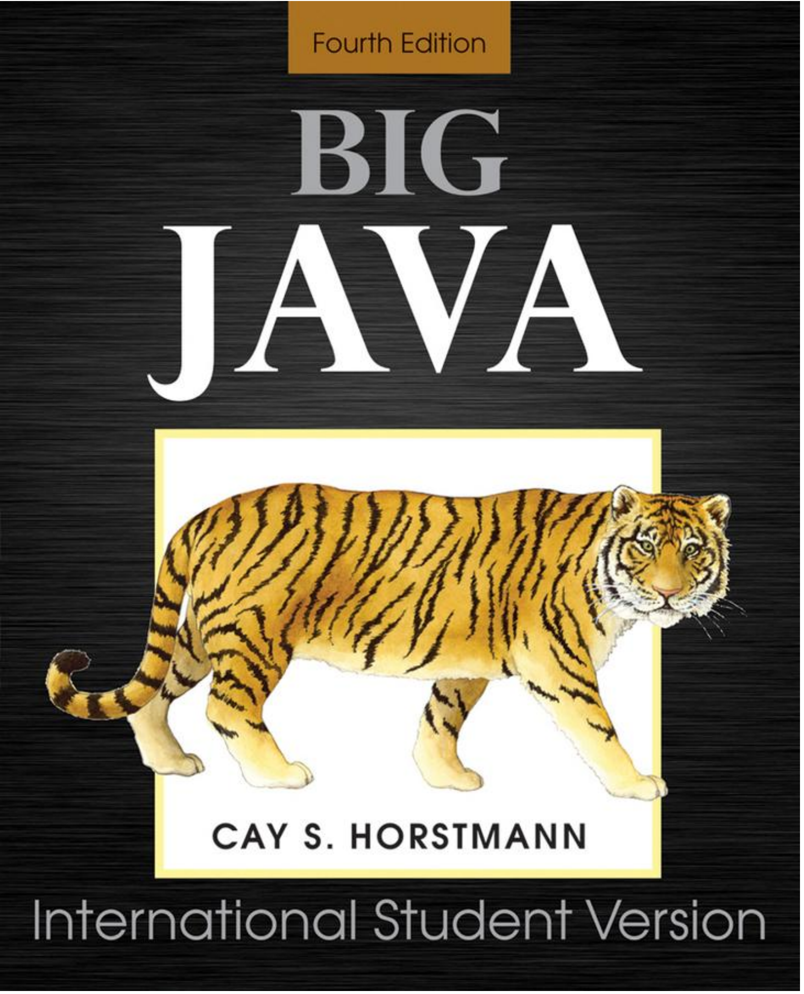

Chapter 7 – Designing Classes

Chapter Goals

- To learn how to discover appropriate classes for a given problem
- To understand the concepts of cohesion and coupling
- To minimize the use of side effects
- To document the responsibilities of methods and their callers with preconditions and postconditions
- To understand static methods and variables
- To understand the scope rules for local variables and instance variables
- To learn about packages

T To learn about unit testing frameworks

Discovering Classes

- A class represents a single concept from the problem domain
- Name for a class should be a noun that describes concept
- Concepts from mathematics:

```
Point
Rectangle
Ellipse
```

- Concepts from real life:

```
BankAccount
CashRegister
```

Discovering Classes

- Actors (end in -er, -or) – objects do some kinds of work for you:

```
Scanner
Random // better name: RandomNumberGenerator
```

- Utility classes – no objects, only static methods and constants:

```
Math
```

- Program starters: only have a `main` method
- Don't turn actions into classes
  - *`Paycheck` is a better name than `ComputePaycheck`*

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Self Check 7.1

What is the rule of thumb for finding classes?

Answer: Look for nouns in the problem description.

Self Check 7.2

Your job is to write a program that plays chess. Might `ChessBoard` be an appropriate class? How about `MovePiece`?

Answer: Yes (`ChessBoard`) and no (`MovePiece`).

Cohesion

- A class should represent a single concept
- The public interface of a class is *cohesive* if all of its features are related to the concept that the class represents
- This class lacks cohesion:

```
public class CashRegister
{
   public void enterPayment(int dollars, int quarters,
      int dimes, int nickels, int pennies)
   ...
   public static final double NICKEL_VALUE = 0.05;
   public static final double DIME_VALUE = 0.1;
   public static final double QUARTER_VALUE = 0.25;
   ...
}
```

Cohesion

- `CashRegister`, as described above, involves two concepts: *cash register* and *coin*
- Solution: Make two classes:

```
public class Coin
{
   public Coin(double aValue, String aName) { ... }
   public double getValue() { ... }
   ...
}

public class CashRegister
{
   public void enterPayment(int coinCount, Coin coinType)
      { ... }
   ...
}
```

Coupling

- A class *depends* on another if it uses objects of that class
- `CashRegister` depends on `Coin` to determine the value of the payment
- `Coin` does not depend on `CashRegister`
- High coupling = Many class dependencies
- Minimize coupling to minimize the impact of interface changes
- To visualize relationships draw class diagrams
- UML: Unified Modeling Language
    - *Notation for object-oriented analysis and design*

