ICOM 4015: Advanced Programming

Lecture 3

Chapter Three: Implementing Classes

Chapter Three: Implementing Classes

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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 fields and local variables
- To appreciate the importance of documentation comments
- To implement classes for drawing graphical shapes

Black Boxes

- A black box magically does its thing
- Hides its inner workings
- Encapsulation: the hiding of unimportant details
- What is the right *concept* for each particular black box?
- Concepts are discovered through abstraction
- Abstraction: taking away inessential features, until only the essence of the concept remains
- In *object-oriented programming* the black boxes from which a program is manufactured are called objects

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Levels of Abstraction: A Real Life Example

- Black boxes in a car: transmission, electronic control module, etc.

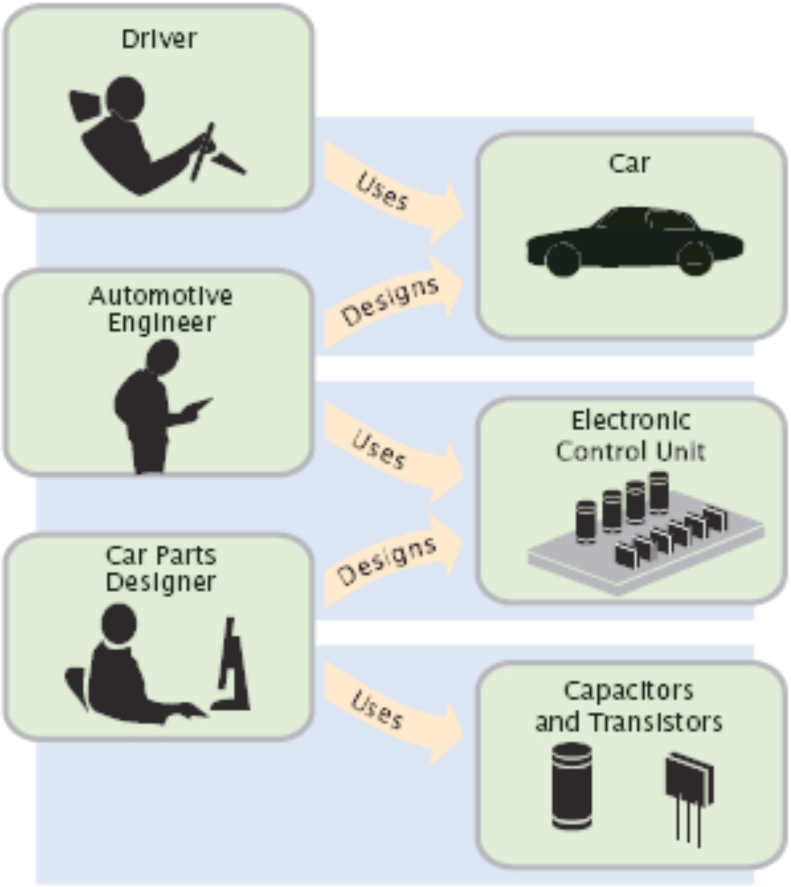

Figure 1

Levels of Abstraction in Automotive Design*ava* by Cay Horstmann

Levels of Abstraction: A Real Life Example

- Users of a car do not need to understand how black boxes work
- Interaction of a black box with outside world is well-defined
  - *Drivers interact with car using pedals, buttons, etc.*
  - *Mechanic can test that engine control module sends the right firing signals to the spark plugs*
  - *For engine control module manufacturers, transistors and capacitors are black boxes magically produced by an electronics component manufacturer*
- Encapsulation leads to efficiency:
  - *Mechanic deals only with car components (e.g. electronic control module), not with sensors and transistors*
  - *Driver worries only about interaction with car (e.g. putting gas in the tank), not about motor or electronic control module*

Levels of Abstraction: Software Design

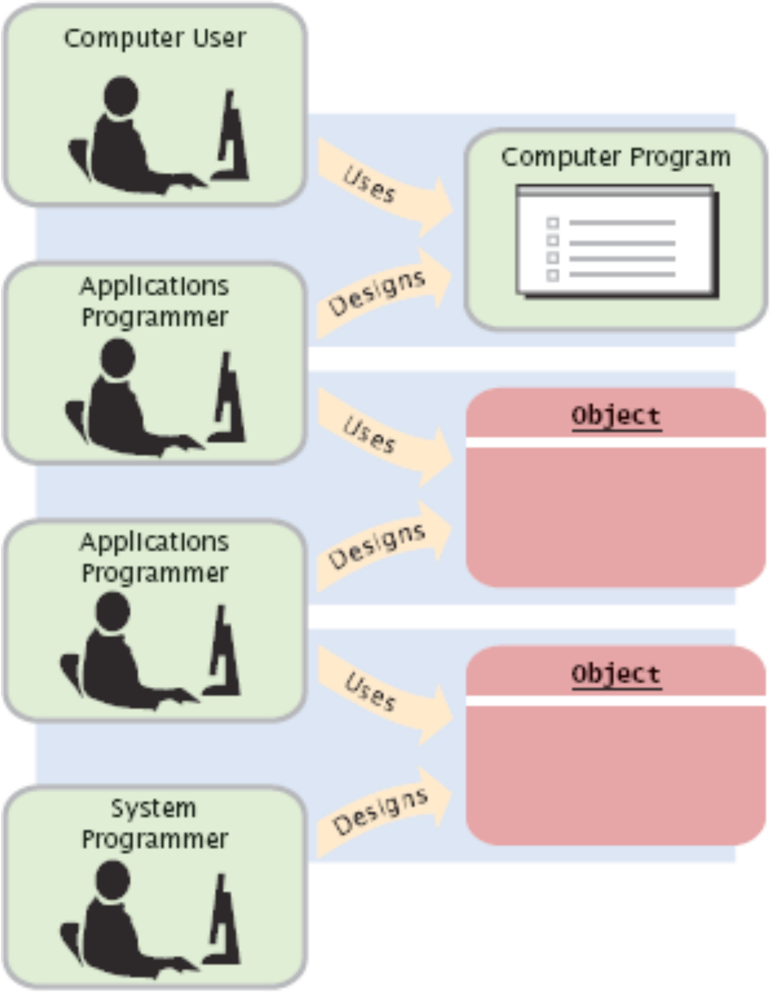

Figure 2

Levels of Abstraction in Software Design

Levels of abstraction: Software Design

- Old times: computer programs manipulated primitive types such as numbers and characters
- Manipulating too many of these primitive quantities is too much for programmers and leads to errors
- Solution: Encapsulate routine computations to software black boxes
- Abstraction used to invent higher-level data types
- In object-oriented programming, objects are black boxes
- Encapsulation: Programmer using an object knows about its behavior, but not about its internal structure

Continued

Levels of abstraction: Software Design (cont.)

- In software design, you can design good and bad abstractions with equal facility; understanding what makes good design is an important part of the education of a software engineer
- First, define behavior of a class; then, implement it

Self Check 3.1

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`?

Answer: The programmers who designed and implemented the Java library.

Self Check 3.2

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?

> **Answer:** Other programmers who work on the personal finance application.

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 Definition

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() { . . . }`

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Syntax 3.1 Method Definition

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

Example:

```
public void deposit(double amount)
{
   . . .
}
```

Purpose:

To define the behavior of a method.

Specifying the Public Interface of a Class: Constructor Definition

- A constructor initializes the instance fields
- 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

Syntax 3.2 Constructor Definition

```
accessSpecifier ClassName(parameterType parameterName, . . .)
{
   constructor body
}
```

Example:

```
public BankAccount(double initialBalance)
{
   . . .
}
```

Purpose:

To define the behavior of a constructor.

`BankAccount` Public Interface

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

```
public class BankAccount
{
   // 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
    }
    // private fields--filled in later
}
```

Syntax 3.3 Class Definition

```
accessSpecifier class ClassName
{
   constructors
   methods
   fields
}
```

Example:

```
public class BankAccount
{
   public BankAccount(double initialBalance) {. . .}
   public void deposit(double amount) {. . .}
   . . .
}
```

Purpose:

To define a class, its public interface, and its implementation details.

