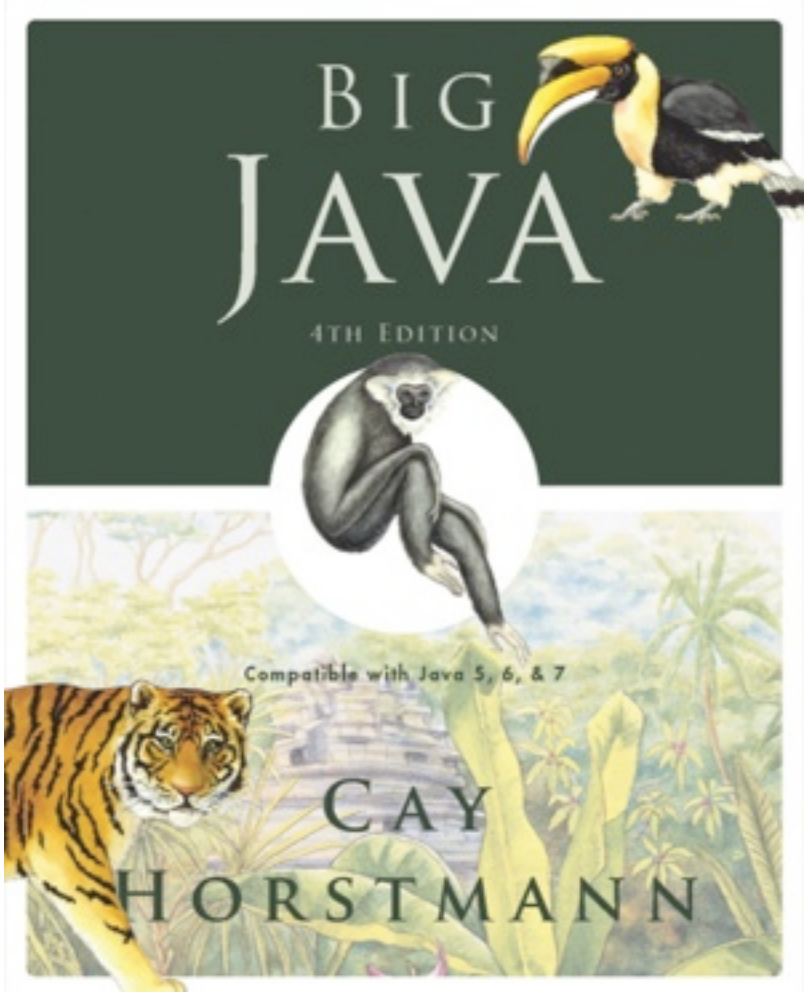


Chapter Three - Implementing Classes

Chapter Goals

- To become familiar with the process of implementing classes
- To be able to implement simple methods
- To understand the purpose and use of constructors
- To understand how to access instance variables and local variables
- To be able to write javadoc comments

G To implement classes for drawing graphical shapes

Instance Variables

- **Example:** tally counter
- Simulator statements:

```
Counter tally = new Counter();
tally.count();
tally.count();
int result = tally.getValue(); // Sets result to 2
```

Figure 1 A Tally Counter

- Each counter needs to store a variable that keeps track of how many times the counter has been advanced

Instance Variables

- **Instance variables** store the data of an object
- **Instance of a class:** an object of the class
- The class declaration specifies the instance variables:

```
public class Counter
{
   private int value;
   …
}
```

Instance Variables

- An instance variable declaration consists of the following parts:
  - *access specifier (*`private`*)*
  - *type of variable (such as* `int`*)*
  - *name of variable (such as* `value`*)*
- Each object of a class has its own set of instance variables
- You should declare all instance variables as private

Instance Variables

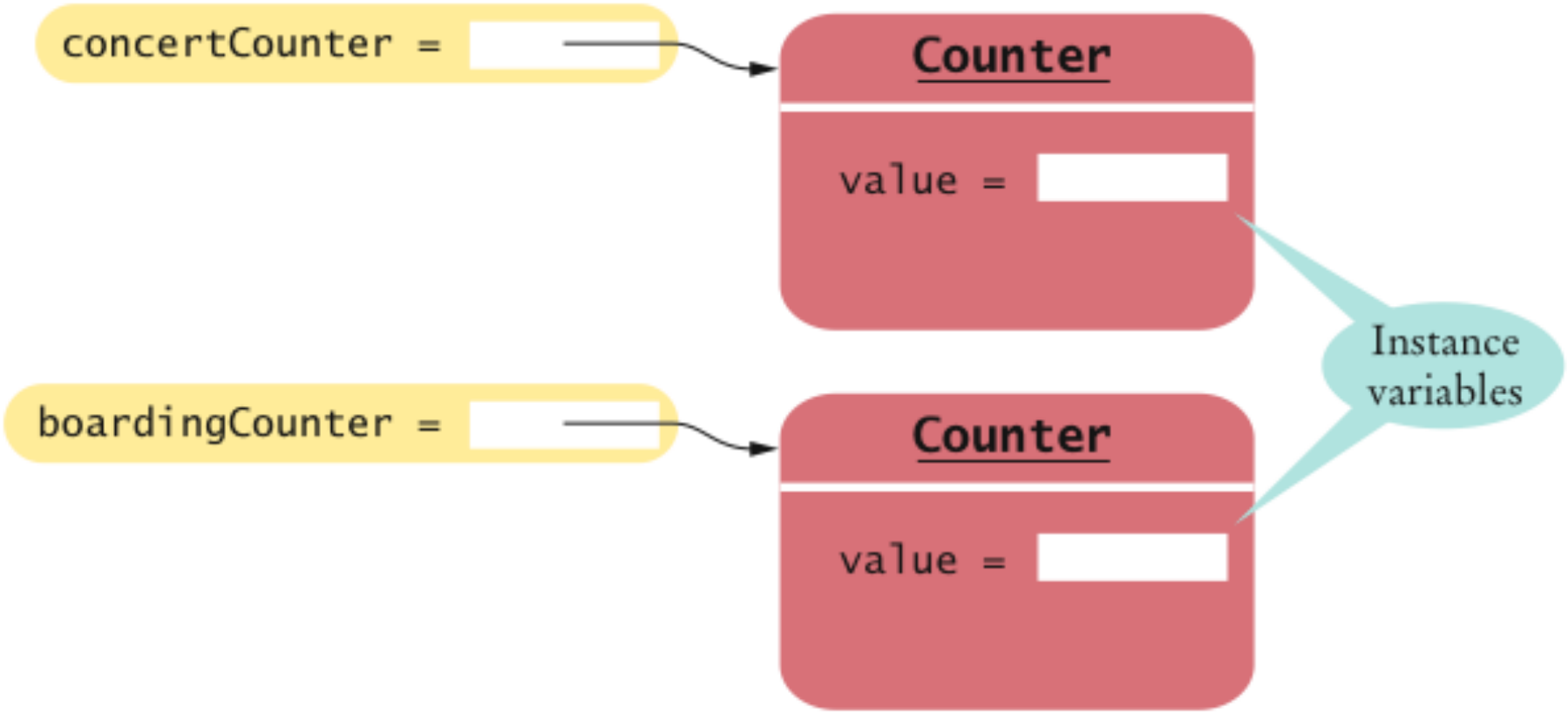


Figure 2 Instance Variables

Syntax 3.1 Instance Variable Declaration

Syntax

```
accessSpecifier class ClassName
{
   accessSpecifier typeName variableName;
   . . .
}
```

Example

```
public class Counter
{
   private int value;
   . . .
}
```

Instance variables should always be private.