Dependency

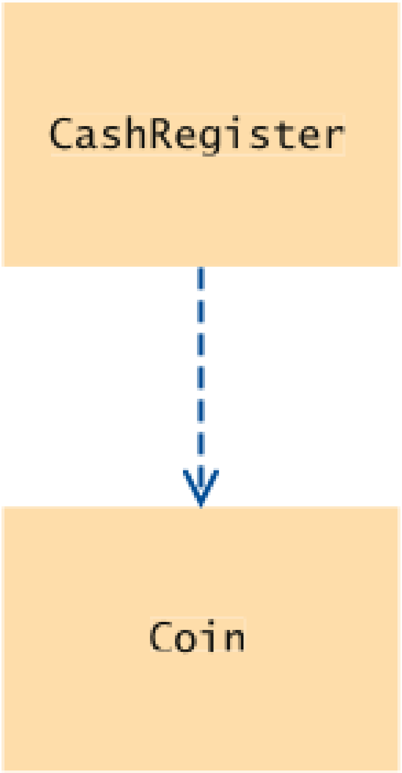

Figure 1
Dependency Relationship Between the CashRegister and Coin Classes

High and Low Coupling Between Classes

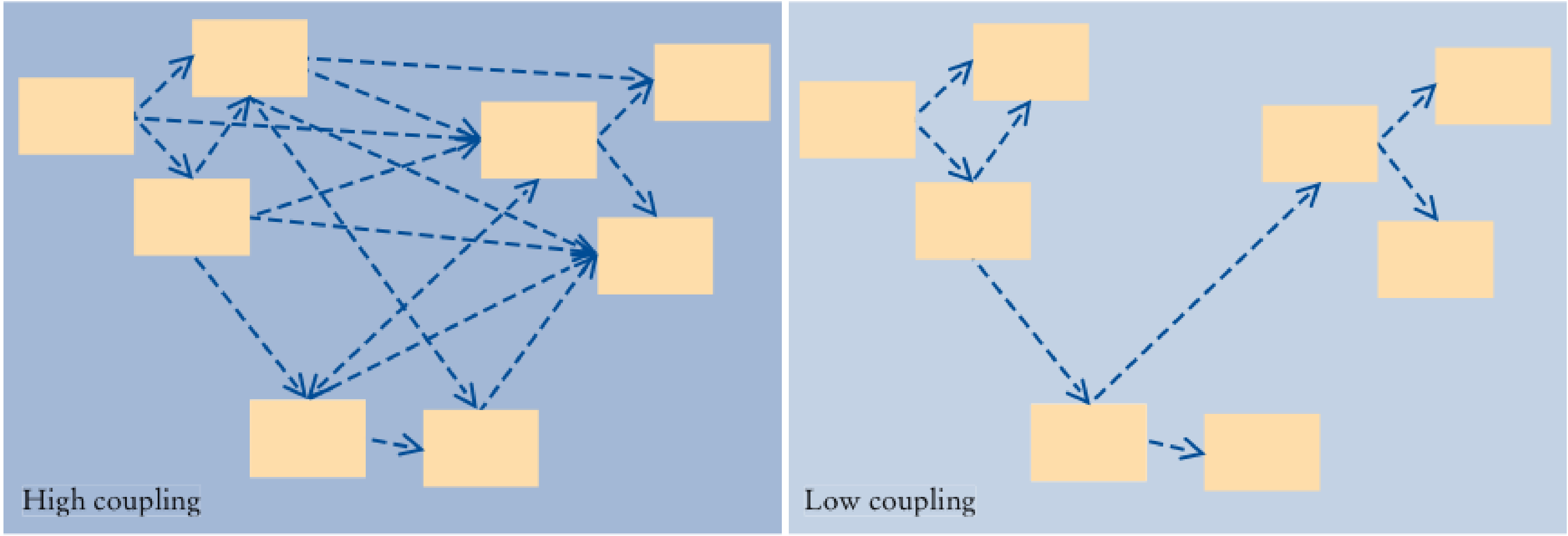

Figure 2 High and Low Coupling Between Classes

Self Check 7.3

Why is the `CashRegister` class from Chapter 4 not cohesive?

> **Answer:** Some of its features deal with payments, others with coin values.

Self Check 7.4

Why does the `Coin` class not depend on the `CashRegister` class?

Answer: None of the `Coin` operations require the `CashRegister` class.

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Self Check 7.5

Why should coupling be minimized between classes?

Answer: If a class doesn’t depend on another, it is not affected by interface changes in the other class.

Immutable Classes

- **Accessor:** Does not change the state of the implicit parameter:

```
double balance = account.getBalance();
```

- **Mutator:** Modifies the object on which it is invoked:

```
account.deposit(1000);
```

- **Immutable class:** Has no mutator methods (e.g., `String`):

```
 String name = "John Q. Public";
 String uppercased = name.toUpperCase();
// name is not changed
```

- It is safe to give out references to objects of immutable classes; no code can modify the object at an unexpected time

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Self Check 7.6

Is the `substring` method of the `String` class an accessor or a mutator?

> **Answer:** It is an accessor — calling `substring` doesn’t modify the string on which the method is invoked. In fact, all methods of the `String` class are accessors.

Self Check 7.7

Is the `Rectangle` class immutable?

Answer: No — `translate` is a mutator.

Side Effects

- **Side effect of a method:** Any externally observable data modification:

```
harrysChecking.deposit(1000);
```

- Modifying explicit parameter can be surprising to programmers— avoid it if possible:

```
public void addStudents(ArrayList<String> studentNames)
{
   while (studentNames.size() > 0)
   {
      String name = studentNames.remove(0);
      // Not recommended
      . . .
   }
}
```

Side Effects

- This method has the expected side effect of modifying the implicit parameter and the explicit parameter `other`:

```
public void transfer(double amount, BankAccount other
{
   balance = balance - amount;
   other.balance = other.balance + amount;
}
```

Side Effects

- Another example of a side effect is output:

```
public void printBalance() // Not recommended
{
   System.out.println("The balance is now $"
      + balance);
 }
```

  Bad idea: Message is in English, and relies on `System.out`

- Decouple input/output from the actual work of your classes
- Minimize side effects that go beyond modification of the implicit parameter

Self Check 7.8

If `a` refers to a bank account, then the call `a.deposit(100)` modifies the bank account object. Is that a side effect?

Answer: It is a side effect; this kind of side effect is common in object-oriented programming.

Self Check 7.9

Consider the DataSet class of Chapter 6. Suppose we add a method

```
void read(Scanner in)
{
   while (in.hasNextDouble())
      add(in.nextDouble());
}
```

Does this method have a side effect other than mutating the data set?

> **Answer:** Yes — the method affects the state of the Scanner parameter.

Common Error: Trying to Modify Primitive Type Parameters

-
  ```
  void transfer(double amount, double otherBalance)
  {
     balance = balance - amount;
     otherBalance = otherBalance + amount;
  }
  ```

- Won’t work

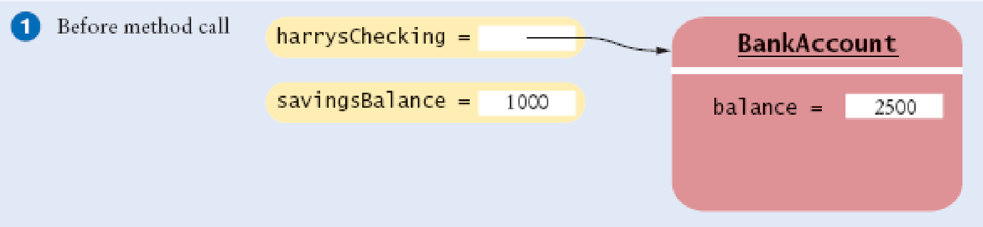
- Scenario:

  ```
     double savingsBalance = 1000;
     harrysChecking.transfer(500, savingsBalance);
     System.out.println(savingsBalance);
  ```

- In Java, a method can never change parameters of primitive type

Common Error: Trying to Modify Primitive Type Parameters

```
double savingsBalance = 1000;
harrysChecking.transfer(500, savingsBalance); ❶
System.out.println(savingsBalance);
...
void transfer(double amount, double otherBalance)
{
   balance = balance - amount;
   otherBalance = otherBalance + amount;
}
```



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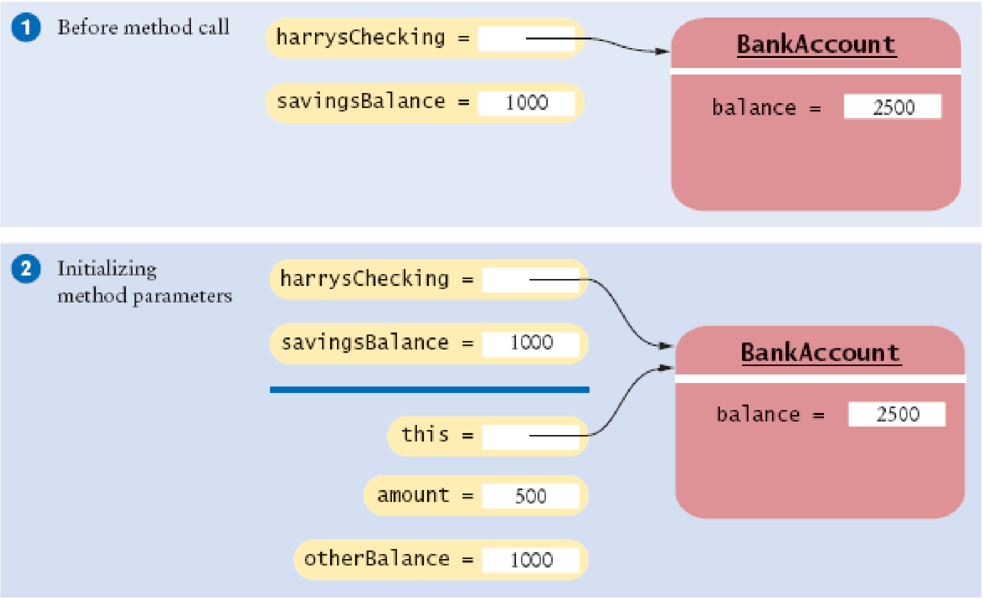
Common Error: Trying to Modify Primitive Type Parameters

```
double savingsBalance = 1000;
harrysChecking.transfer(500, savingsBalance); ❶
System.out.println(savingsBalance);
...
void transfer(double amount, double otherBalance) ❷
{
   balance = balance - amount;
   otherBalance = otherBalance + amount;
}
```