Self Check 3.3

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

Answer:

```
harrysChecking.withdraw(harrysChecking.getBalance())
```

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Self Check 3.4

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?

Answer: Add an `accountNumber` parameter to the constructors, and add a `getAccountNumber` method. There is no need for a `setAccountNumber` method – the account number never changes after construction.

Commenting the Public Interface

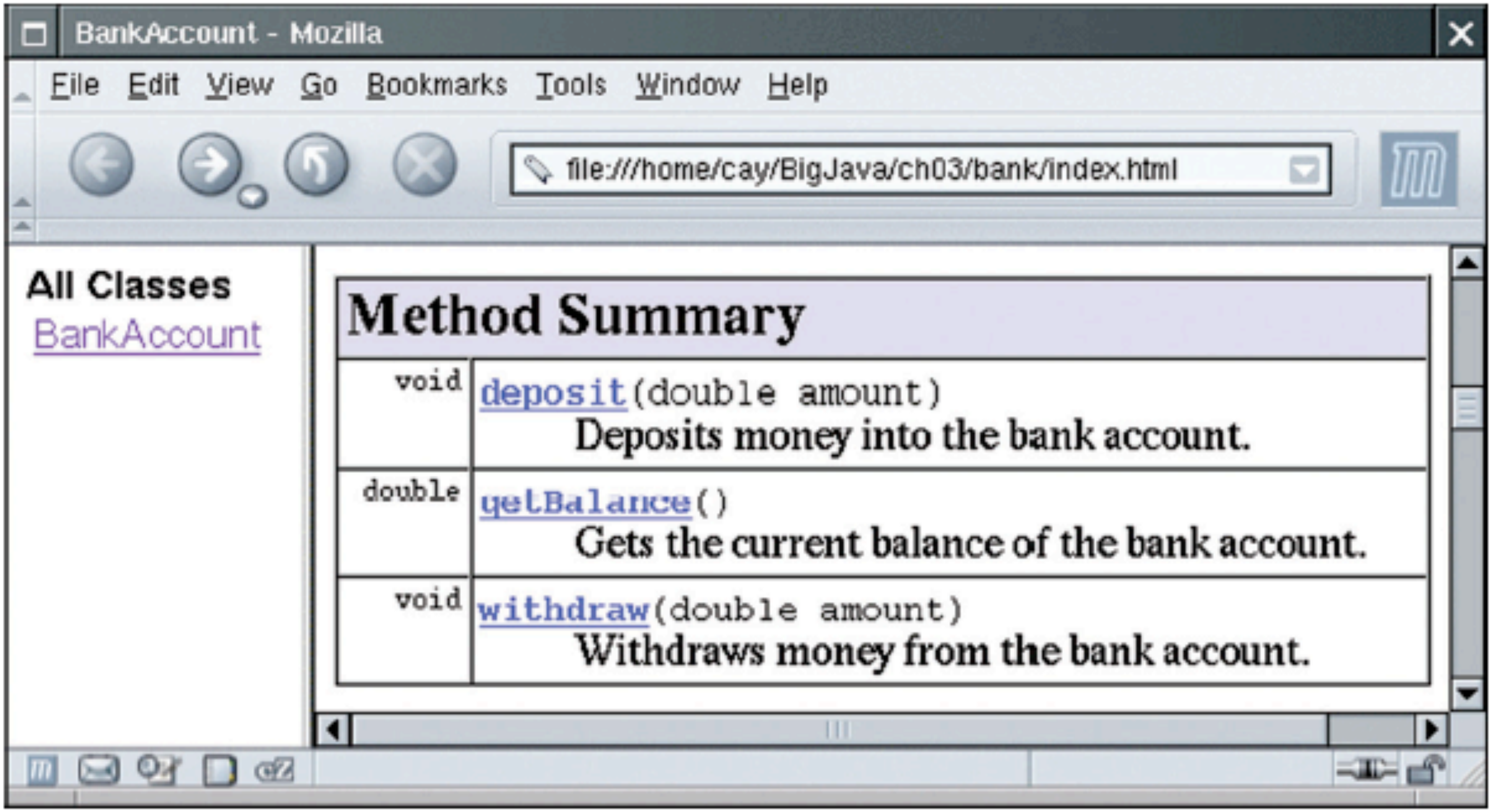
```
/**
   Withdraws money from the bank account.
   @param the amount to withdraw
*/
public void withdraw(double amount)
{
   //implementation filled in later
}
/**
   Gets the current balance of the bank account.
   @return the current balance
*/
public double getBalance()
{
   //implementation filled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

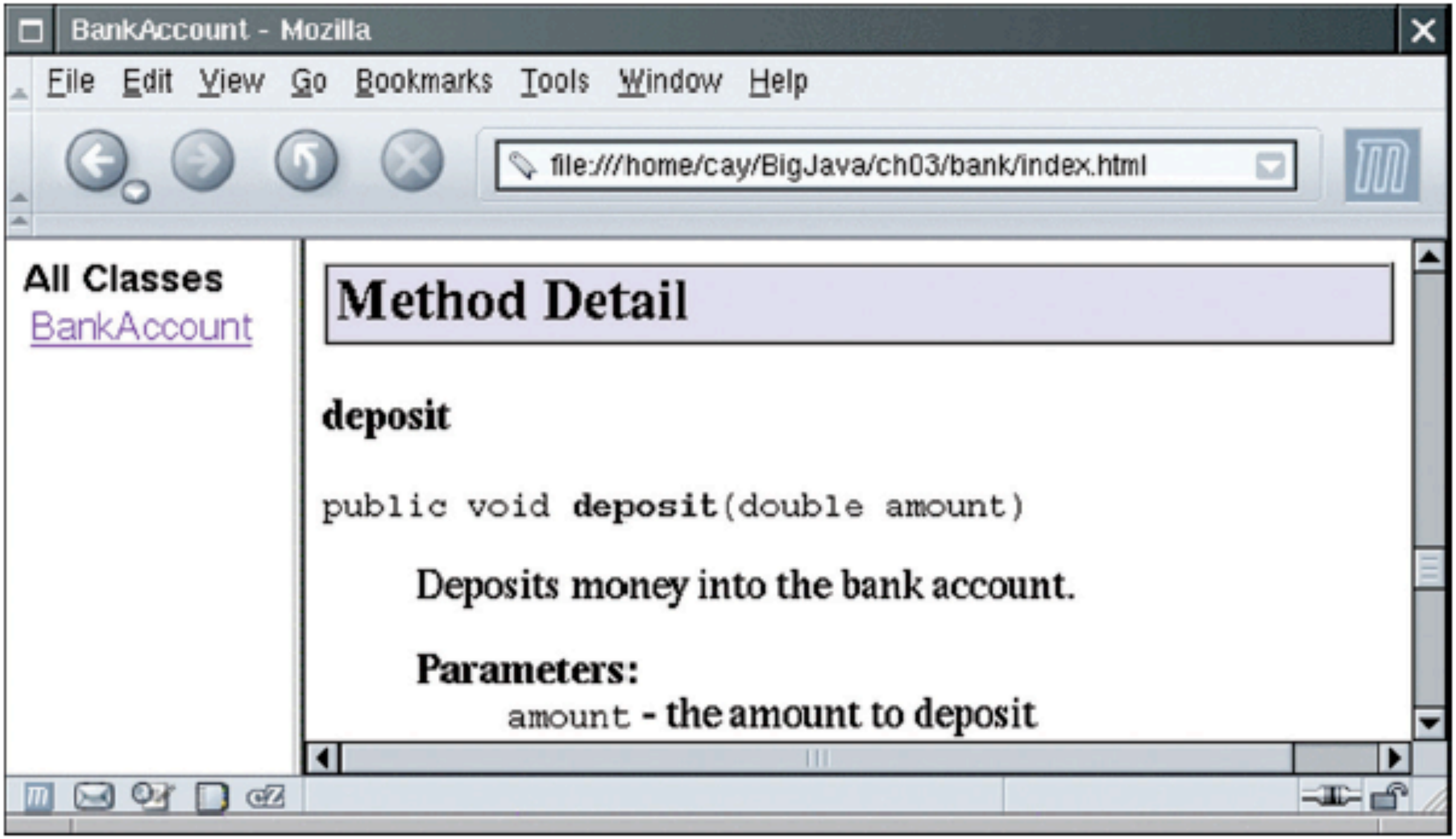

BankAccount - Mozilla
File Edit View Go Bookmarks Tools Window Help
file:///home/cay/BigJava/ch03/bank/index.html
All Classes
BankAccount

Method Summary

`void`	`deposit(double amount)` Deposits money into the bank account.
`double`	`getBalance()` Gets the current balance of the bank account.
`void`	`withdraw(double amount)` Withdraws money from the bank account.

Figure 3 A Method Summary Generated by javadoc

Javadoc Method Detail


BankAccount - Mozilla
File Edit View Go Bookmarks Tools Window Help
file:///home/cay/BigJava/ch03/bank/index.html

All Classes

BankAccount

Method Detail

deposit