Each object of this class has a separate copy of this instance variable.

Type of the variable

Accessing Instance Variables

- The `count` method advances the counter value by 1:

```
public void count()
{
   value = value + 1;
}
```

- The `getValue` method returns the current value:

```
public int getValue()
{
   return value;
}
```

- Private instance variables can only be accessed by methods of the same class

Self Check 3.1

Supply the body of a method `public void reset()` that resets the counter back to zero.

Self Check 3.2

Suppose you use a class `Clock` with private instance variables `hours` and `minutes`. How can you access these variables in your program?

Instance Variables

- **Encapsulation** is the process of hiding object data and providing methods for data access
- To encapsulate data, declare instance variables as `private` and declare public methods that access the variables
- Encapsulation allows a programmer to use a class without having to know its implementation
- Information hiding makes it simpler for the implementor of a class to locate errors and change implementations

Self Check 3.3

Consider the `Counter` class. A counter's value starts at 0 and is advanced by the `count` method, so it should never be negative. Suppose you found a negative `value` variable during testing. Where would you look for the error?

Self Check 3.4

In Chapters 1 and 2, you used `System.out` as a black box to cause output to appear on the screen. Who designed and implemented `System.out`?

Self Check 3.5

Suppose you are working in a company that produces personal finance software. You are asked to design and implement a class for representing bank accounts. Who will be the users of your class?

Specifying the Public Interface of a Class

Behavior of bank account (abstraction):

- deposit money
- withdraw money
- get balance

Specifying the Public Interface of a Class: Methods

- Methods of `BankAccount` class:
  - `deposit`
  - `withdraw`
  - `getBalance`
- We want to support method calls such as the following:

```
harrysChecking.deposit(2000);
harrysChecking.withdraw(500);
System.out.println(harrysChecking.getBalance());
```

Specifying the Public Interface of a Class: Method Declaration

access specifier (such as `public`)

- return type (such as `String` or `void`)
- method name (such as `deposit`)
- list of parameters (`double amount` for `deposit`)
- method body in `{ }`

Examples:

- `public void deposit(double amount) { . . . }`
- `public void withdraw(double amount) { . . . }`
- `public double getBalance() { . . . }`

Specifying the Public Interface of a Class: Method Header

- access specifier (such as `public`)
- return type (such as `void` or `double`)
- method name (such as `deposit`)
- list of parameter variables (such as `double amount`)

Examples:

- `public void deposit(double amount)`
- `public void withdraw(double amount)`
- `public double getBalance()`

Specifying the Public Interface of a Class: Constructor Declaration

- A constructor initializes the instance variables
- Constructor name = class name

```
public BankAccount()
{
   // body--filled in later
}
```

- Constructor body is executed when new object is created
- Statements in constructor body will set the internal data of the object that is being constructed
- All constructors of a class have the same name
- Compiler can tell constructors apart because they take different parameters

`BankAccount` Public Interface

The public constructors and methods of a class form the *public interface* of the class:

```
public class BankAccount
{
   // private variables--filled in later

   // Constructors public BankAccount()
   {
      // body--filled in later
   }

   public BankAccount(double initialBalance)
   {
      // body--filled in later
   }
```

Continued

`BankAccount` Public Interface (cont.)

```
   // Methods
   public void deposit(double amount)
   {
      // body--filled in later
   }
   public void withdraw(double amount)
   {
      // body--filled in later
   }
   public double getBalance()
   {
      // body--filled in later
   }
}
```

Syntax 3.2 Class Declaration

Syntax

accessSpecifier `class` *ClassName*
{
    instance variables
    constructors
    methods
}

Example

```
public class Counter
{
   private int value;

   public Counter(double initialValue) { value = initialValue; }

   public void count() { value = value + 1; }
   public int getValue() { return value; }
}
```

Public interface

Private implementation

Self Check 3.6

How can you use the methods of the public interface to *empty* the `harrysChecking` bank account?

Self Check 3.7

What is wrong with this sequence of statements?

```
BankAccount harrysChecking = new BankAccount(10000);
System.out.println(harrysChecking.withdraw(500));
```

Self Check 3.8

Suppose you want a more powerful bank account abstraction that keeps track of an *account number* in addition to the balance. How would you change the public interface to accommodate this enhancement?

Commenting the Public Interface

```
/**
   Withdraws money from the bank account.
   @param amount the amount to withdraw
*/
public void withdraw(double amount)
{
   //implementation filled in later
}
/**
   Gets the current balance of the bank account.
   @return the current balance
*/
public double getBalance()
{
   //implementation filled in later
}
```

Class Comment

```
/**
   A bank account has a balance that can be changed by
   deposits and withdrawals.
*/
public class BankAccount
{
   . . .
}
```

- Provide documentation comments for
  - *every class*
  - *every method*
  - *every parameter*
  - *every return value*