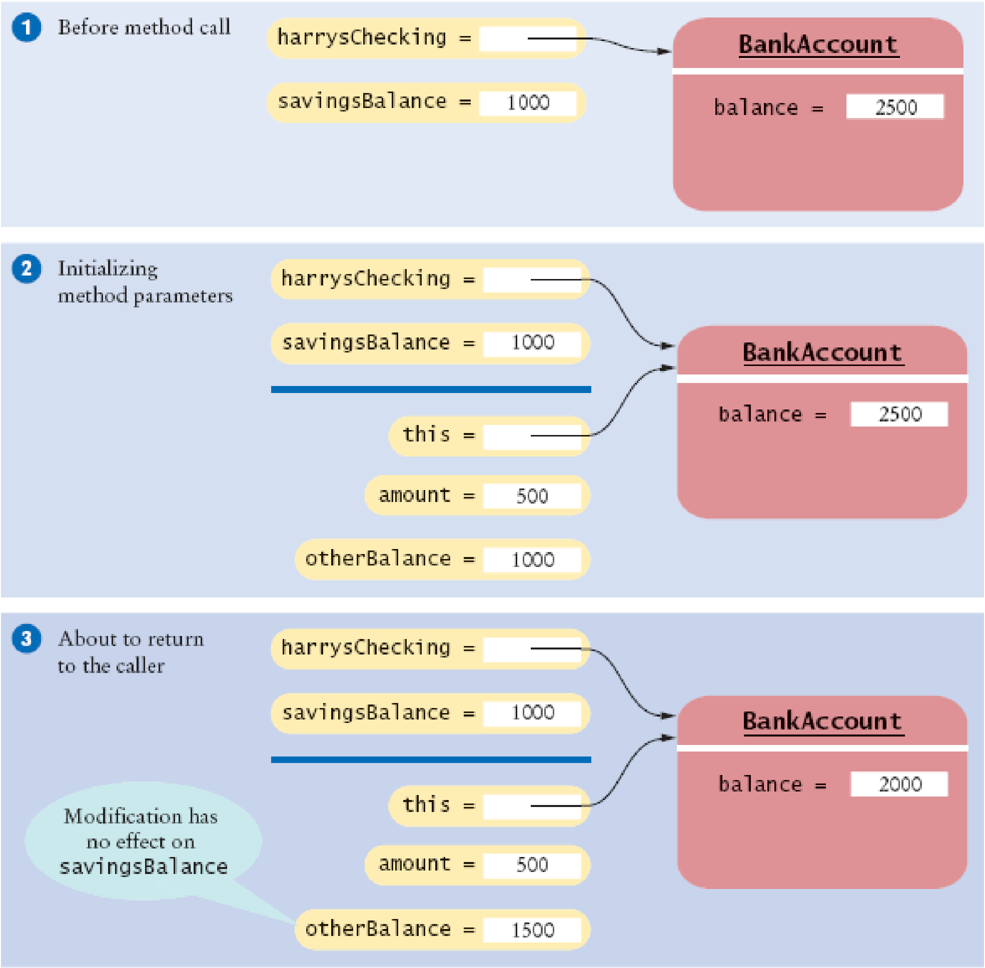


Common Error: Trying to Modify Primitive Type Parameters

```
double savingsBalance = 1000;
harrysChecking.transfer(500, savingsBalance); ❶
System.out.println(savingsBalance);
...
void transfer(double amount, double otherBalance)  ❷
{
   balance = balance - amount;
   otherBalance = otherBalance + amount;
} ❸
```

Continued

Common Error: Trying to Modify Primitive Type Parameters



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Common Error: Trying to Modify Primitive Type Parameters

```
double savingsBalance = 1000;
harrysChecking.transfer(500, savingsBalance); ❶
System.out.println(savingsBalance); ❹
...
void transfer(double amount, double otherBalance)  ❷
{
   balance = balance - amount;
   otherBalance = otherBalance + amount;
} ❸
```

Continued

Common Error: Trying to Modify Primitive Type Parameters

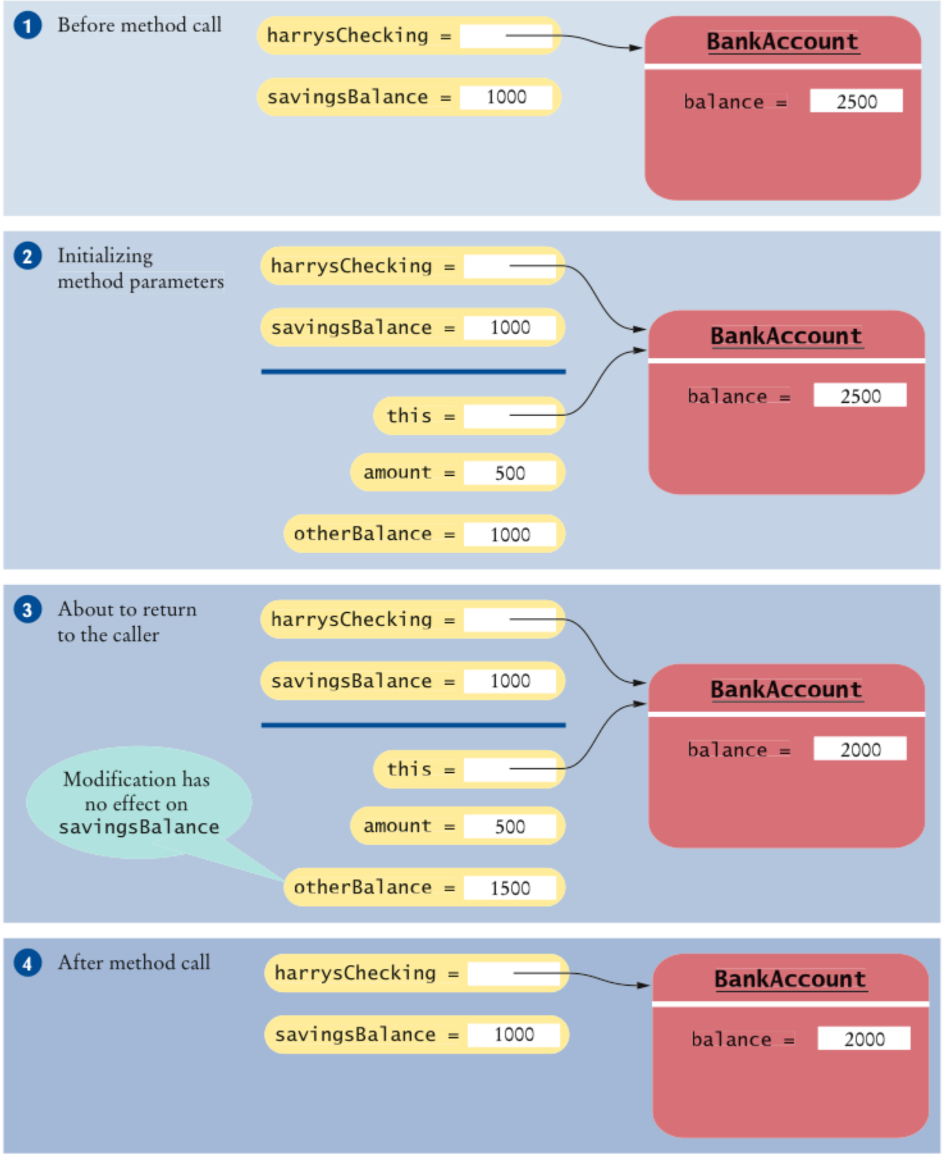

Figure 3 Modifying a Numeric Parameter Has No Effect on Caller

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Call by Value and Call by Reference