```
public void deposit(double amount)
```

Deposits money into the bank account.

Parameters:

`amount` - the amount to deposit

Figure 4 Method Detail Generated by javadoc

Self Check 3.5

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)
```

Answer:

```
/**
 Constructs a new bank account with a given initial
 balance.
 @param accountNumber the account number for
 this account
 @param initialBalance the initial balance
 for this account
 */
```

Self Check 3.6

Why is the following documentation comment questionable?

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

Answer: The first sentence of the method description should describe the method – it is displayed in isolation in the summary table.

Instance Fields

- An object stores its data in instance fields
- Field: a technical term for a storage location inside a block of memory
- Instance of a class: an object of the class
- The class declaration specifies the instance fields

```
public class BankAccount
{
   . . .
   private double balance;
}
```

Instance Fields

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

Instance Fields

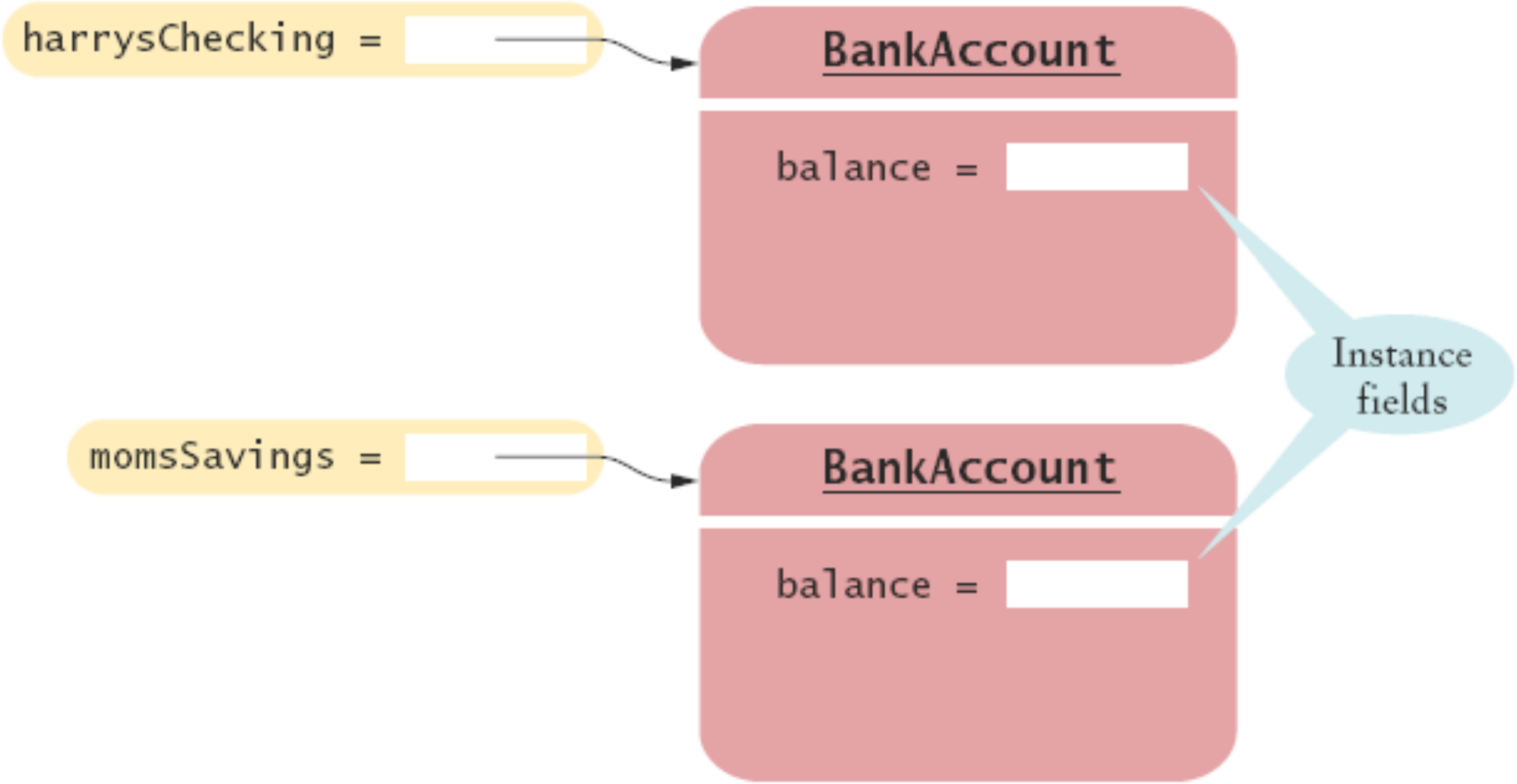


Figure 5 Instance Fields

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Syntax 3.4 Instance Field Declaration

```
accessSpecifier class ClassName
{
   . . .
   accessSpecifier fieldType fieldName;
   . . .
}
```

Example:

```
public class BankAccount
{
   . . .
   private double balance;
   . . .
}
```

Purpose:

To define a field that is present in every object of a class.

Accessing Instance Fields

- The `deposit` method of the BankAccount class can access the private instance field:

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

Continued

Accessing Instance Fields (cont.)

- Other methods cannot:

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

- *Encapsulation* is the process of hiding object data and providing methods for data access
- To encapsulate data, declare instance fields as `private` and define public methods that access the fields

Self Check 3.7

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

Answer: An instance field

```
private int accountNumber;
```

needs to be added to the class.

Self Check 3.8

What are the instance fields of the `Rectangle` class?

Answer: There are four fields, `x`, `y`, `width` and `height`. All four fields have type `int`.