Javadoc Method Summary

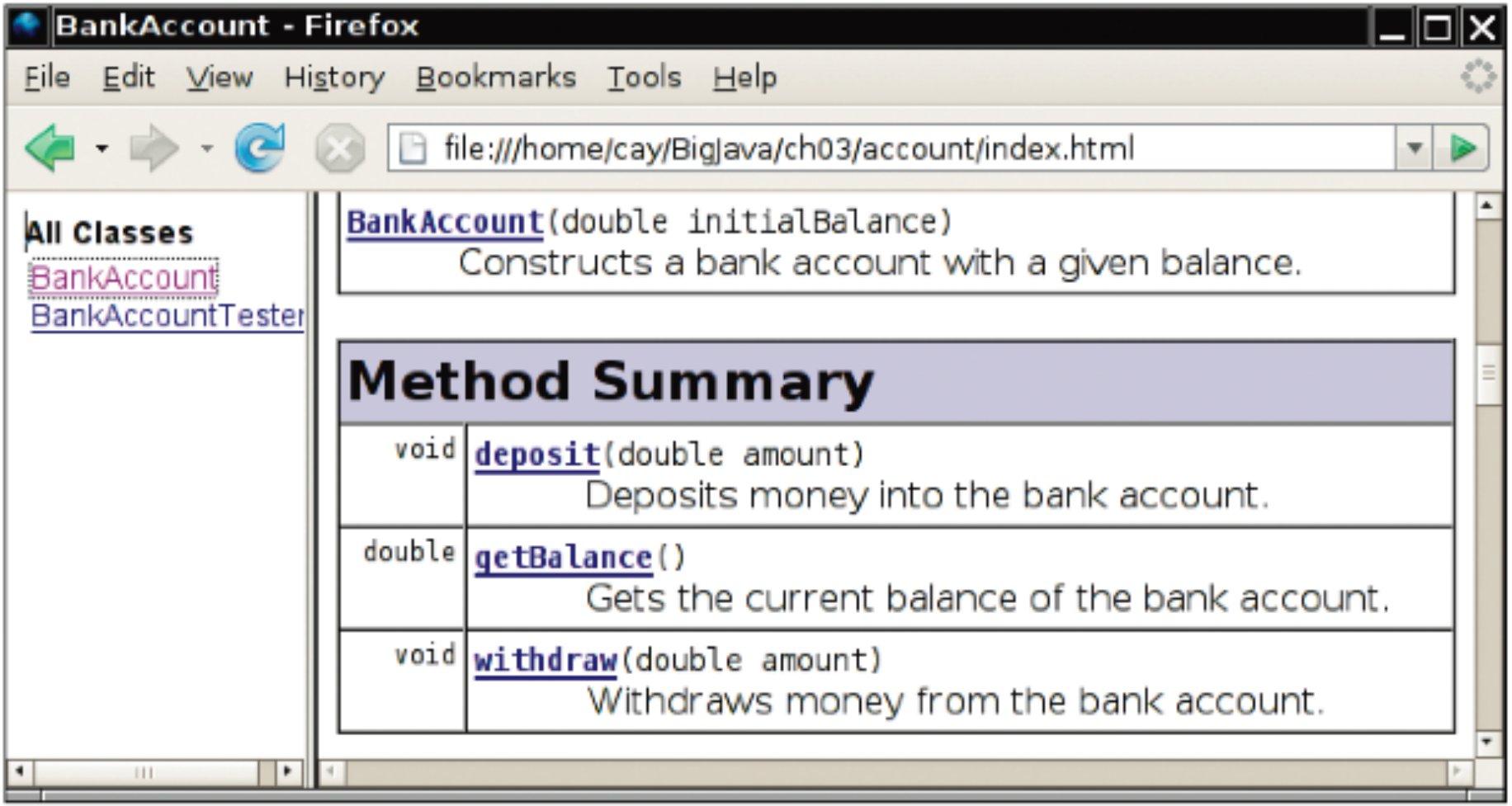


Figure 3 A Method Summary Generated by javadoc

Javadoc Method Detail

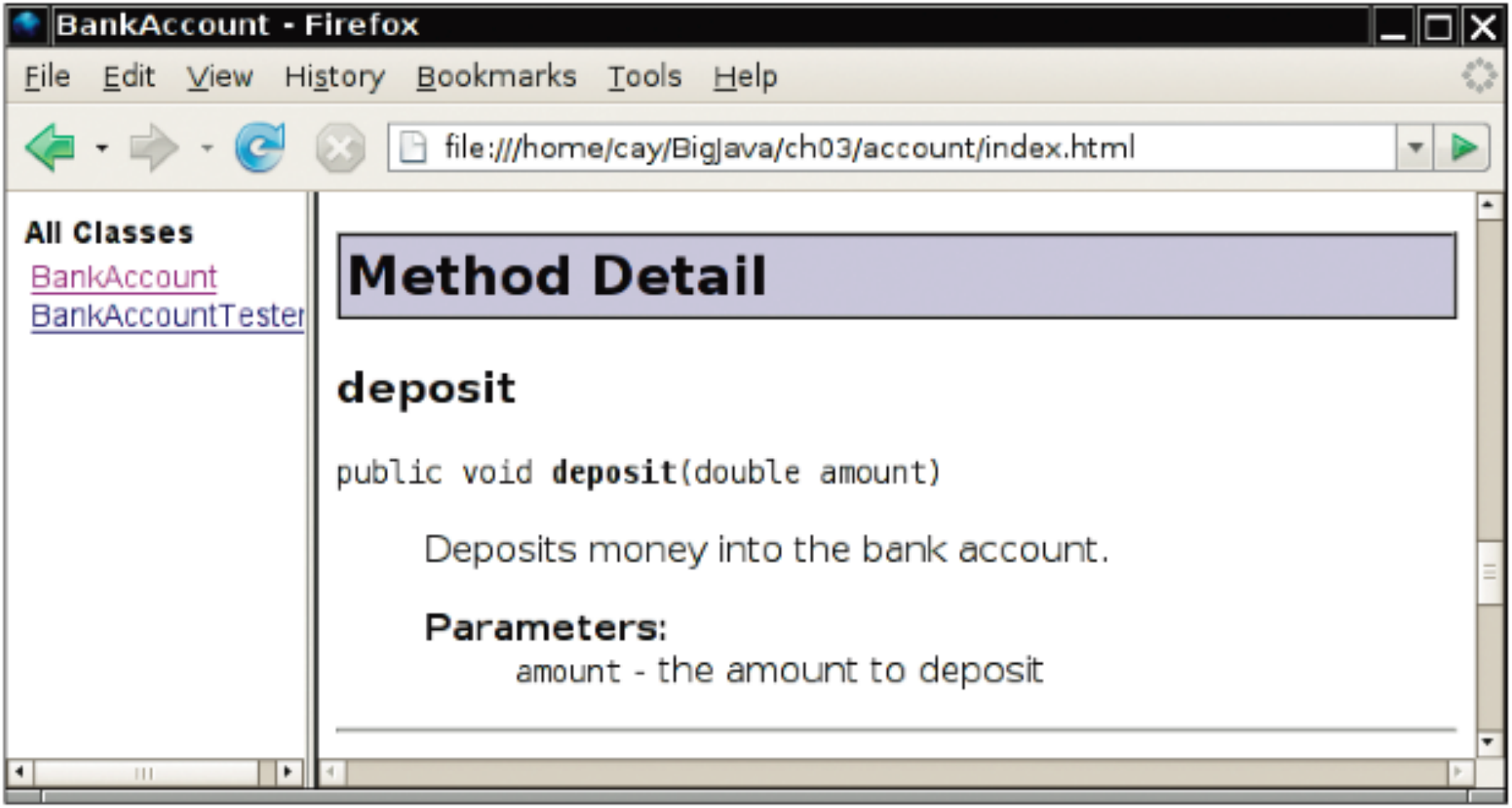


Figure 4 Method Detail Generated by javadoc

Self Check 3.9

Provide documentation comments for the `Counter` class of Section 3.1.

