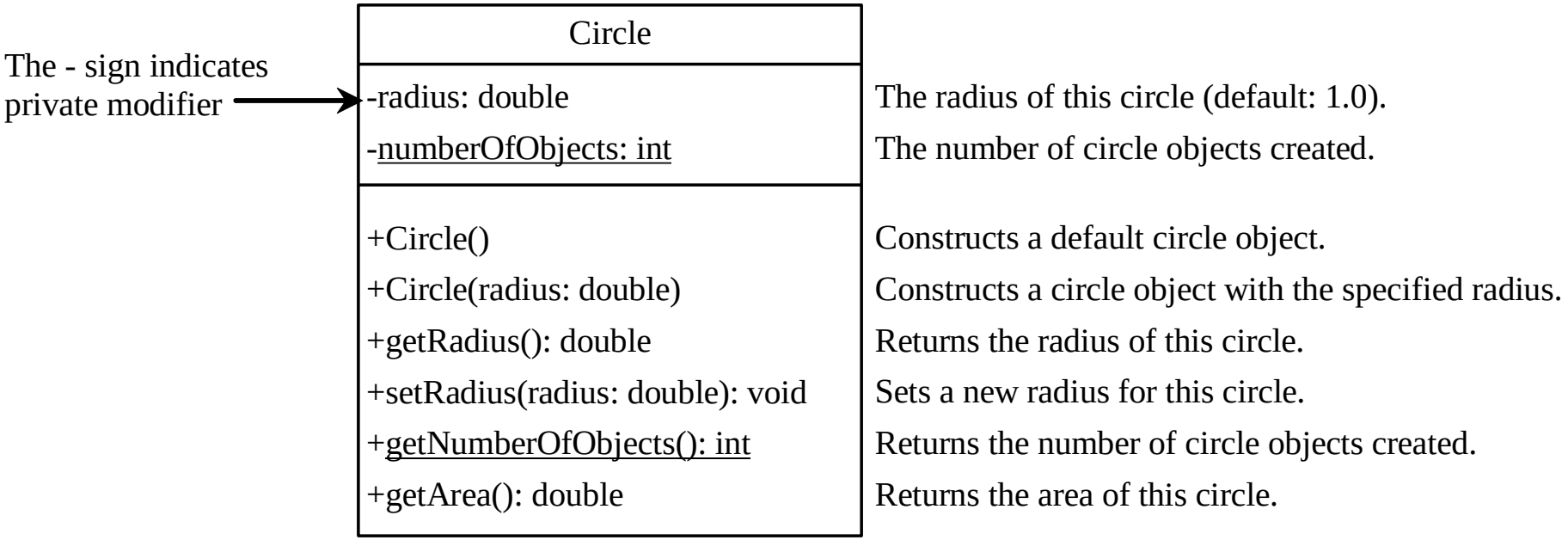
- Accessor
  - Provide a *getter* method to read a private data field
  - Use syntax

```
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

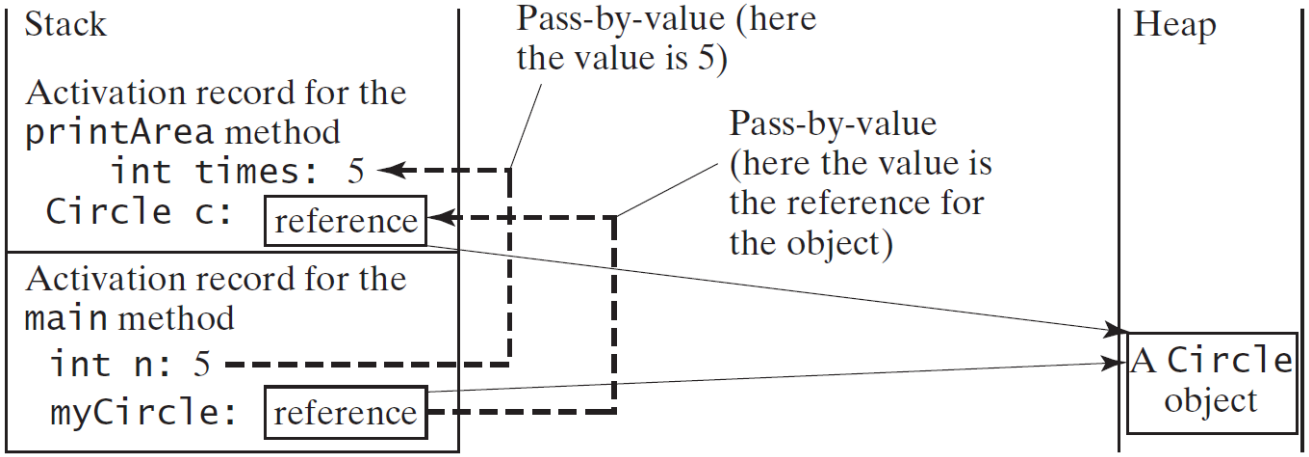


Pass by value

- 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

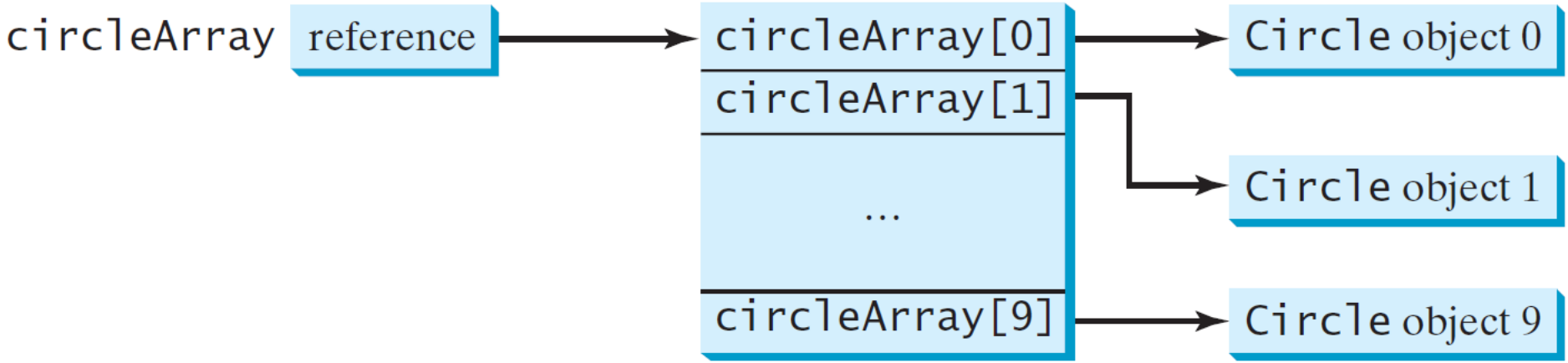
Arrays of objects

- 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

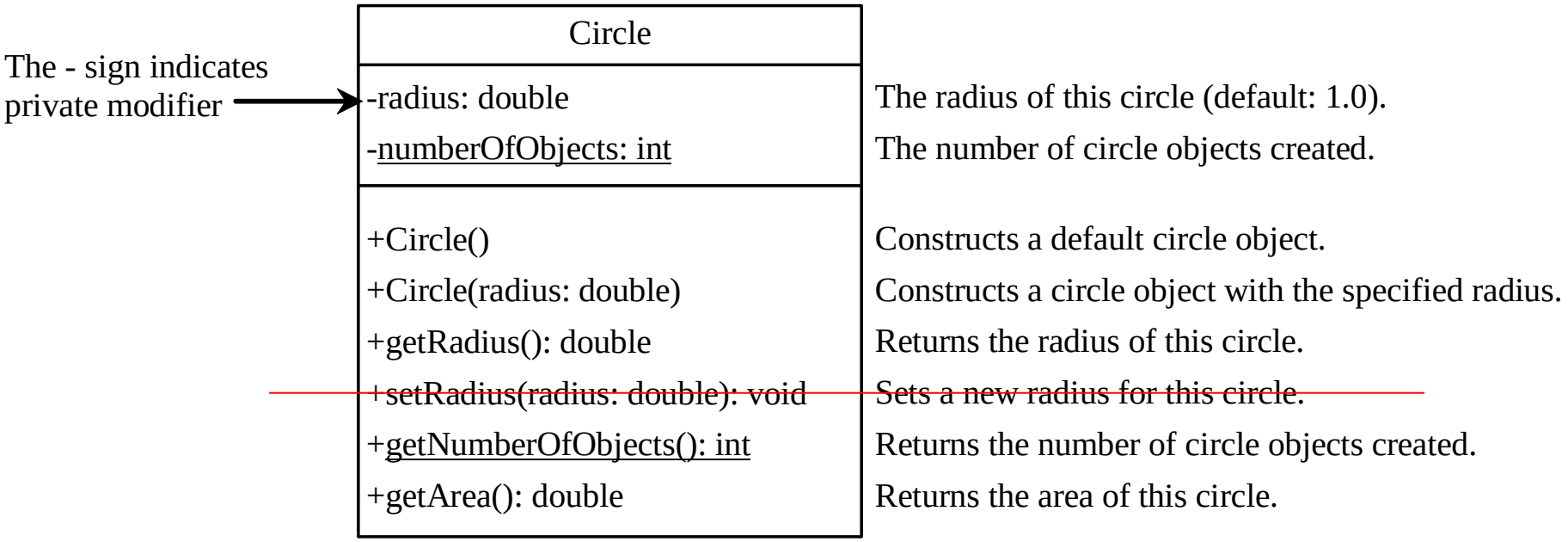


Immutable objects and classes

- 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; // Instance 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

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

Use `this` to reference data fields

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

```
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;
  }
}
```

```
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
- One common use of 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

Next Lecture

- Object-oriented thinking
- Reading
  - Liang
    - Chapter 10