Implementing Constructors

- Constructors contain instructions to initialize the instance fields of an object

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

Constructor Call Example

- `BankAccount harrysChecking = new BankAccount(1000);`
  - *Create a new object of type `BankAccount`*
  - *Call the second constructor (since a construction parameter is supplied)*
  - *Set the parameter variable `initialBalance` to `1000`*
  - *Set the `balance` instance field 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*

Implementing Methods

- Some methods do not return a value

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

- Some methods return an output value

```
public double getBalance()
{
   return balance;
}
```

Method Call Example

- `harrysChecking.deposit(500);`
  - *Set the parameter variable `amount` to 500*
  - *Fetch the `balance` field of the object whose location is stored in `harrysChecking`*
  - *Add the value of amount to `balance` and store the result in the variable `newBalance`*
  - *Store the value of `newBalance` in the `balance` instance field, overwriting the old value*

Syntax 3.5 The `return` Statement

```
return expression;
```

or

```
return;
```

Example:

```
return balance;
```

Purpose:

To specify the value that a method returns, and exit the method immediately. The return value becomes the value of the method call expression.

ch03/account/BankAccount.java

```java
/**
   A bank account has a balance that can be changed by
   deposits and withdrawals.
*/
public class BankAccount
{
   /**
      Constructs a bank account with a zero balance.
   */
   public BankAccount()
   {
      balance = 0;
   }

   /**
      Constructs a bank account with a given balance.
      @param initialBalance the initial balance
   */
   public BankAccount(double initialBalance)
   {
      balance = initialBalance;
   }

```

Continued

ch03/account/BankAccount.java (cont.)

```java
   /**
      Deposits money into the bank account.
      @param amount the amount to deposit
   */
   public void deposit(double amount)
   {
      double newBalance = balance + amount;
      balance = newBalance;
   }

   /**
      Withdraws money from the bank account.
      @param amount the amount to withdraw
   */
   public void withdraw(double amount)
   {
      double newBalance = balance - amount;
      balance = newBalance;
   }

   /**
      Gets the current balance of the bank account.
      @return the current balance
   */
```

Continued

ch03/account/BankAccount.java (cont.)

```java
   public double getBalance()
   {
      return balance;
   }

   private double balance;
}
```

Self Check 3.9

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

Answer:

```
public int getWidth()
 {
    return width;
 }
```

Self Check 3.10

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

Answer: There is more than one correct answer. One possible implementation is as follows:

```
public void translate(int dx, int dy)
{
   int newx = x + dx;
   x = newx;
   int newy = y + dy;
   y = newy;
}
```

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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.
- *Test 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*

Continued

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*

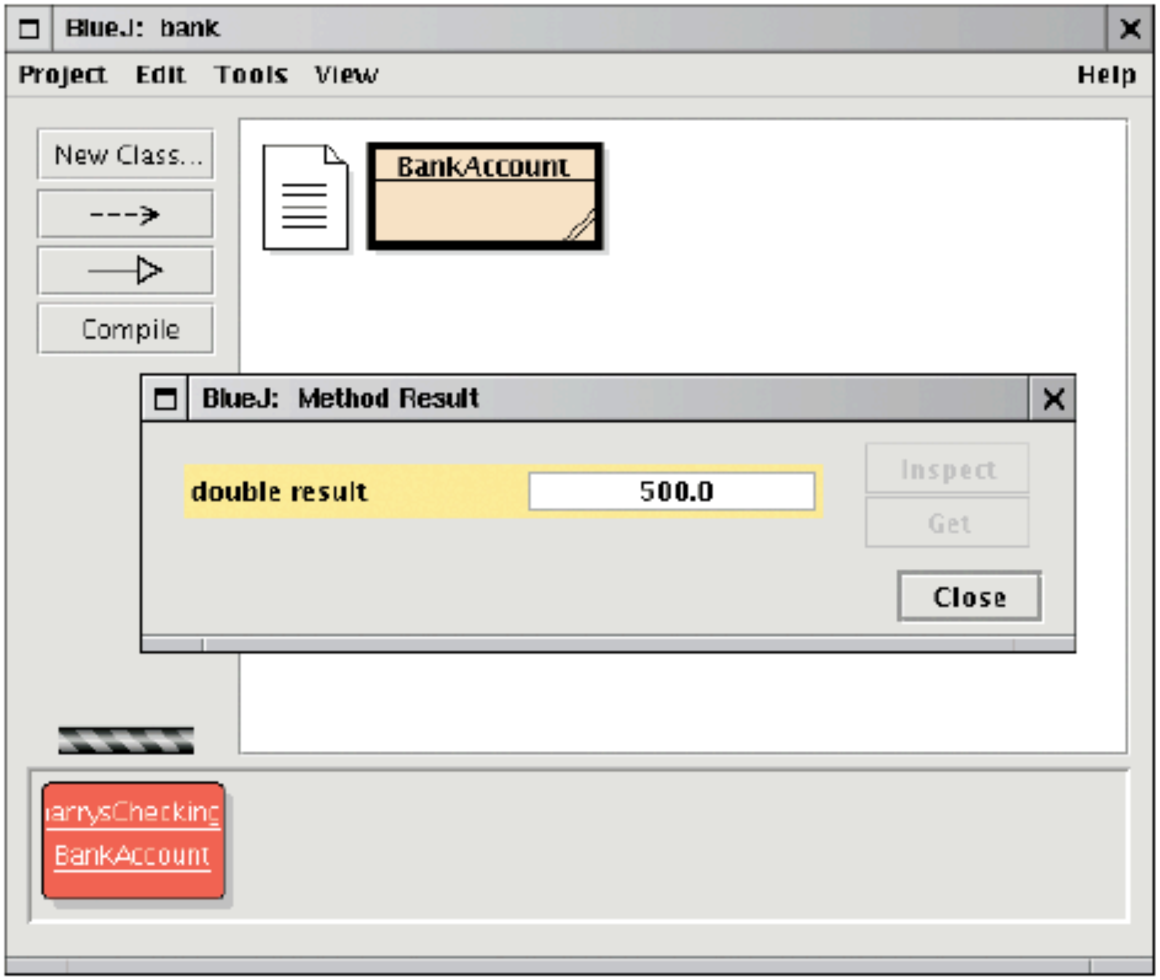
ch03/account/BankAccountTester.java

```java
/**
   A class to test the BankAccount class.
*/
public class BankAccountTester
{
   /**
      Tests the methods of the BankAccount class.
      @param args not used
   */
   public static void main(String[] args)
   {
      BankAccount harrysChecking = new BankAccount();
      harrysChecking.deposit(2000);
      harrysChecking.withdraw(500);
      System.out.println(harrysChecking.getBalance());
      System.out.println("Expected: 1500");
   }
}
```

Output:

```
1500
Expected: 1500
```

Testing With BlueJ



double result 500.0

Figure 6
The Return Value of the getBalance Method in BlueJ

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Self Check 3.11

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

> **Answer:** One `BankAccount` object, no `BankAccountTester` object. The purpose of the `BankAccountTester` class is merely to hold the main method.