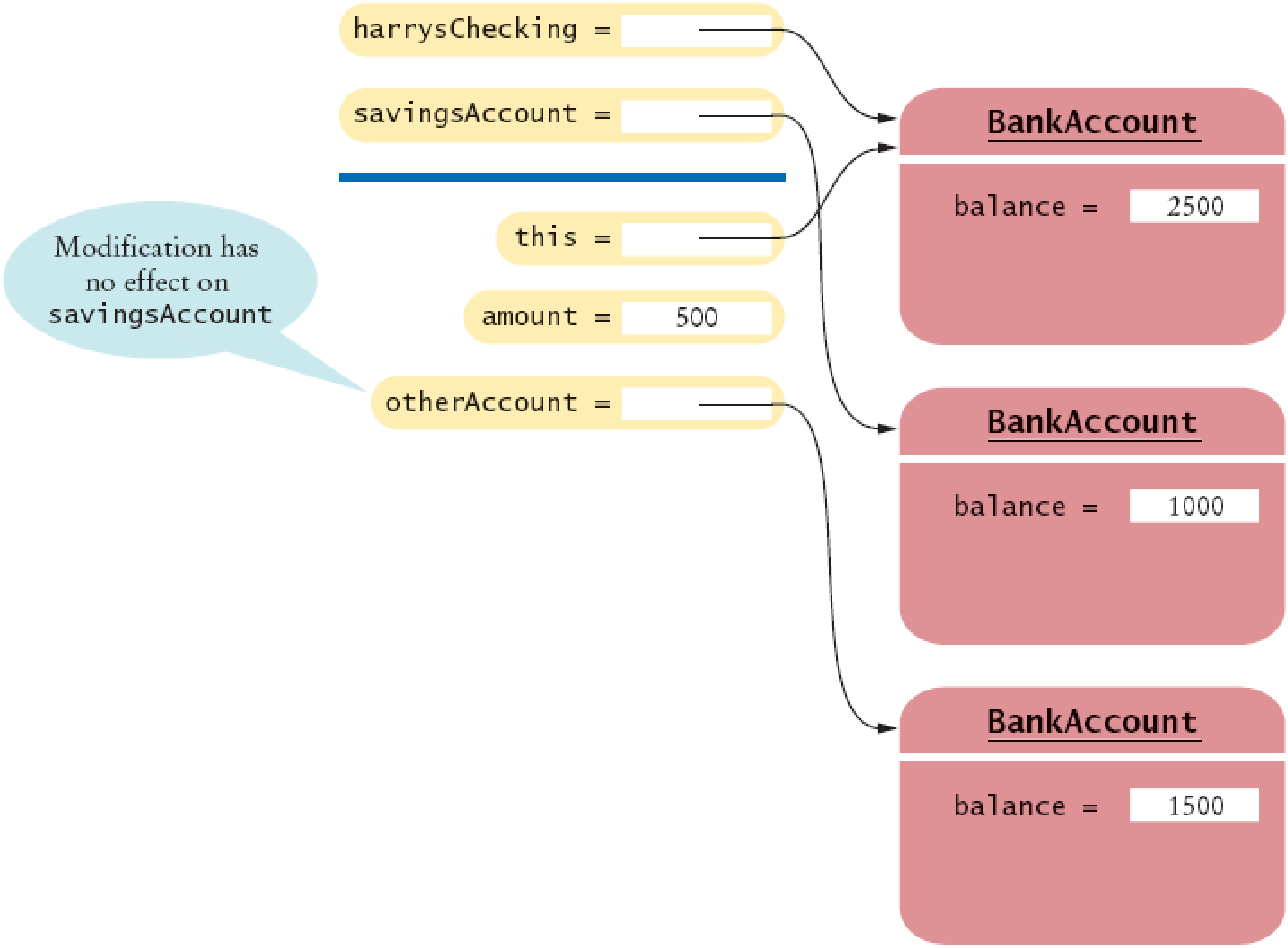
- **Call by value:** Method parameters are copied into the parameter variables when a method starts
- **Call by reference:** Methods can modify parameters
- Java has call by value
- A method can change state of object reference parameters, but cannot replace an object reference with another

Call by Value and Call by Reference

```
public class BankAccount
{
   public void transfer(double amount, BankAccount
      otherAccount)
   {
      balance = balance - amount;
      double newBalance = otherAccount.balance + amount;
      otherAccount = new BankAccount(newBalance);
     // Won't work
   }
}
```

Call by Value Example

```
harrysChecking.transfer(500, savingsAccount);
```



Modifying an Object Reference Parameter Has No Effect on the Caller

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Preconditions

- **Precondition:** Requirement that the caller of a method must meet
- Publish preconditions so the caller won't call methods with bad parameters:

-
  ```
  /**
     Deposits money into this account.
     @param amount the amount of money to deposit
     (Precondition: amount >= 0)
  */
  ```
- Typical use:
    1. *To restrict the parameters of a method*
    2. *To require that a method is only called when the object is in an appropriate state*

Preconditions

- If precondition is violated, method is not responsible for computing the correct result. It is free to do *anything*
- Method may throw exception if precondition violated — more in Chapter 11:

```
if (amount < 0) throw new IllegalArgumentException();
balance = balance + amount;
```

- Method doesn’t have to test for precondition. (Test may be costly):

```
// if this makes the balance negative, it's the
// caller's fault
balance = balance + amount;
```

Preconditions

- Method can do an assertion check:

  ```
  assert amount >= 0;
  balance = balance + amount;
  ```

  To enable assertion checking:

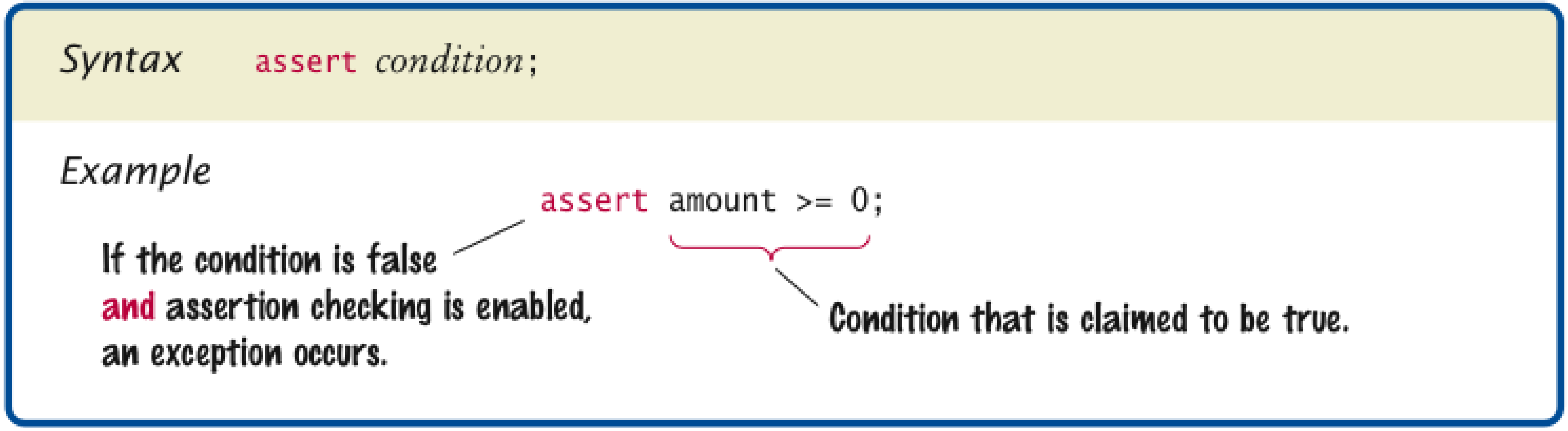
  ```
  java -enableassertions MainClass
  ```