Continued

Self Check 3.10

Suppose we enhance the `BankAccount` class so that each account has an account number. Supply a documentation comment for the constructor

```
public BankAccount(int accountNumber, double initialBalance)
```

Self Check 3.11

Why is the following documentation comment questionable?

```
/**
   Each account has an account number.
   @return the account number of this account
*/
public int getAccountNumber()
```

Implementing Constructors

- Constructors contain instructions to initialize the instance variables of an object:

```
public BankAccount()
{
   balance = 0;
}

public BankAccount(double initialBalance)
{
   balance = initialBalance;
}
```

Constructor Call Example

- Statement:

```
BankAccount harrysChecking = new BankAccount(1000);
```

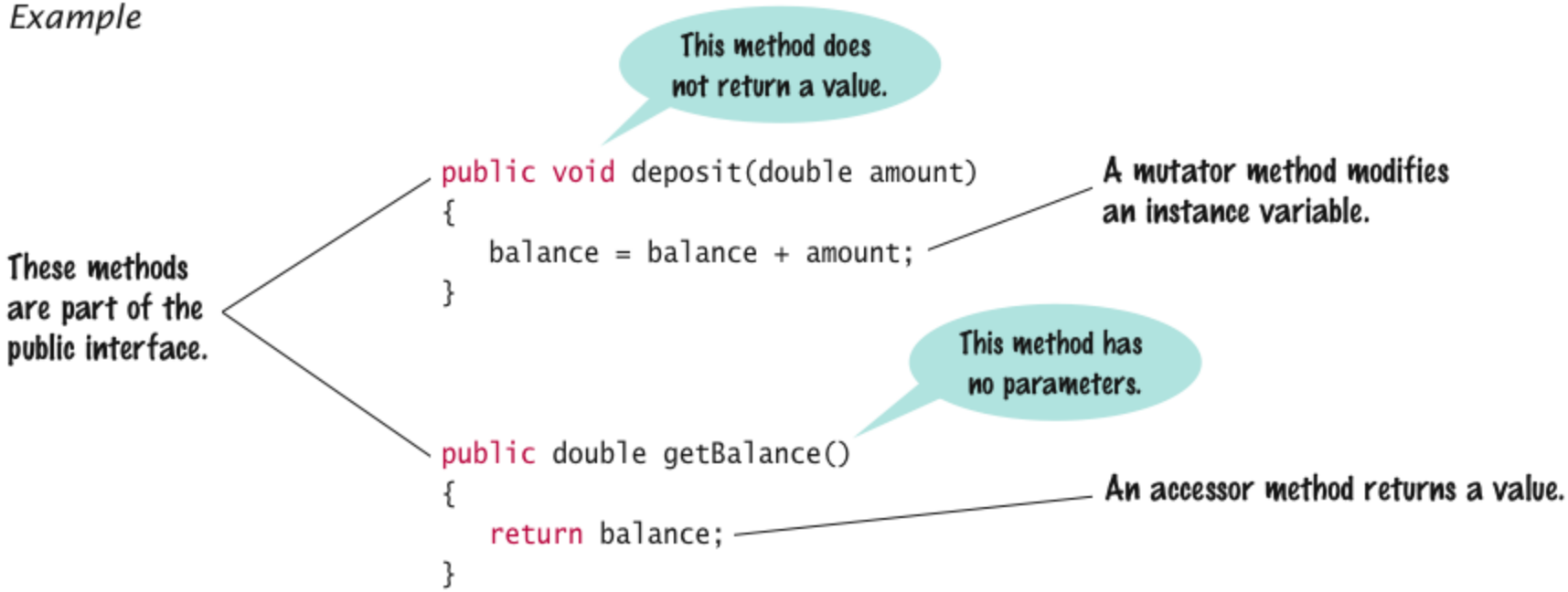
  - *Create a new object of type* `BankAccount`
  - *Call the second constructor (because a construction parameter is supplied in the constructor call)*
  - *Set the parameter variable* `initialBalance` *to* `1000`
  - *Set the* `balance` *instance variable of the newly created object to* `initialBalance`
  - *Return an object reference, that is, the memory location of the object, as the value of the* `new` *expression*
  - *Store that object reference in the* `harrysChecking` *variable*

Syntax 3.3 Method Declaration

Syntax

```
accessSpecifier returnType methodName(parameterType parameterName, . . . )
{
   method body
}
```

Example



Implementing Methods

- `deposit` method:

```
public void deposit(double amount)
{
   balance = balance + amount;
}
```

Method Call Example

- Statement:

```
harrysChecking.deposit(500);
```

  - *Set the parameter variable* `amount` *to 500*
  - *Fetch the* `balance` *variable of the object whose location is stored in* `harrysChecking`
  - *Add the value of* `amount` *to* `balance`
  - *Store the sum in the* `balance` *instance variable, overwriting the old value*

Implementing Methods

- ```
  public void withdraw(double amount)
  {
     balance = balance - amount;
  }
  ```
- ```
  public double getBalance()
  {
     return balance;
  }
  ```

ch03/account/BankAccount.java

```
1  /**
2     A bank account has a balance that can be changed by
3     deposits and withdrawals.
4  */
5  public class BankAccount
6  {
7     private double balance;
8
9     /**
10       Constructs a bank account with a zero balance.
11    */
12    public BankAccount()
13    {
14       balance = 0;
15    }
16
17    /**
18       Constructs a bank account with a given balance.
19       @param initialBalance the initial balance
20    */
21    public BankAccount(double initialBalance)
22    {
23       balance = initialBalance;
24    }
```

Continued

ch03/account/BankAccount.java (cont.)

```
25
26      /**
27         Deposits money into the bank account.
28         @param amount the amount to deposit
29      */
30      public void deposit(double amount)
31      {
32         balance = balance + amount;
33      }
34
35      /**
36         Withdraws money from the bank account.
37         @param amount the amount to withdraw
38      */
39      public void withdraw(double amount)
40      {
41         balance = balance - amount;
42      }
43
```

Continued

ch03/account/BankAccount.java (cont.)

```
44      /**
45         Gets the current balance of the bank account.
46         @return the current balance
47      */
48      public double getBalance()
49      {
50         return balance;
51      }
52   }
```

Self Check 3.12

Suppose we modify the `BankAccount` class so that each bank account has an account number. How does this change affect the instance variables?

Self Check 3.13

Why does the following code not succeed in robbing mom's bank account?

```
public class BankRobber
{
   public static void main(String[] args)
   {
      BankAccount momsSavings = new BankAccount(1000);
      momsSavings.balance = 0;
   }
}
```

Self Check 3.14

The `Rectangle` class has four instance variables: `x`, `y`, `width`, and `height`. Give a possible implementation of the `getWidth` method.