Self Check 3.12

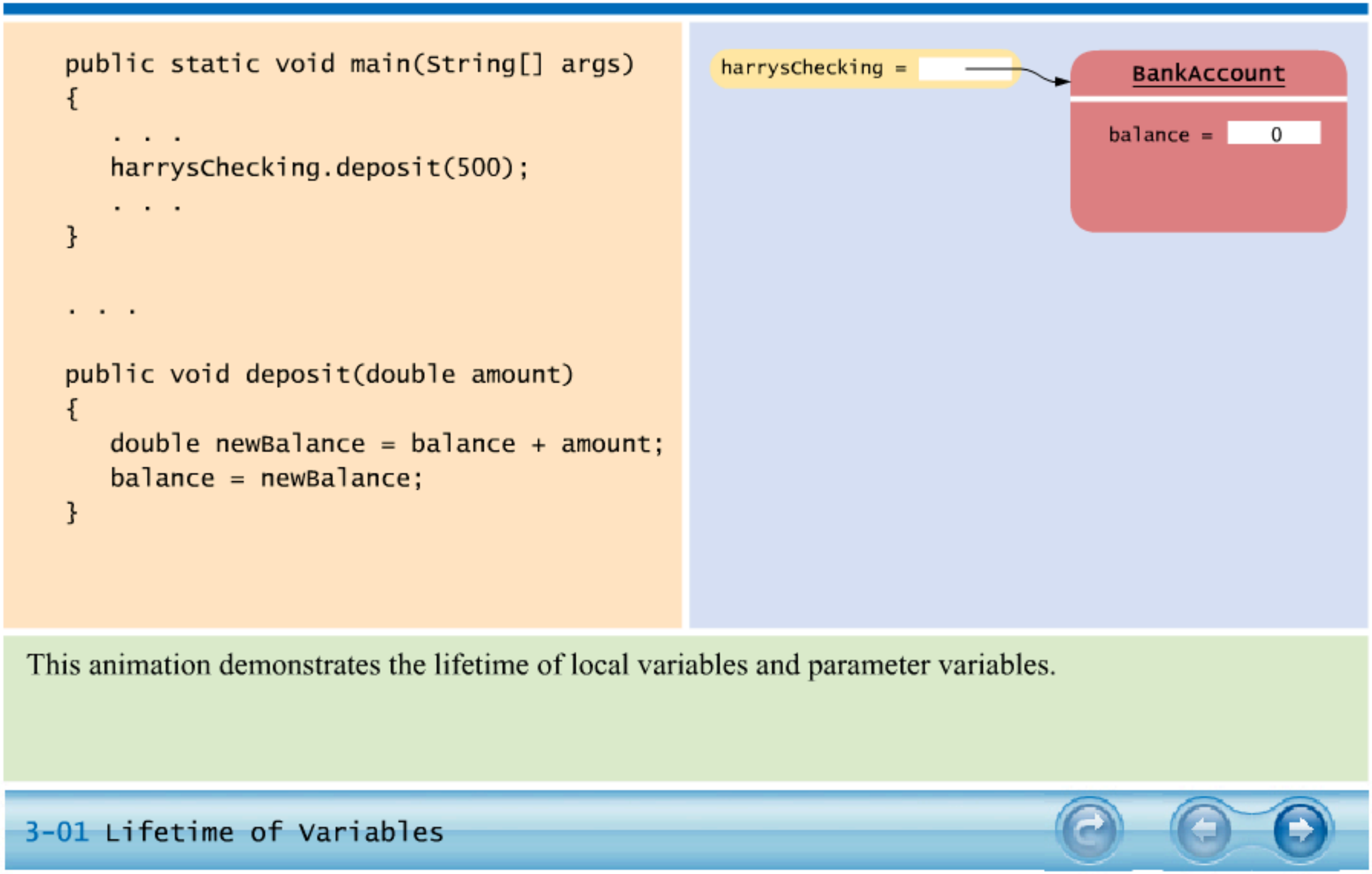
Why is the `BankAccountTester` class unnecessary in development environments that allow interactive testing, such as BlueJ?

> **Answer:** In those environments, you can issue interactive commands to construct `BankAccount` objects, invoke methods, and display their return values.

Categories of Variables

- Categories of variables
  1. *Instance fields (balance in* `BankAccount`*)*
  2. *Local variables (*`newBalance` *in* `deposit` *method)*
  3. *Parameter variables (*`amount` *in* `deposit` *method)*
- An `instance` field belongs to an object
- The fields stay alive until no method uses the object any longer
- In Java, the *garbage collector* periodically reclaims objects when they are no longer used
- Local and parameter variables belong to a method
- Instance fields are initialized to a default value, but you must initialize local variables

Animation 3.1 –

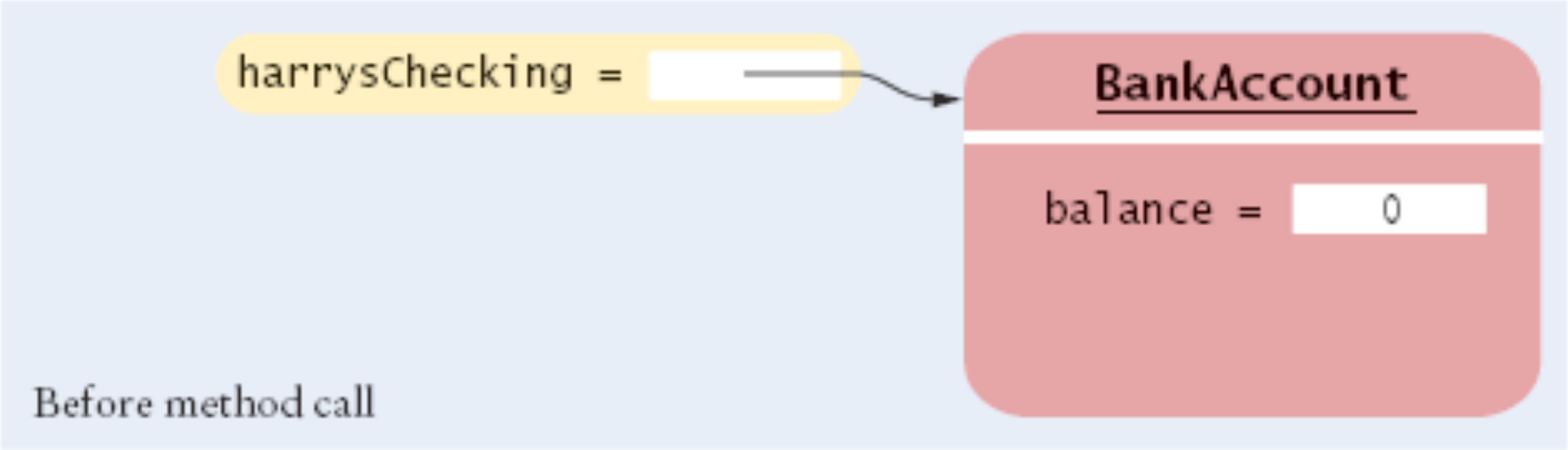


```
public static void main(String[] args)
{
   . . .
   harrysChecking.deposit(500);
   . . .
}

. . .

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

This animation demonstrates the lifetime of local variables and parameter variables.

Lifetime of Variables – Calling Method `deposit`

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



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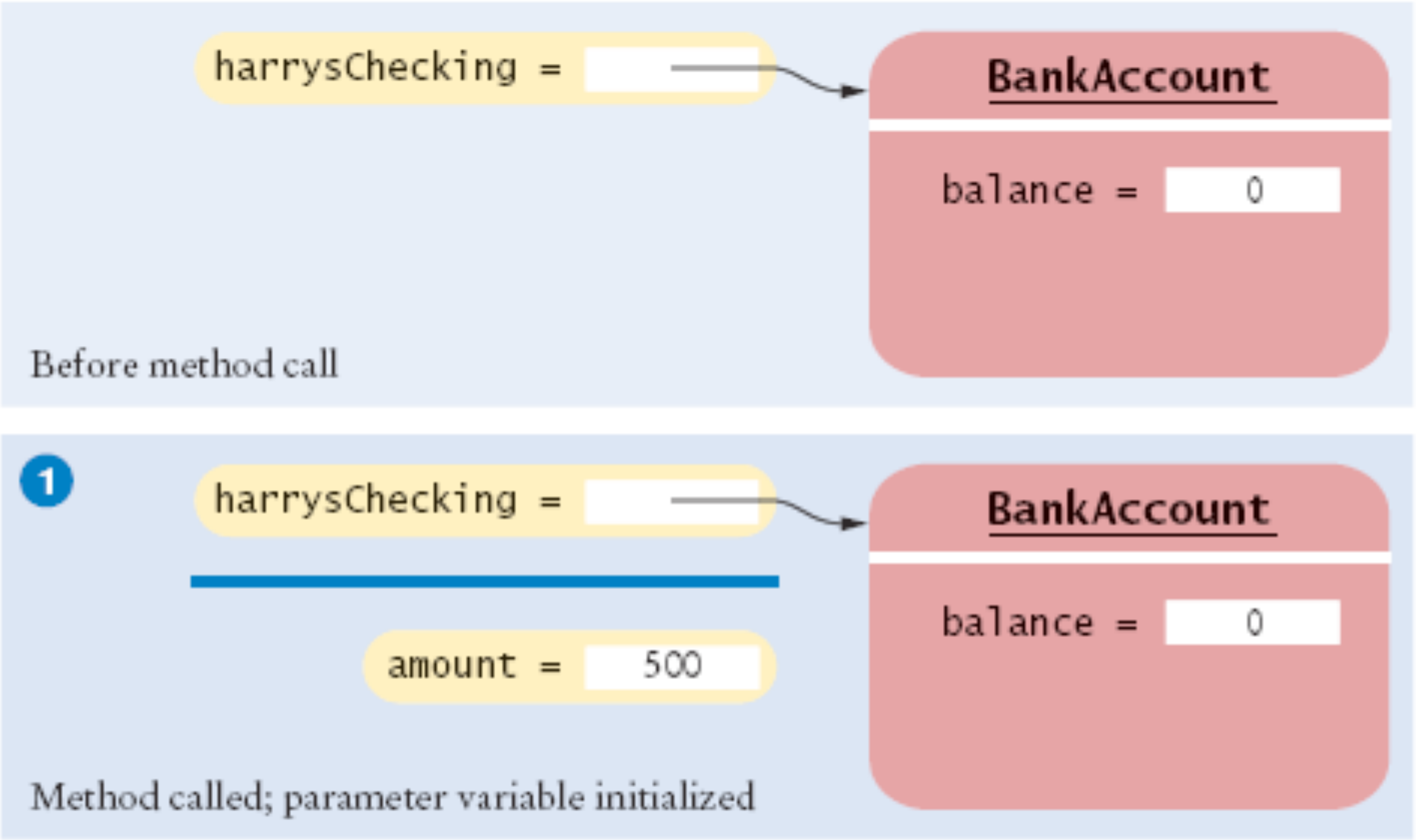
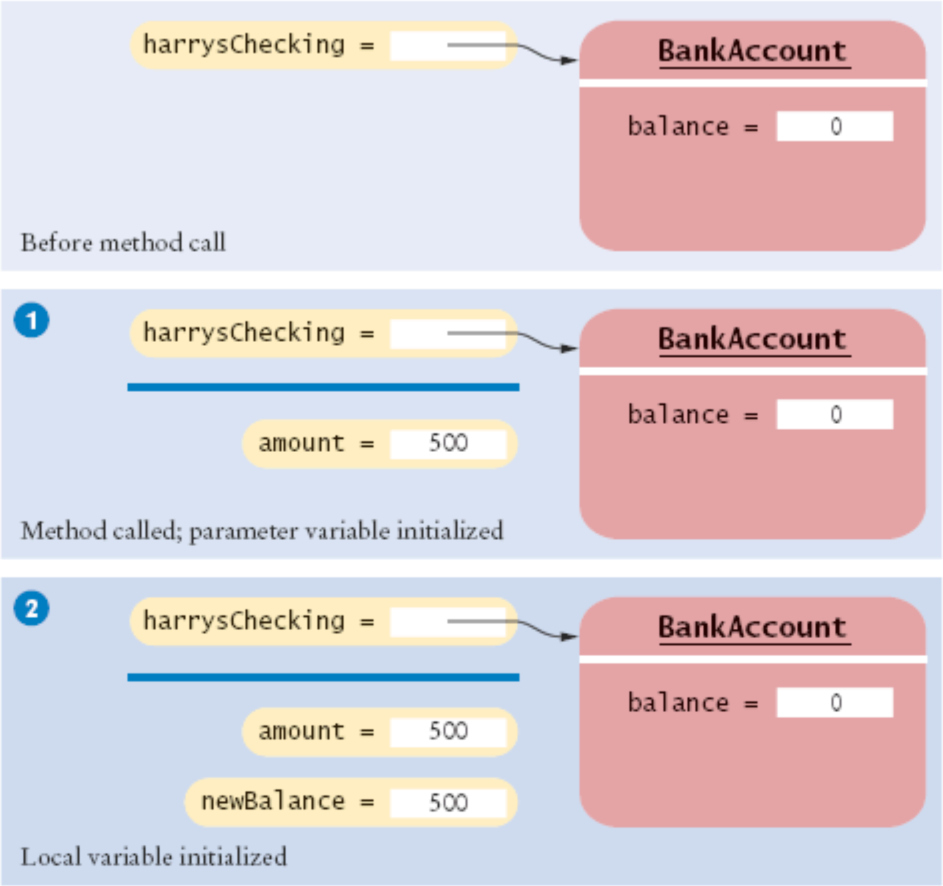
Lifetime of Variables – Calling Method `deposit`

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



Lifetime of Variables – Calling Method `deposit`