  You can turn assertions off after you have tested your program, so that it runs at maximum speed

- Many beginning programmers silently return to the caller

  ```
  if (amount < 0)
     return; // Not recommended; hard to debug
  balance = balance + amount;
  ```

Syntax 7.1 Assertion



Syntax `assert condition;`

Example

```
assert amount >= 0;
```

If the condition is false **and** assertion checking is enabled, an exception occurs.

Condition that is claimed to be true.

Postconditions

- **Postcondition:** requirement that is true after a method has completed
- If method call is in accordance with preconditions, it must ensure that postconditions are valid
- There are two kinds of postconditions:
  - *The return value is computed correctly*
  - *The object is in a certain state after the method call is completed*
-
```
/**
   Deposits money into this account.
   (Postcondition: getBalance() >= 0)
   @param amount the amount of money to deposit
   (Precondition: amount >= 0)
*/
```

Postconditions

- Don’t document trivial postconditions that repeat the `@return` clause
- Formulate pre- and postconditions only in terms of the interface of the class:

```
amount <= getBalance() // this is the way to state a
   postcondition
amount <= balance // wrong postcondition formulation
```

- Contract: If caller fulfills preconditions, method must fulfill postconditions

Self Check 7.10

Why might you want to add a precondition to a method that you provide for other programmers?

> **Answer:** Then you don't have to worry about checking for invalid values — it becomes the caller's responsibility.

Self Check 7.11

When you implement a method with a precondition and you notice that the caller did not fulfill the precondition, do you have to notify the caller?

> **Answer:** No — you can take any action that is convenient for you.

Static Methods

- Every method must be in a class
- A static method is not invoked on an object
- Why write a method that does not operate on an object
- Common reason: encapsulate some computation that involves only numbers.
  - *Numbers aren't objects, you can't invoke methods on them. E.g.* `x.sqrt()` *can never be legal in Java*

Static Methods

- Example:

```
public class Financial
{
   public static double percentOf(double p, double a)
   {
      return (p / 100) * a;
   }
   // More financial methods can be added here.
}
```

- Call with class name instead of object:

```
double tax = Financial.percentOf(taxRate, total);
```

Static Methods

- If a method manipulates a class that you do not own, you cannot add it to that class
- A static method solves this problem:

```
public class Geometry
{
   public static double area(Rectangle rect)
   {
      return rect.getWidth() * rect.getHeight();
   }
   // More geometry methods can be added here.
}
```

- `main` is static — there aren't any objects yet

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Self Check 7.12

Suppose Java had no static methods. How would you use the `Math.sqrt` method for computing the square root of a number *x*?

Answer:

```
Math m = new Math();
y = m.sqrt(x);
```

Self Check 7.13

The following method computes the average of an array list of numbers:

```
public static double average(ArrayList<Double> values)
```

Why must it be a static method?

> **Answer:** You cannot add a method to the `ArrayList` class — it is a class in the standard Java library that you cannot modify.

Static Variables

- A static variable belongs to the class, not to any object of the class:

```
public class BankAccount
{
   . . .
   private double balance;
   private int accountNumber;
   private static int lastAssignedNumber = 1000;
}
```

- If `lastAssignedNumber` was not `static`, each instance of `BankAccount` would have its own value of `lastAssignedNumber`

Static Variables

-
  ```
  public BankAccount()
  {
     // Generates next account number to be assigned
     lastAssignedNumber++; // Updates the static variable
     accountNumber = lastAssignedNumber;
     // Sets the instance variable
  }
  ```

A Static Variable and Instance Variables

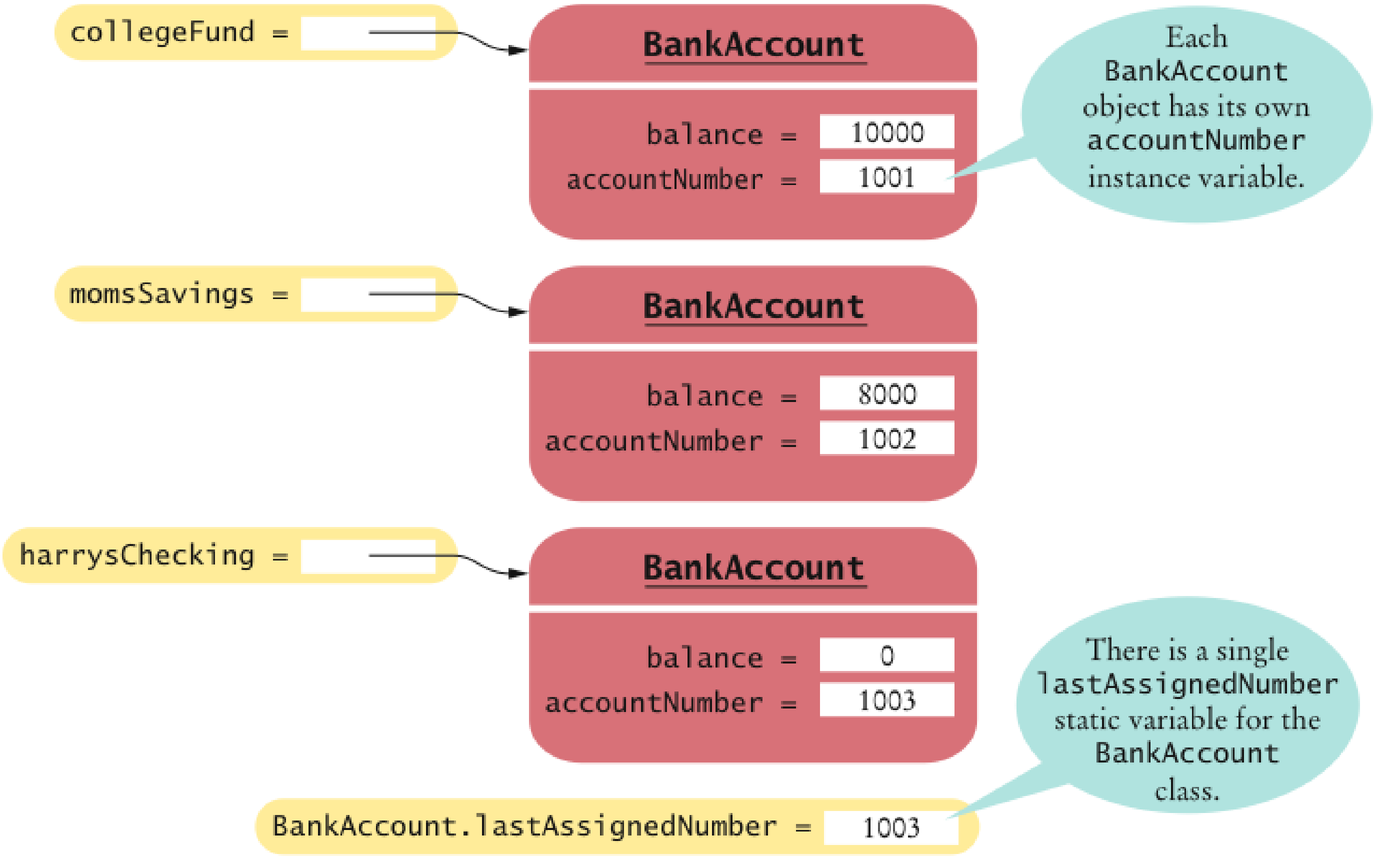
collegeFund =
BankAccount
balance = 10000
accountNumber = 1001
Each BankAccount object has its own accountNumber instance variable.
momsSavings =
BankAccount
balance = 8000
accountNumber = 1002
harrysChecking =
BankAccount
balance = 0
accountNumber = 1003
There is a single lastAssignedNumber static variable for the BankAccount class.
BankAccount.lastAssignedNumber = 1003