Self Check 3.15

Give a possible implementation of the `translate` method of the `Rectangle` class.

Unit Testing

- *Unit test*: Verifies that a class works correctly in isolation, outside a complete program
- To test a class, use an environment for interactive testing, or write a tester class
- *Tester class*: A class with a main method that contains statements to test another class
- Typically carries out the following steps:
  1. *Construct one or more objects of the class that is being tested*
  2. *Invoke one or more methods*
  3. *Print out one or more results*
  4. *Print the expected results*

Continued

ch03/account/BankAccountTester.java

```
1  /**
2     A class to test the BankAccount class.
3  */
4  public class BankAccountTester
5  {
6     /**
7        Tests the methods of the BankAccount class.
8        @param args not used
9     */
10    public static void main(String[] args)
11    {
12       BankAccount harrysChecking = new BankAccount();
13       harrysChecking.deposit(2000);
14       harrysChecking.withdraw(500);
15       System.out.println(harrysChecking.getBalance());
16       System.out.println("Expected: 1500");
17    }
18 }
```

Program Run:

```
1500
Expected: 1500
```

Unit Testing (cont.)

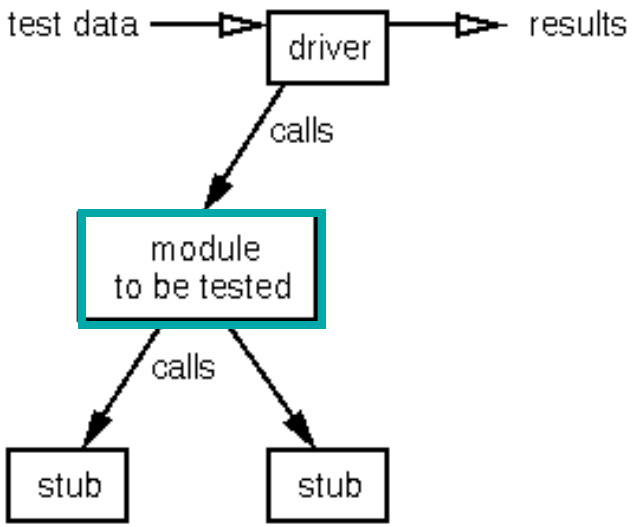
- Details for building the program vary. In most environments, you need to carry out these steps:
  1. *Make a new subfolder for your program*
  2. *Make two files, one for each class*
  3. *Compile both files*
  4. *Run the test program*

Module testing

- Experimental environment needed to create the environment in which the module should be tested
  - stubs
    - Fake modules used by the module under test
  - driver
    - module activating the module under test

Module (Unit) Testing

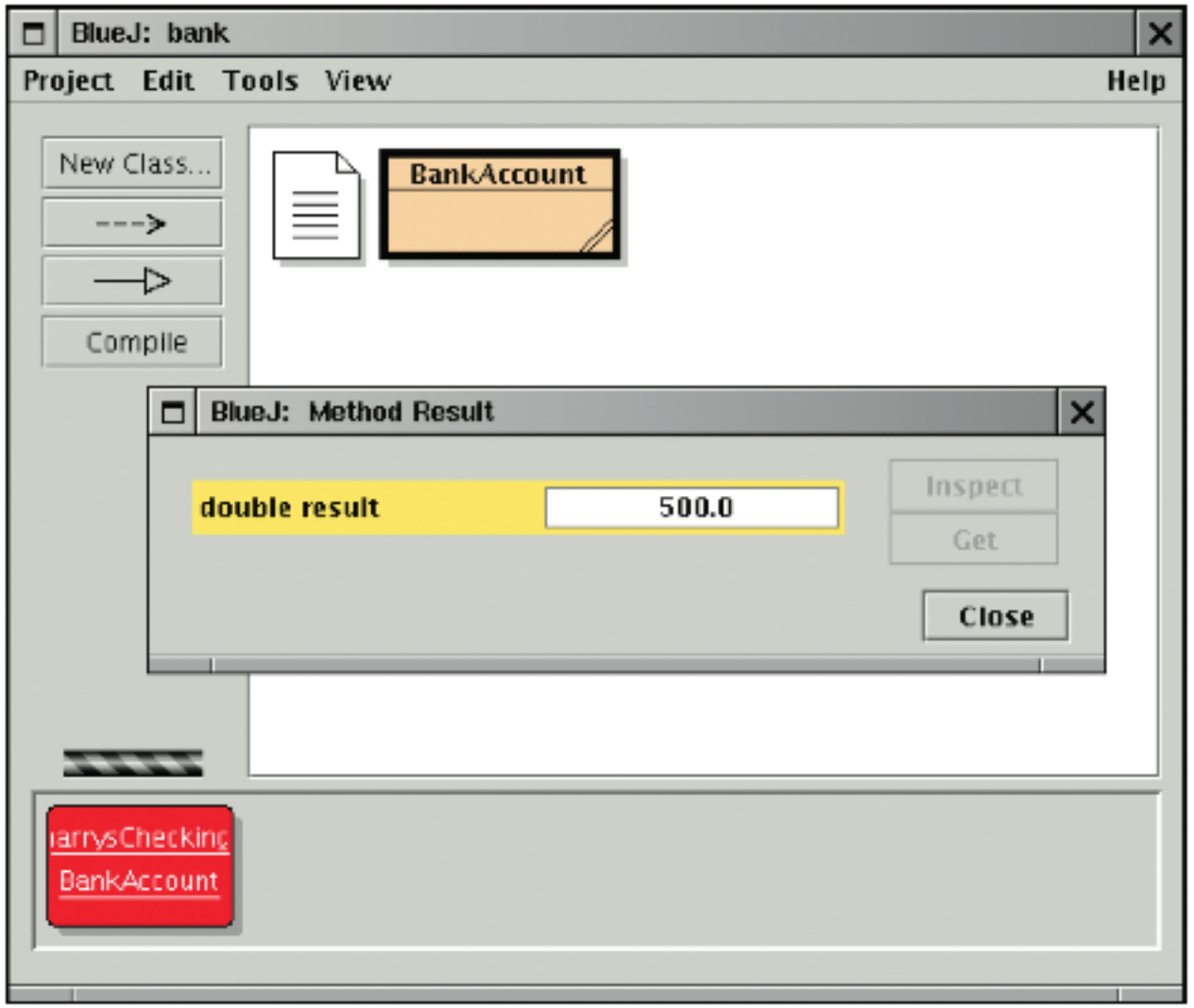
- Driver
  - Usually main program that accepts data and passes to the module to be tested and prints relevant results.
- Stub
  - Simulates a subroutine module that is called by the module to be tested
- Test harness
  - A collection of drivers and stubs
  - An automatic test-result checking with anticipated-result will accelerate the testing process.