```
harrysChecking.deposit(500);  1
double newBalance = balance + amount;  2
```



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Lifetime of Variables – Calling Method `deposit`

```
harrysChecking.deposit(500); ❶
double newBalance = balance + amount; ❷
balance = newBalance; ❸
```

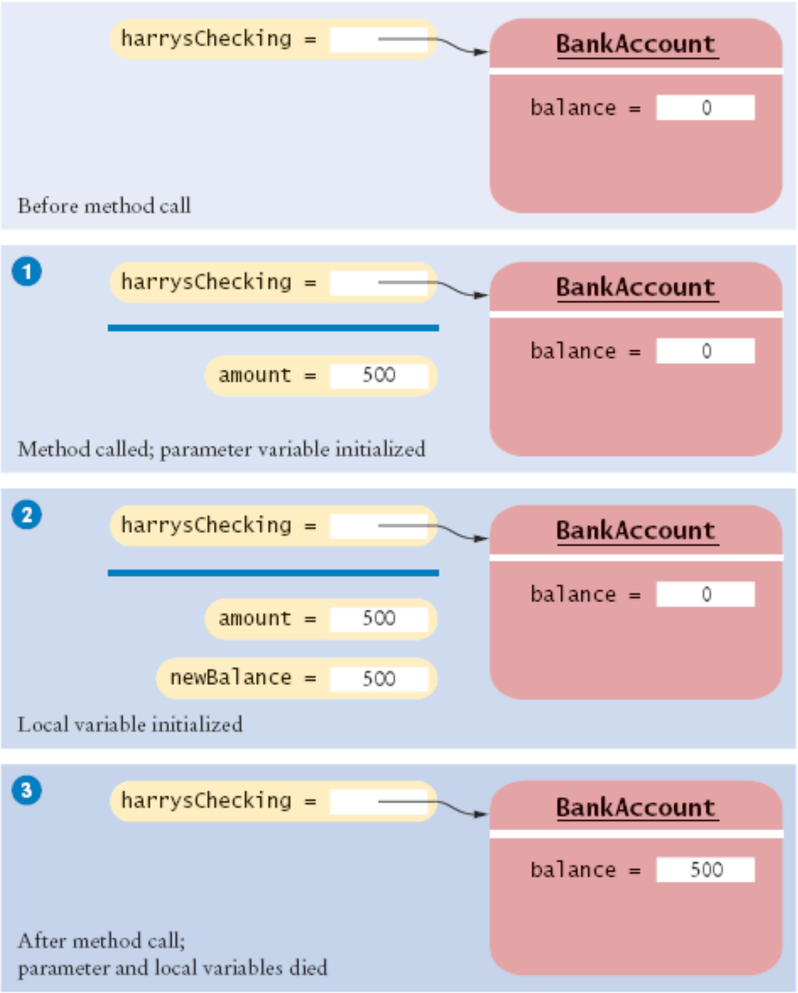

Figure 7 Lifetime of Variables

Self Check 3.13

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

Answer: Variables of both categories belong to methods – they come alive when the method is called, and they die when the method exits. They differ in their initialization. Parameter variables are initialized with the call values; local variables must be explicitly initialized.

Self Check 3.14

During execution of the `BankAccountTester` program in the preceding section, how many instance fields, local variables, and parameter variables were created, and what were their names?

Answer: One instance field, named `balance`. Three local variables, one named `harrysChecking` and two named `newBalance` (in the `deposit` and `withdraw` methods); two parameter variables, both named `amount` (in the `deposit` and `withdraw` methods).

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Implicit and Explicit Method Parameters

- The implicit parameter of a method is the object on which the method is invoked
- The `this` reference denotes the implicit parameter
- Use of an instance field name in a method denotes the instance field of the implicit parameter

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

Continued

Implicit and Explicit Method Parameters (cont.)

- `balance` is the balance of the object to the left of the dot:

  ```
  momsSavings.withdraw(500)
  ```

  means

  ```
  double newBalance = momsSavings.balance - amount;
  >momsSavings.balance = newBalance;
  ```

Implicit Parameters and `this`

- Every method has one implicit parameter
- The implicit parameter is always called `this`
- Exception: Static methods do not have an implicit parameter (more on Chapter 8)
-
  ```
  double newBalance = balance + amount;
  // actually means
  double newBalance = this.balance + amount;
  ```
- When you refer to an instance field in a method, the compiler automatically applies it to the `this` parameter

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

Implicit Parameters and `this`

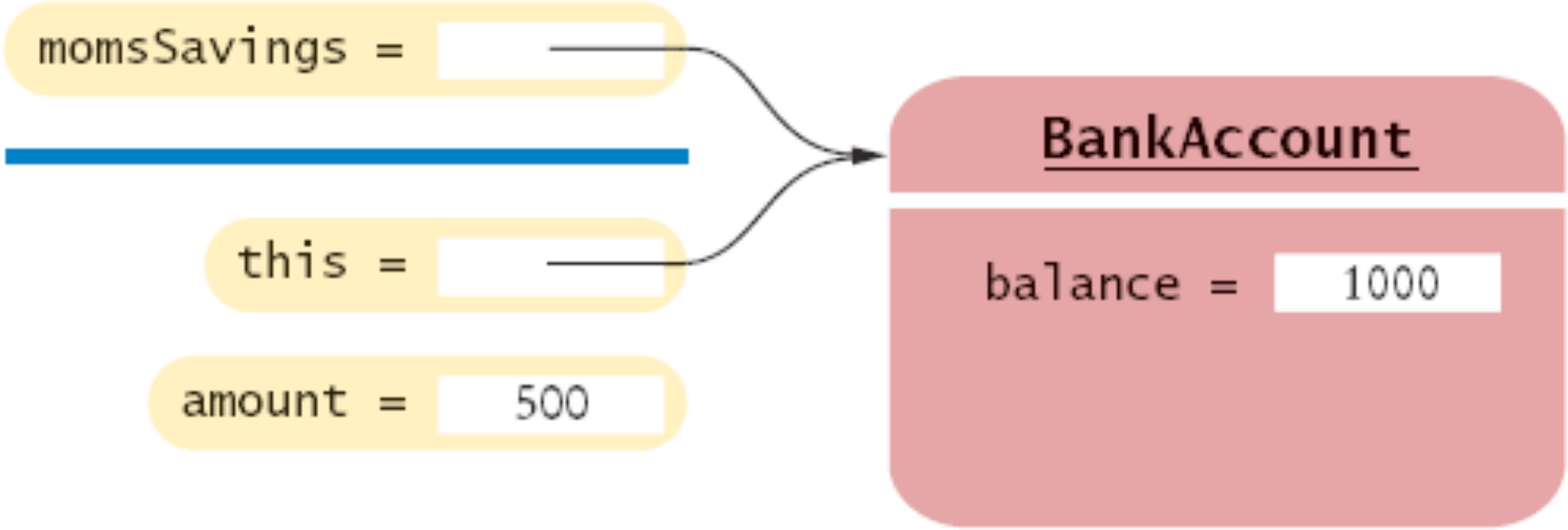

Figure 8 The Implicit Parameter of a Method Call

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Self Check 3.15

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

> **Answer:** One implicit parameter, called `this`, of type `BankAccount`, and one explicit parameter, called `amount`, of type `double`.

Self Check 3.16

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

Answer: It is not a legal expression. `this` is of type `BankAccount` and the `BankAccount` class has no field named `amount`.

Self Check 3.17

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

> **Answer:** No implicit parameter–the method is static–and one explicit parameter, called `args`.

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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.)

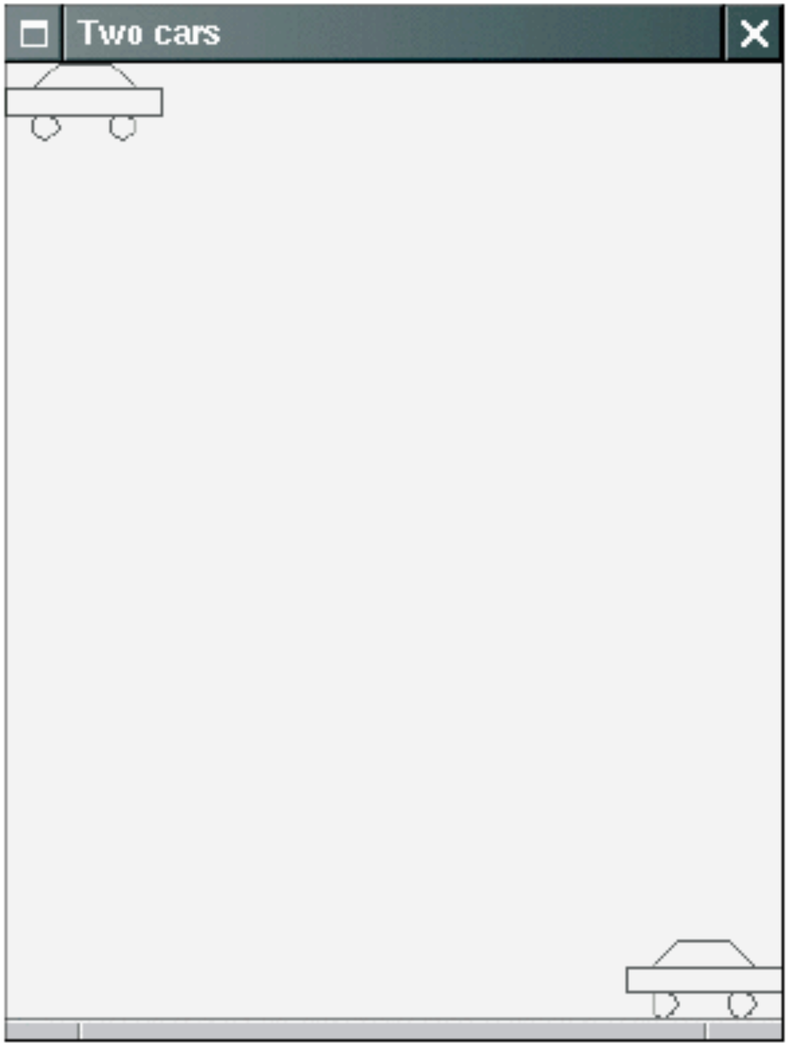

Figure 9
The Car Component Draws Two Car Shapes

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Plan Complex Shapes on Graph Paper

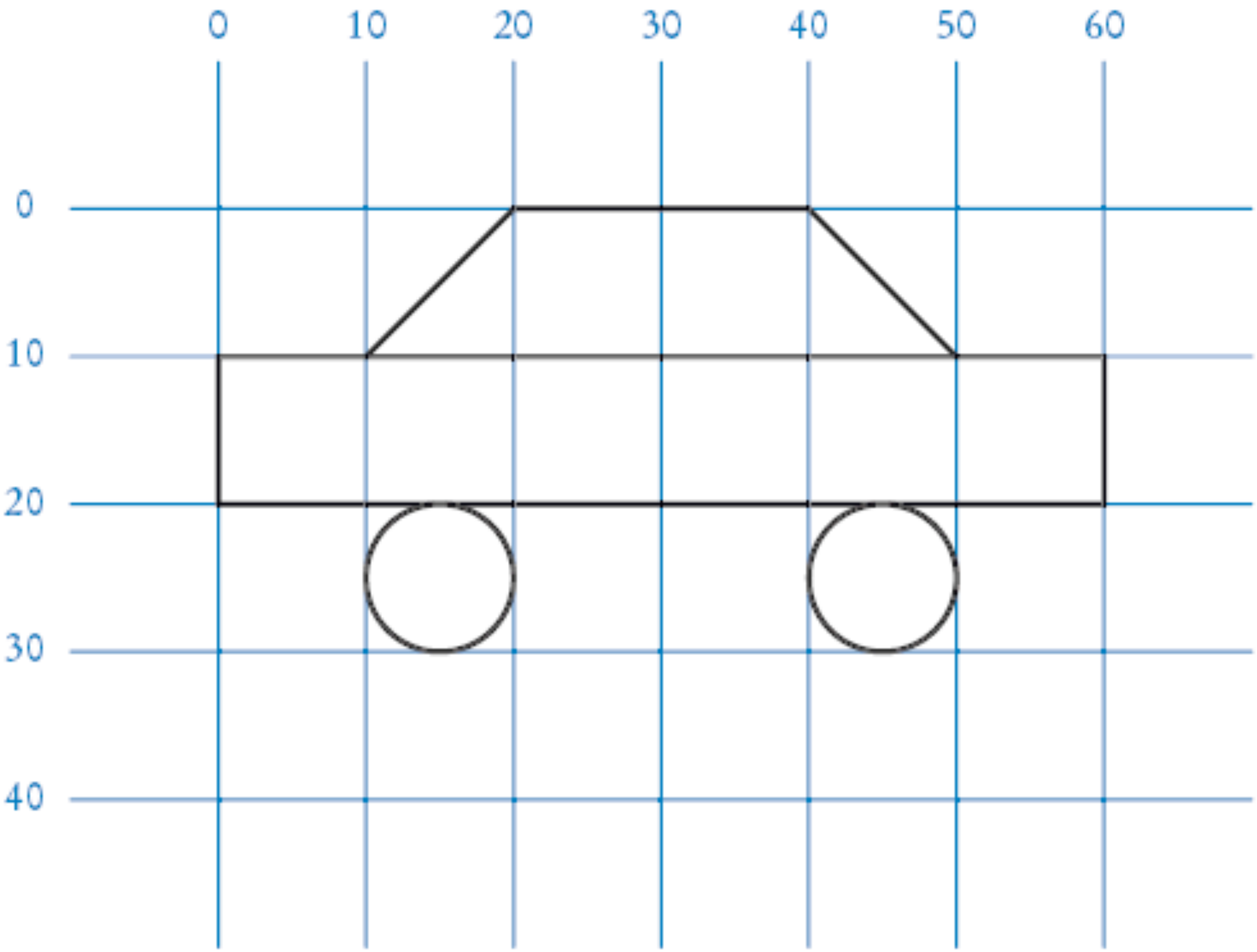

Figure 10 Using Graph Paper to Find Shape Coordinates

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