Figure 4
A Static Variable and Instance Variables

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Static Variables

- Three ways to initialize:

  1. *Do nothing. variable is initialized with* `0` *(for numbers),* `false` *(for boolean values), or* `null` *(for objects)*

  2. *Use an explicit initializer, such as*

     ```
     public class BankAccount
     {
        ...
        private static int lastAssignedNumber = 1000;
           // Executed once,
     }
     ```

  3. *Use a static initialization block*

- Static variables should always be declared as `private`

Static Variables

- Exception: Static constants, which may be either private or public:

```
public class BankAccount
{
   . . .
   public static final double OVERDRAFT_FEE = 5;
   // Refer to it as BankAccount.OVERDRAFT_FEE
}
```

- Minimize the use of static variables (static final variables are ok)

Self Check 7.14

Name two static variables of the `System` class.

Answer: `System.in` and `System.out`.

Self Check 7.15

Harry tells you that he has found a great way to avoid those pesky objects: Put all code into a single class and declare all methods and variables `static`. Then `main` can call the other static methods, and all of them can access the static variables. Will Harry's plan work? Is it a good idea?

> **Answer:** Yes, it works. Static methods can access static variables of the same class. But it is a terrible idea. As your programming tasks get more complex, you will want to use objects and classes to organize your programs.

Scope of Local Variables

- **Scope of variable:** Region of program in which the variable can be accessed
- Scope of a local variable extends from its declaration to end of the block that encloses it

Scope of Local Variables

- Sometimes the same variable name is used in two methods:

```
public class RectangleTester
{
   public static double area(Rectangle rect)
   {
      double r = rect.getWidth() * rect.getHeight();
      return r;
   }
   public static void main(String[] args)
   {
      Rectangle r = new Rectangle(5, 10, 20, 30);
      double a = area(r);
      System.out.println(r);
   }
}
```

- These variables are independent from each other; their scopes are disjoint

Scope of Local Variables

- Scope of a local variable cannot contain the definition of another variable with the same name:

```
Rectangle r = new Rectangle(5, 10, 20, 30);
if (x >= 0)
{
   double r = Math.sqrt(x);
   // Error - can't declare another variable
  // called r here
   ...
}
```

Scope of Local Variables

- However, can have local variables with identical names if scopes do not overlap:

```
if (x >= 0)
{
   double r = Math.sqrt(x);
   . . .
   } // Scope of r ends here
else
{
   Rectangle r = new Rectangle(5, 10, 20, 30);
   // OK - it is legal to declare another r here
   . . .
}
```

Overlapping Scope

- A local variable can *shadow* a variable with the same name
- Local scope wins over class scope:

```
public class Coin
{
   ...
   public double getExchangeValue(double exchangeRate)
   {
      double value; // Local variable
      ...
      return value;
   }
   private String name;
   private double value; // variable with the same name
}
```

Overlapping Scope

- Access shadowed variables by qualifying them with the `this` reference:

```
value = this.value * exchangeRate;
```

Overlapping Scope

- Generally, shadowing an instance variable is poor code — error-prone, hard to read
- Exception: when implementing constructors or setter methods, it can be awkward to come up with different names for instance variables and parameters
- OK:

```
public Coin(double value, String name)
{
   this.value = value;
   this.name = name;
}
```

Self Check 7.16

Consider the following program that uses two variables named `r`. Is this legal?

```
public class RectangleTester
{
   public static double area(Rectangle rect)
   {
      double r = rect.getWidth() * rect.getHeight();
      return r;
   }
   public static void main(String[] args)
   {
      Rectangle r = new Rectangle(5, 10, 20, 30);
      double a = area(r);
      System.out.println(r);
   }
}
```

Answer: Yes. The scopes are disjoint.

Self Check 7.17

What is the scope of the `balance` variable of the `BankAccount` class?

> **Answer:** It starts at the beginning of the class and ends at the end of the class.

Packages

- **Package:** Set of related classes
- Important packages in the Java library:

Package	Purpose	Sample Class
`java.lang`	Language support	`Math`
`java.util`	Utilities	`Random`
`java.io`	Input and output	`PrintStream`
`java.awt`	Abstract Windowing Toolkit	`Color`
`java.applet`	Applets	`Applet`
`java.net`	Networking	`Socket`
`java.sql`	Database Access	`ResultSet`
`javax.swing`	Swing user interface	`JButton`
`omg.w3c.dom`	Document Object Model for XML documents	`Document`

Organizing Related Classes into Packages

- To put classes in a package, you must place a line

  ```
  package packageName;
  ```

  as the first instruction in the source file containing the classes
- Package name consists of one or more identifiers separated by periods

Organizing Related Classes into Packages

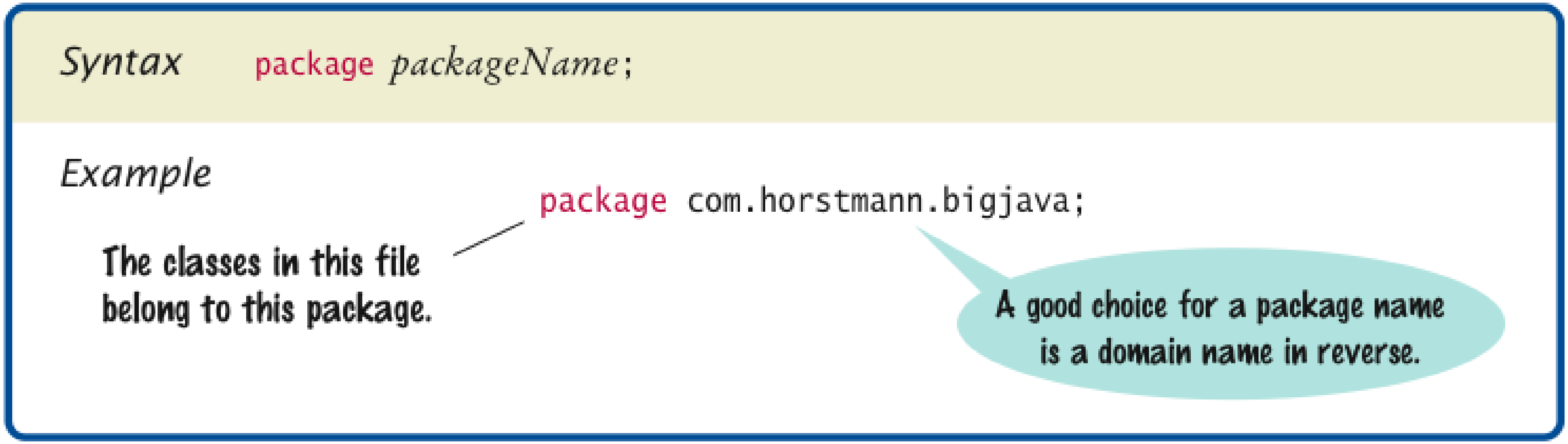
- For example, to put the `Financial` class introduced into a package named `com.horstmann.bigjava`, the `Financial.java` file must start as follows:

```
package com.horstmann.bigjava;

public class Financial
{
   ...
}
```

- Default package has no name, no `package` statement

Syntax 7.2 Package Specification



Syntax package *packageName*;

Example

```
package com.horstmann.bigjava;
```

The classes in this file belong to this package.