How do you design a stub?

Testing With BlueJ

Figure 5
The Return Value of the `getBalance` Method in BlueJ



Self Check 3.16

When you run the `BankAccountTester` program, how many objects of class `BankAccount` are constructed? How many objects of type `BankAccountTester`?

Self Check 3.17

Why is the `BankAccountTester` class unnecessary in development environments that allow interactive testing, such as BlueJ?

.

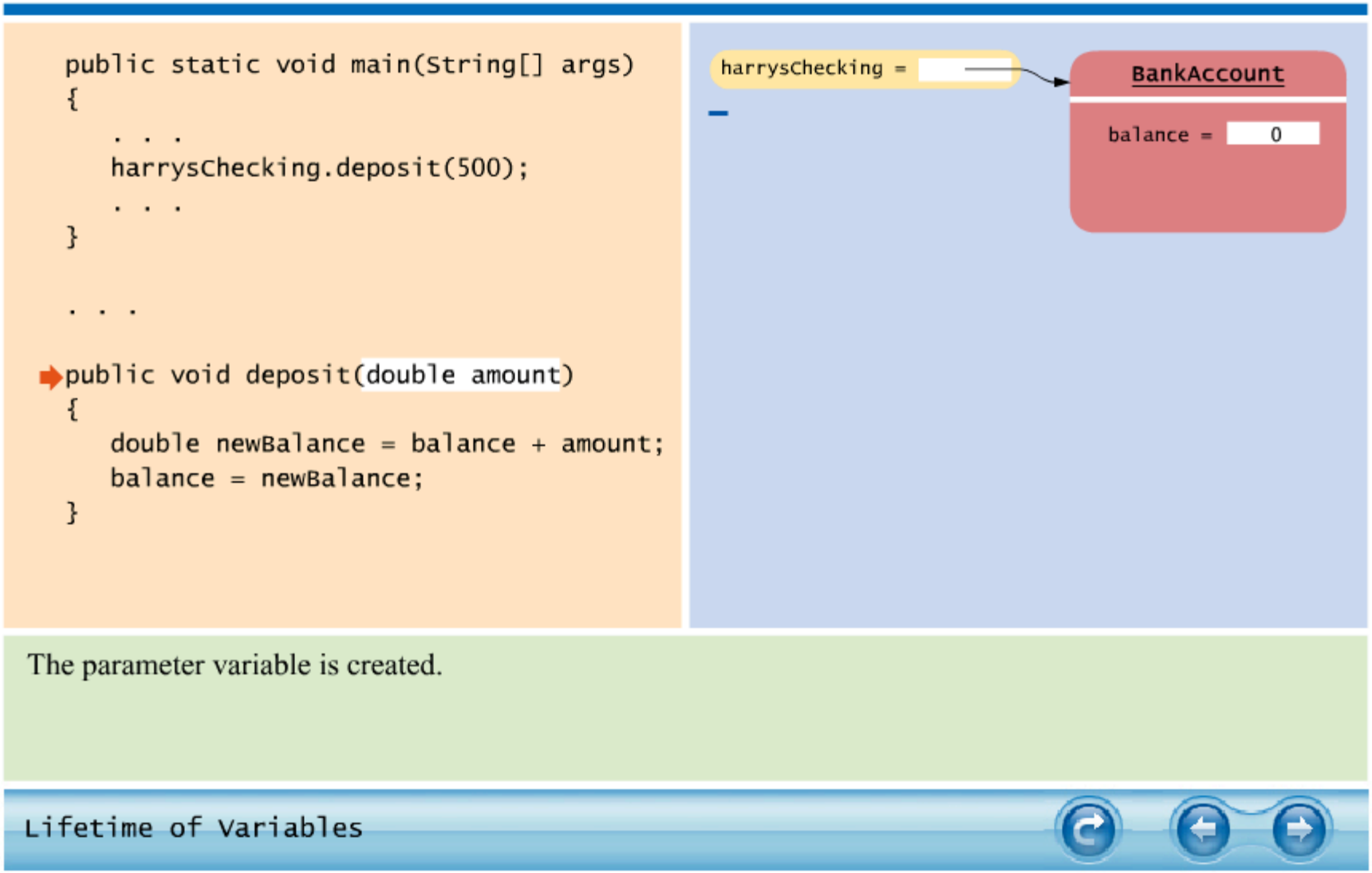
Local Variables

- Local and parameter variables belong to a method
  - *When a method or constructor runs, its local and parameter variables come to life*
  - *When the method or constructor exits, they are removed immediately*
- Instance variables belongs to an objects, not methods
  - *When an object is constructed, its instance variables are created*
  - *The instance variables stay alive until no method uses the object any longer*

Local Variables

- In Java, the *garbage collector* periodically reclaims objects when they are no longer used
- Instance variables are initialized to a default value, but you must initialize local variables

Animation 3.1: Lifetime of Variables



Self Check 3.18

What do local variables and parameter variables have in common? In which essential aspect do they differ?

Self Check 3.19

Why was it necessary to introduce the local variable `change` in the `giveChange` method? That is, why didn't the method simply end with the statement

```
return payment - purchase;
```

Implicit Parameter

- The **implicit parameter** of a method is the object on which the method is invoked

```
public void deposit(double amount)
{
   balance = balance + amount;
}
```

- In the call

```
momsSavings.deposit(500)
```

The implicit parameter is `momsSavings` and the explicit parameter is `500`

- When you refer to an instance variable inside a method, it means the instance variable of the implicit parameter

Implicit Parameters and `this`

- The `this` reference denotes the implicit parameter
- `balance = balance + amount;`

  actually means

  `this.balance = this.balance + amount;`
- When you refer to an instance variable in a method, the compiler automatically applies it to the `this` reference