```java
import java.awt.Graphics2D;
import java.awt.Rectangle;
import java.awt.geom.Ellipse2D;
import java.awt.geom.Line2D;
import java.awt.geom.Point2D;

/**
   A car shape that can be positioned anywhere on the screen.
*/
public class Car
{
   /**
      Constructs a car with a given top left corner
      @param x the x coordinate of the top left corner
      @param y the y coordinate of the top left corner
   */
   public Car(int x, int y)
   {
      xLeft = x;
      yTop = y;
   }

```

Continued

ch03/car/Car.java (cont.)

```java
   /**
      Draws the car.
      @param g2 the graphics context
   */
   public void draw(Graphics2D g2)
   {
      Rectangle body
            = new Rectangle(xLeft, yTop + 10, 60, 10);
      Ellipse2D.Double frontTire
            = new Ellipse2D.Double(xLeft + 10, yTop + 20, 10, 10);
      Ellipse2D.Double rearTire
            = new Ellipse2D.Double(xLeft + 40, yTop + 20, 10, 10);

      // The bottom of the front windshield
      Point2D.Double r1
            = new Point2D.Double(xLeft + 10, yTop + 10);
      // The front of the roof
      Point2D.Double r2
            = new Point2D.Double(xLeft + 20, yTop);
      // The rear of the roof
      Point2D.Double r3
            = new Point2D.Double(xLeft + 40, yTop);
      // The bottom of the rear windshield
```

Continued

ch03/car/Car.java (cont.)

```
      Point2D.Double r4
            = new Point2D.Double(xLeft + 50, yTop + 10);

      Line2D.Double frontWindshield
            = new Line2D.Double(r1, r2);
      Line2D.Double roofTop
            = new Line2D.Double(r2, r3);
      Line2D.Double rearWindshield
            = new Line2D.Double(r3, r4);

      g2.draw(body);
      g2.draw(frontTire);
      g2.draw(rearTire);
      g2.draw(frontWindshield);
      g2.draw(roofTop);
      g2.draw(rearWindshield);
   }

   private int xLeft;
   private int yTop;
}
```

ch03/car/CarComponent.java

```java
import java.awt.Graphics;
import java.awt.Graphics2D;
import javax.swing.JComponent;

/**
   This component draws two car shapes.
*/
public class CarComponent extends JComponent
{
   public void paintComponent(Graphics g)
   {
      Graphics2D g2 = (Graphics2D) g;

      Car car1 = new Car(0, 0);

      int x = getWidth() - 60;
      int y = getHeight() - 30;

      Car car2 = new Car(x, y);

      car1.draw(g2);
      car2.draw(g2);
   }
}
```

ch03/car/CarViewer.java

```java
import javax.swing.JFrame;

public class CarViewer
{
   public static void main(String[] args)
   {
      JFrame frame = new JFrame();

      frame.setSize(300, 400);
      frame.setTitle("Two cars");
      frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

      CarComponent component = new CarComponent();
      frame.add(component);

      frame.setVisible(true);
   }
}
```

Self Check 3.18

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

Answer: `CarComponent`

Self Check 3.19

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

Answer: In the `draw` method of the `Car` class, call

```
g2.fill(frontTire);
g2.fill(rearTire);
```

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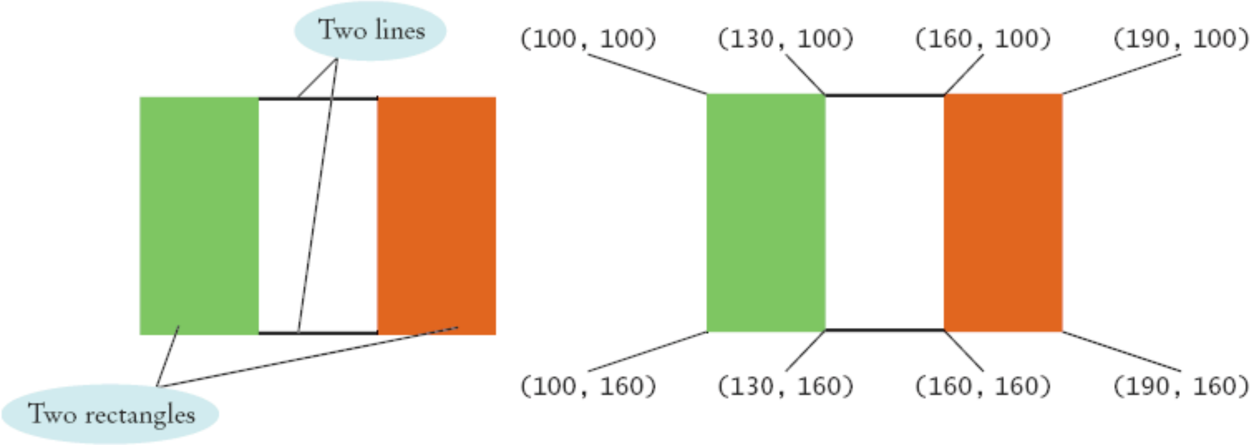
Self Check 3.20

How do you make the cars twice as big?

Answer: Double all measurements in the `draw` method of the `Car` class.

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);
```

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