A good choice for a package name is a domain name in reverse.

Importing Packages

- Can always use class without importing:

```
java.util.Scanner in = new java.util.Scanner(System.in);
```

- Tedious to use fully qualified name
- Import lets you use shorter class name:

```
import java.util.Scanner;
...
Scanner in = new Scanner(System.in)
```

- Can import all classes in a package:

```
import java.util.*;
```

- Never need to import `java.lang`
- You don’t need to import other classes in the same package

Package Names

- Use packages to avoid name clashes

  ```
  java.util.Timer
  ```

  vs.

  ```
  javax.swing.Timer
  ```

- Package names should be unambiguous
- Recommendation: start with reversed domain name:

  ```
  com.horstmann.bigjava
  ```

- `edu.sjsu.cs.walters`: for Britney Walters' classes (`walters@cs.sjsu.edu`)
- Path name should match package name:

  ```
  com/horstmann/bigjava/Financial.java
  ```

Package and Source Files

- **Base directory:** holds your program's Files
- Path name, relative to base directory, must match package name:

```
com/horstmann/bigjava/Financial.java
```

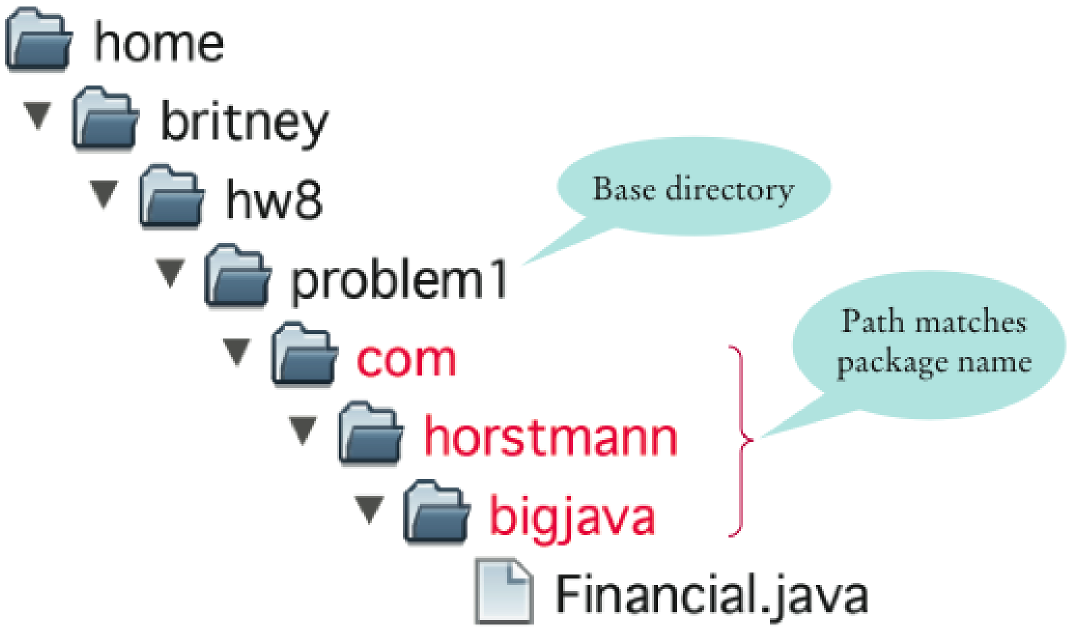


Figure 5
Base Directories and Subdirectories for Packages

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Self Check 7.18

Which of the following are packages?

a. `java`

b. `java.lang`

c. `java.util`

d. `java.lang.Math`

Answer:

a.No

b.Yes

c.Yes

d.No

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Self Check 7.19

Is a Java program without `import` statements limited to using the default and `java.lang` packages?

> **Answer:** No — you simply use fully qualified names for all other classes, such as `java.util.Random` and `java.awt.Rectangle`.

Self Check 7.20

Suppose your homework assignments are located in the directory `/home/me/cs101` (`c:\Users\me\cs101` on Windows). Your instructor tells you to place your homework into packages. In which directory do you place the class `hw1.problem1.TicTacToeTester`?

> **Answer:** `/home/me/cs101/hw1/problem1` or, on Windows, `c:\Users\me\cs101\hw1\problem1`