Implicit Parameters and `this`

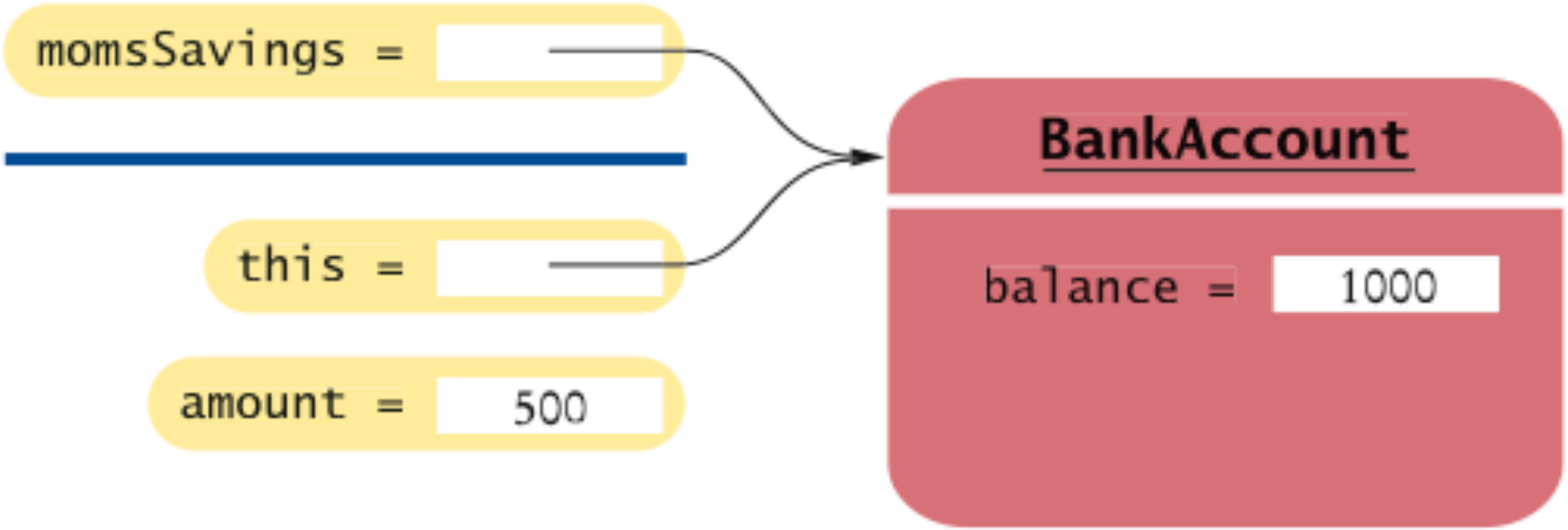


Figure 6 The Implicit Parameter of a Method Call

Implicit Parameters and `this`

- Some programmers feel that manually inserting the `this` reference before every instance variable reference makes the code clearer:

```
public BankAccount(double initialBalance)
{
   this.balance = initialBalance;
}
```

Implicit Parameters and `this`

- A method call without an implicit parameter is applied to the same object
- Example:

```
public class BankAccount
{
   . . .
   public void monthlyFee()
   {
      withdraw(10); // Withdraw $10 from this account
   }
}
```

- The implicit parameter of the `withdraw` method is the (invisible) implicit parameter of the `monthlyFee` method

Implicit Parameters and `this`

- You can use the `this` reference to make the method easier to read:

```
public class BankAccount
{
   . . .
   public void monthlyFee()
   {
      this.withdraw(10); // Withdraw $10 from this account
   }
}
```

Self Check 3.20

How many implicit and explicit parameters does the `withdraw` method of the `BankAccount` class have, and what are their names and types?

Self Check 3.21

In the `deposit` method, what is the meaning of `this.amount`? Or, if the expression has no meaning, why not?

Self Check 3.22

How many implicit and explicit parameters does the `main` method of the `BankAccountTester` class have, and what are they called?

Shape Classes

- Good practice: Make a class for each graphical shape

```
public class Car
{
   public Car(int x, int y)
   {
      // Remember position
      . . .
   }
      public void draw(Graphics2D g2)
   {
      // Drawing instructions
      . . .
   }
}
```

Drawing Cars

- Draw two cars: one in top-left corner of window, and another in the bottom right
- Compute bottom right position, inside `paintComponent` method:

```
int x = getWidth() - 60;
int y = getHeight() - 30;
Car car2 = new Car(x, y);
```

- `getWidth` and `getHeight` are applied to object that executes `paintComponent`
- If window is resized `paintComponent` is called and car position recomputed

Continued

Drawing Cars (cont.)