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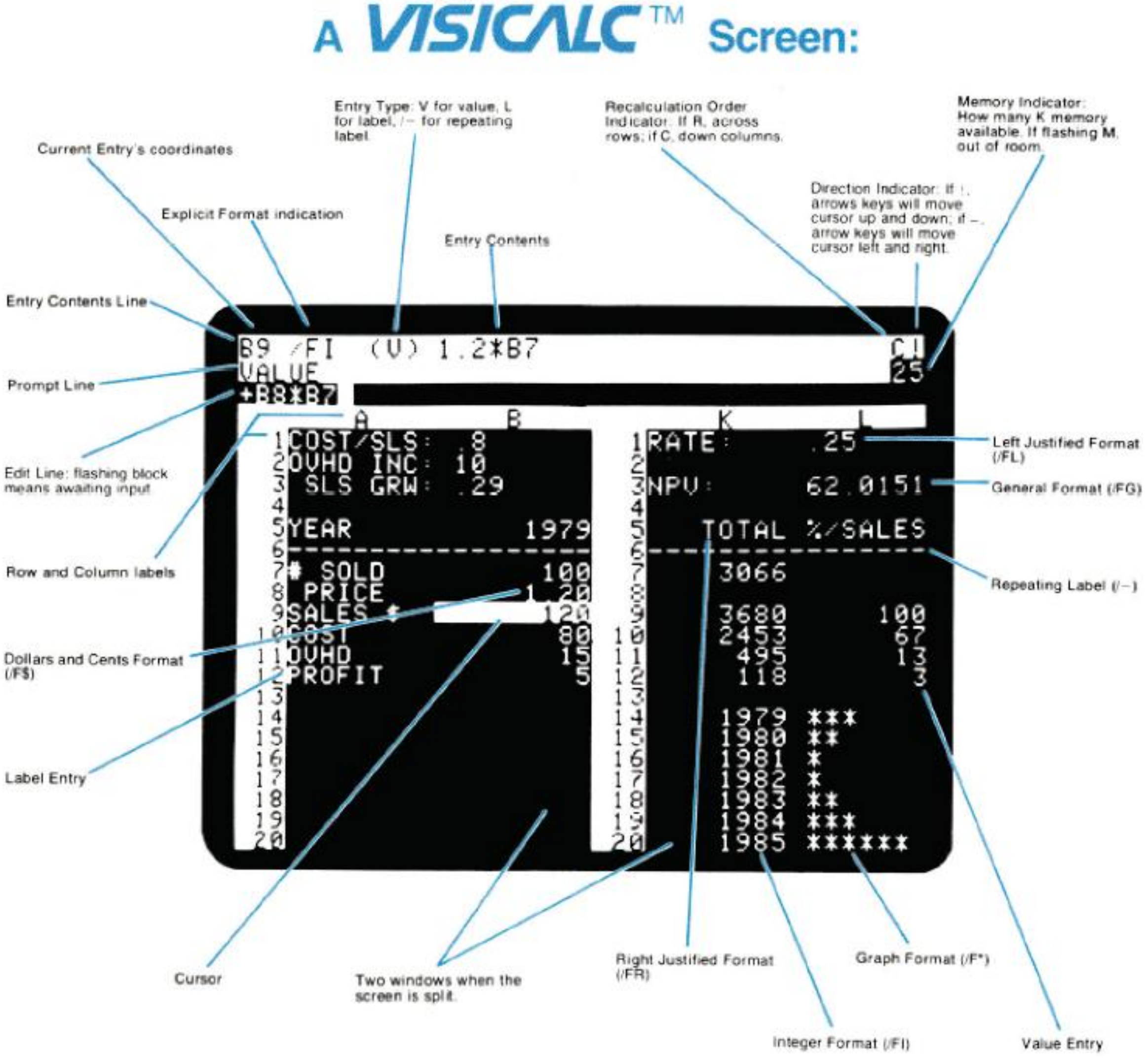
The Explosive Growth of Personal Computers



```
B9 /FI  (V) 1.2*B7                          C!
VALUE                                       25
+B8*B7
        A          B            K          L
 1COST/SLS:  .8             1RATE:        .25
 2OVHD INC:  10             2
 3 SLS GRW:  .29            3NPV:      62.0151
 4                          4
 5YEAR            1979      5    TOTAL %/SALES
 6-------------------       6-----------------
 7# SOLD           100      7    3066
 8 PRICE          1.20      8
 9SALES $          120      9    3680      100
10COST              80     10    2453       67
11OVHD              15     11     495       13
12PROFIT             5     12     118        3
13                         13
14                         14    1979 ***
15                         15    1980 **
16                         16    1981 *
17                         17    1982 *
18                         18    1983 **
19                         19    1984 ***
20                         20    1985 ******
```

A VISICALC™ Screen:
Current Entry's coordinates
Explicit Format indication
Entry Type: V for value, L for label, /– for repeating label.
Entry Contents
Recalculation Order Indicator. If R, across rows; if C, down columns.
Memory Indicator: How many K memory available. If flashing M, out of room.
Direction Indicator: If ↕, arrows keys will move cursor up and down; if ↔, arrow keys will move cursor left and right.
Entry Contents Line
Prompt Line
Edit Line: flashing block means awaiting input
Row and Column labels
Dollars and Cents Format (/F$)
Label Entry
Left Justified Format (/FL)
General Format (/FG)
Repeating Label (/–)
Cursor
Two windows when the screen is split.
Right Justified Format (/FR)
Integer Format (/FI)
Graph Format (/F*)
Value Entry

The VisiCalc Spreadsheet Running on an Apple II

Unit Testing Frameworks

- Unit test frameworks simplify the task of writing classes that contain many test cases
- JUnit: `http://junit.org`
  - *Built into some IDEs like BlueJ and Eclipse*
- Philosophy: whenever you implement a class, also make a companion test class. Run all tests whenever you change your code

Unit Testing Frameworks

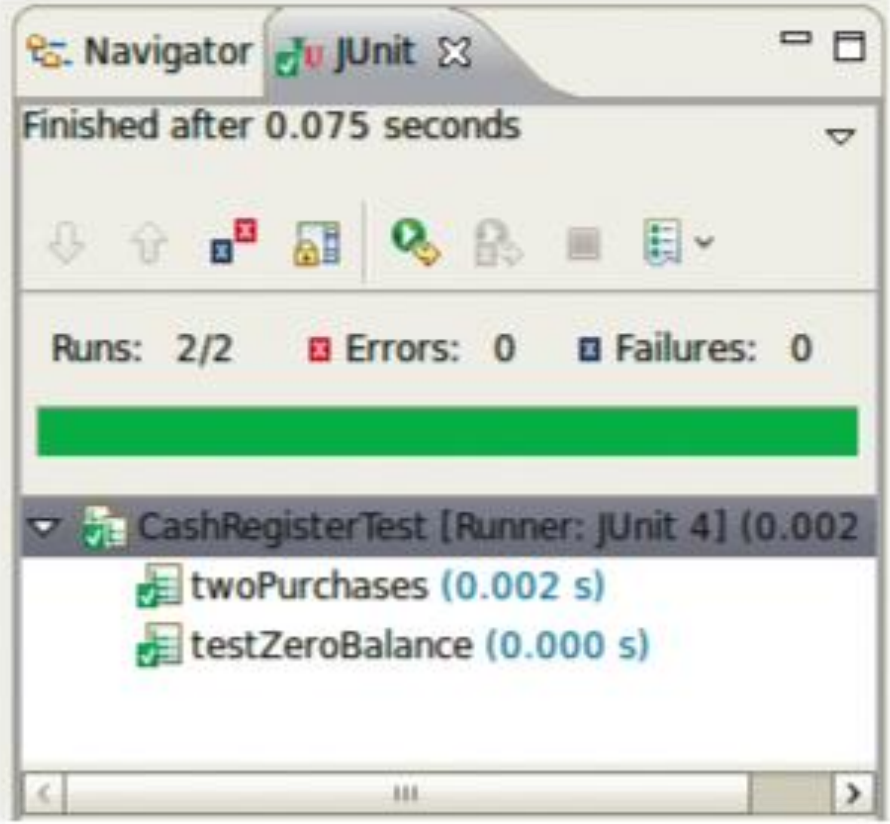
- Customary that name of the test class ends in `Test`:

```
import org.junit.Test;
import org.junit.Assert;
public class CashRegisterTest
{
   @Test public void twoPurchases()
   {
      CashRegister register = new CashRegister();
      register.recordPurchase(0.75);
      register.recordPurchase(1.50);
      register.enterPayment(2, 0, 5, 0, 0);
      double expected = 0.25;
      Assert.assertEquals(expected, register.giveChange(),
         EPSILON);
   }
   // More test cases
   . . .
}
```

Unit Testing Frameworks

- If all test cases pass, the JUnit tool shows a green bar:

Figure 6
Unit Testing with JUnit



Finished after 0.075 seconds

Runs: 2/2 Errors: 0 Failures: 0

CashRegisterTest [Runner: JUnit 4] (0.002
twoPurchases (0.002 s)
testZeroBalance (0.000 s)

Big Java by Cay Horstmann

Self Check 7.21

Provide a JUnit test class with one test case for the `Earthquake` class in Chapter 5.

Answer: Here is one possible answer, using the JUnit 4 style.

```
public class EarthquakeTest
{
   @Test public void testLevel4()
   {
      Earthquake quake = new Earthquake(4);
      Assert.assertEquals("Felt by many people, no destruction”,
         quake.getDescription());
   }
}
```

Self Check 7.22

What is the significance of the `EPSILON` parameter in the `assertEquals` method?

Answer: It is a tolerance threshold for comparing floating-point numbers. We want the equality test to pass if there is a small roundoff error.