Figure 7
The Car Component Draws Two Car Shapes

Plan Complex Shapes on Graph Paper

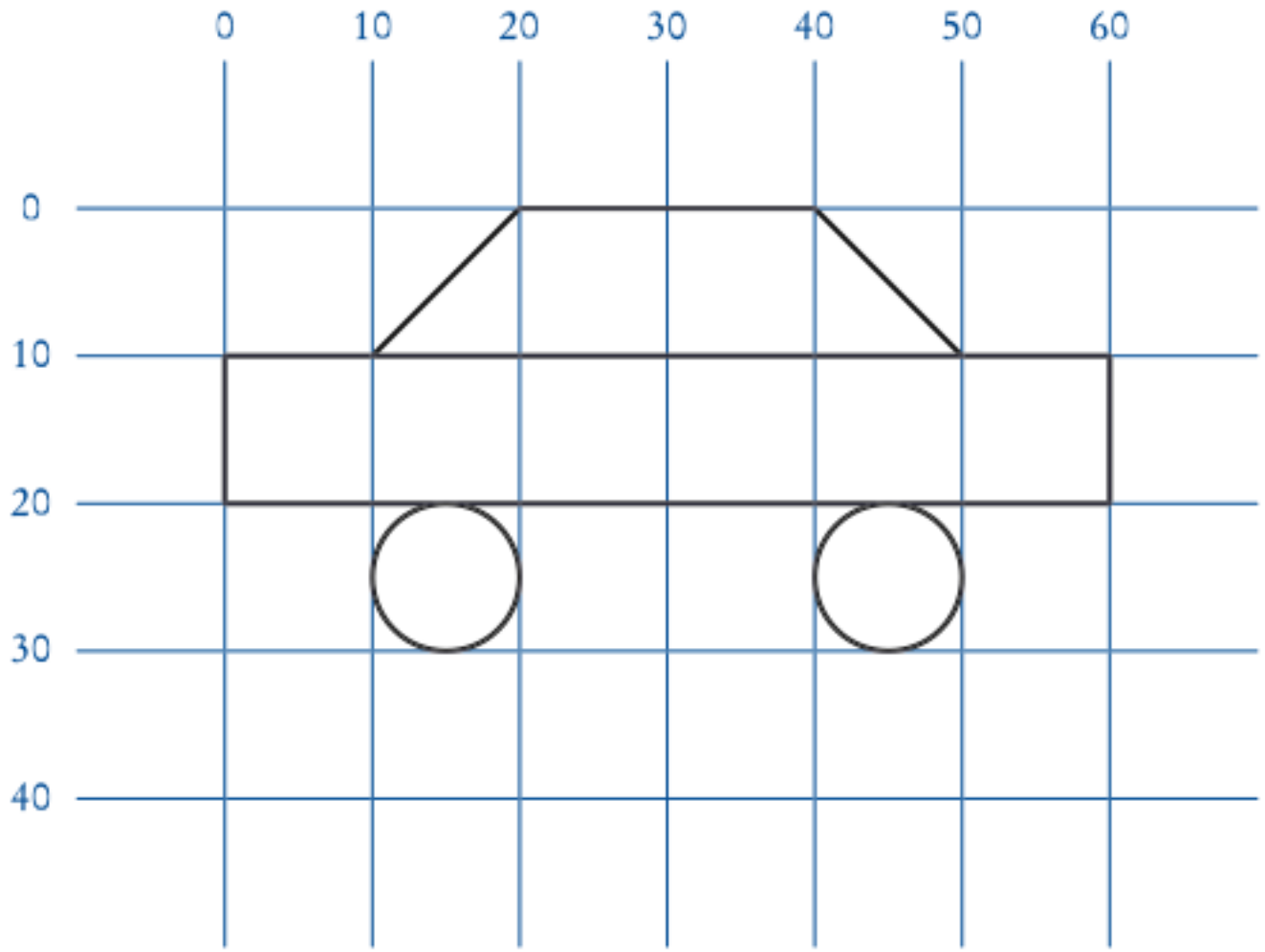


Figure 8 Using Graph Paper to Find Shape Coordinates

Classes of Car Drawing Program

- `Car`: responsible for drawing a single car
  - *Two objects of this class are constructed, one for each car*
- `CarComponent`: displays the drawing
- `CarViewer`: shows a frame that contains a `CarComponent`

ch03/car/Car.java

```
1  import java.awt.Graphics2D;
2  import java.awt.Rectangle;
3  import java.awt.geom.Ellipse2D;
4  import java.awt.geom.Line2D;
5  import java.awt.geom.Point2D;
6
7  /**
8     A car shape that can be positioned anywhere on the screen.
9  */
10 public class Car
11 {
12    private int xLeft;
13    private int yTop;
14
15    /**
16       Constructs a car with a given top left corner.
17       @param x the x coordinate of the top left corner
18       @param y the y coordinate of the top left corner
19    */
20    public Car(int x, int y)
21    {
22       xLeft = x;
23       yTop = y;
24    }
```

Continued

ch03/car/Car.java (cont.)

```
25
26      /**
27         Draws the car.
28         @param g2 the graphics context
29      */
30      public void draw(Graphics2D g2)
31      {
32         Rectangle body
33               = new Rectangle(xLeft, yTop + 10, 60, 10);
34         Ellipse2D.Double frontTire
35               = new Ellipse2D.Double(xLeft + 10, yTop + 20, 10, 10);
36         Ellipse2D.Double rearTire
37               = new Ellipse2D.Double(xLeft + 40, yTop + 20, 10, 10);
38
39         // The bottom of the front windshield
40         Point2D.Double r1
41               = new Point2D.Double(xLeft + 10, yTop + 10);
42         // The front of the roof
43         Point2D.Double r2
44               = new Point2D.Double(xLeft + 20, yTop);
45         // The rear of the roof
46         Point2D.Double r3
47               = new Point2D.Double(xLeft + 40, yTop);
```

Continued

ch03/car/Car.java (cont.)

```
48          // The bottom of the rear windshield
49          Point2D.Double r4
50                = new Point2D.Double(xLeft + 50, yTop + 10);
51
52          Line2D.Double frontWindshield
53                = new Line2D.Double(r1, r2);
54          Line2D.Double roofTop
55                = new Line2D.Double(r2, r3);
56          Line2D.Double rearWindshield
57                = new Line2D.Double(r3, r4);
58
59          g2.draw(body);
60          g2.draw(frontTire);
61          g2.draw(rearTire);
62          g2.draw(frontWindshield);
63          g2.draw(roofTop);
64          g2.draw(rearWindshield);
65       }
66    }
```

ch03/car/CarComponent.java

```
1  import java.awt.Graphics;
2  import java.awt.Graphics2D;
3  import javax.swing.JComponent;
4
5  /**
6     This component draws two car shapes.
7  */
8  public class CarComponent extends JComponent
9  {
10    public void paintComponent(Graphics g)
11    {
12       Graphics2D g2 = (Graphics2D) g;
13
14       Car car1 = new Car(0, 0);
15
16       int x = getWidth() - 60;
17       int y = getHeight() - 30;
18
19       Car car2 = new Car(x, y);
20
21       car1.draw(g2);
22       car2.draw(g2);
23    }
24 }
```

ch03/car/CarViewer.java

```
 1  import javax.swing.JFrame;
 2
 3  public class CarViewer
 4  {
 5     public static void main(String[] args)
 6     {
 7        JFrame frame = new JFrame();
 8
 9        frame.setSize(300, 400);
10        frame.setTitle("Two cars");
11        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
12
13        CarComponent component = new CarComponent();
14        frame.add(component);
15
16        frame.setVisible(true);
17     }
18  }
```

Self Check 3.23

Which class needs to be modified to have the two cars positioned next to each other?

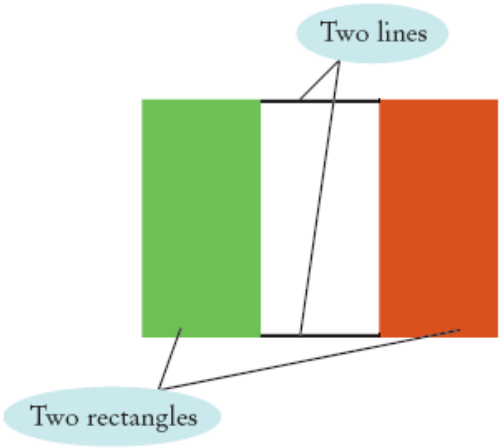
Self Check 3.24

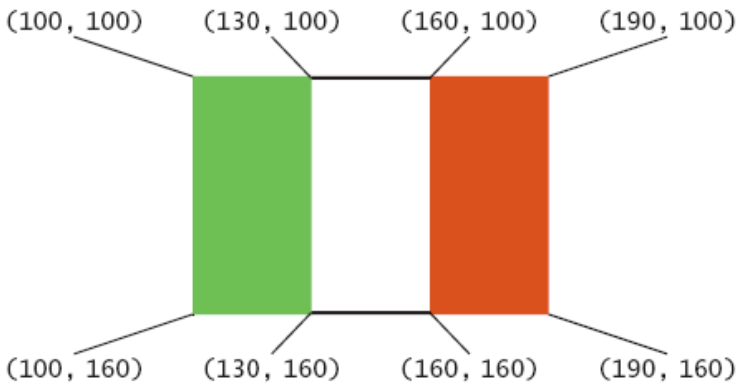
Which class needs to be modified to have the car tires painted in black, and what modification do you need to make?

Self Check 3.25

How do you make the cars twice as big?

Drawing Graphical Shapes






```
Rectangle leftRectangle = new Rectangle(100, 100, 30, 60);
Rectangle rightRectangle = new Rectangle(160, 100, 30, 60);
Line2D.Double topLine = new Line2D.Double(130, 100, 160, 100);
Line2D.Double bottomLine = new Line2D.Double(130, 160, 160, 160);
```