Chapter 1 Introduction to Java

Objectives

- To describe the relationship between Java and the World Wide Web (§1.5).
- To understand the meaning of Java language specification, API, JDK, and IDE (§1.6).
- To write a simple Java program (§1.7).
- To display output on the console (§1.7).
- To explain the basic syntax of a Java program (§1.7).
- To create, compile, and run Java programs (§1.8).
- To use sound Java programming style and document programs properly (§1.9).
- To explain the differences between syntax errors, runtime errors, and logic errors (§1.10).
- To develop Java programs using NetBeans (§1.11).
- To develop Java programs using Eclipse (§1.12).

Popular High-Level Languages

Language	Description
Ada	Named for Ada Lovelace, who worked on mechanical general-purpose computers. The Ada language was developed for the Department of Defense and is used mainly in defense projects.
BASIC	Beginner's All-purpose Symbolic Instruction Code. It was designed to be learned and used easily by beginners.
C	Developed at Bell Laboratories. C combines the power of an assembly language with the ease of use and portability of a high-level language.
C++	C++ is an object-oriented language, based on C.
C#	Pronounced "C Sharp." It is a hybrid of Java and C++ and was developed by Microsoft.
COBOL	COmmon Business Oriented Language. Used for business applications.
FORTRAN	FORmula TRANslation. Popular for scientific and mathematical applications.
Java	Developed by Sun Microsystems, now part of Oracle. It is widely used for developing platform-independent Internet applications.
Pascal	Named for Blaise Pascal, who pioneered calculating machines in the seventeenth century. It is a simple, structured, general-purpose language primarily for teaching programming.
Python	A simple general-purpose scripting language good for writing short programs.
Visual Basic	Visual Basic was developed by Microsoft and it enables the programmers to rapidly develop graphical user interfaces.

Why Java?

The answer is that Java enables users to develop and deploy applications on the Internet for servers, desktop computers, and small hand-held devices. The future of computing is being profoundly influenced by the Internet, and Java promises to remain a big part of that future. Java is the Internet programming language.

- Java is a general purpose programming language.
- Java is the Internet programming language.

Java, Web, and Beyond

- Java can be used to develop standalone applications.
- Java can be used to develop applications running from a browser.
- Java can also be used to develop applications for hand-held devices.
- Java can be used to develop applications for Web servers.

Java's History

- James Gosling and Sun Microsystems
- Oak
- Java, May 20, 1995, Sun World
- HotJava
  - The first Java-enabled Web browser
- Early History Website:

http://www.java.com/en/javahistory/index.jsp

Companion Website

Characteristics of Java

- Java Is Simple
- Java Is Object-Oriented
- Java Is Distributed
- Java Is Interpreted
- Java Is Robust
- Java Is Secure
- Java Is Architecture-Neutral
- Java Is Portable
- Java's Performance
- Java Is Multithreaded
- Java Is Dynamic

www.cs.armstrong.edu/liang/JavaCharacteristics.pdf

Companion Website

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Java is partially modeled on C++, but greatly simplified and improved. Some people refer to Java as "C++--" because it is like C++ but with more functionality and fewer negative aspects.

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Java is inherently object-oriented. Although many object-oriented languages began strictly as procedural languages, Java was designed from the start to be object-oriented. Object-oriented programming (OOP) is a popular programming approach that is replacing traditional procedural programming techniques.

One of the central issues in software development is how to reuse code. Object-oriented programming provides great flexibility, modularity, clarity, and reusability through encapsulation, inheritance, and polymorphism.

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Distributed computing involves several computers working together on a network. Java is designed to make distributed computing easy. Since networking capability is inherently integrated into Java, writing network programs is like sending and receiving data to and from a file.

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You need an interpreter to run Java programs. The programs are compiled into the Java Virtual Machine code called bytecode. The bytecode is machine-independent and can run on any machine that has a Java interpreter, which is part of the Java Virtual Machine (JVM).

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Java compilers can detect many problems that would first show up at execution time in other languages.

Java has eliminated certain types of error-prone programming constructs found in other languages.

Java has a runtime exception-handling feature to provide programming support for robustness.

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Java implements several security mechanisms to protect your system against harm caused by stray programs.

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Write once, run anywhere

With a Java Virtual Machine (JVM), you can write one program that will run on any platform.

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Because Java is architecture neutral, Java programs are portable. They can be run on any platform without being recompiled.

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Java's performance Because Java is architecture neutral, Java programs are portable. They can be run on any platform without being recompiled.

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Multithread programming is smoothly integrated in Java, whereas in other languages you have to call procedures specific to the operating system to enable multithreading.

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- Java Is Robust
- Java Is Secure
- Java Is Architecture-Neutral
- Java Is Portable
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- Java Is Dynamic

Java was designed to adapt to an evolving environment. New code can be loaded on the fly without recompilation. There is no need for developers to create, and for users to install, major new software versions. New features can be incorporated transparently as needed.

JDK Versions

- JDK 1.02 (1995)
- JDK 1.1 (1996)
- JDK 1.2 (1998)
- JDK 1.3 (2000)
- JDK 1.4 (2002)
- JDK 1.5 (2004) a. k. a. JDK 5 or Java 5
- JDK 1.6 (2006) a. k. a. JDK 6 or Java 6
- JDK 1.7 (2011) a. k. a. JDK 7 or Java 7
- JDK 1.8 (2014) a. k. a. JDK 8 or Java 8

JDK Editions

- Java Standard Edition (J2SE)
  - J2SE can be used to develop client-side standalone applications or applets.
- Java Enterprise Edition (J2EE)
  - J2EE can be used to develop server-side applications such as Java servlets, Java ServerPages, and Java ServerFaces.
- Java Micro Edition (J2ME).
  - J2ME can be used to develop applications for mobile devices such as cell phones.
- This book uses J2SE to introduce Java programming.

Popular Java IDEs

- NetBeans
- Eclipse

A Simple Java Program

Listing 1.1

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

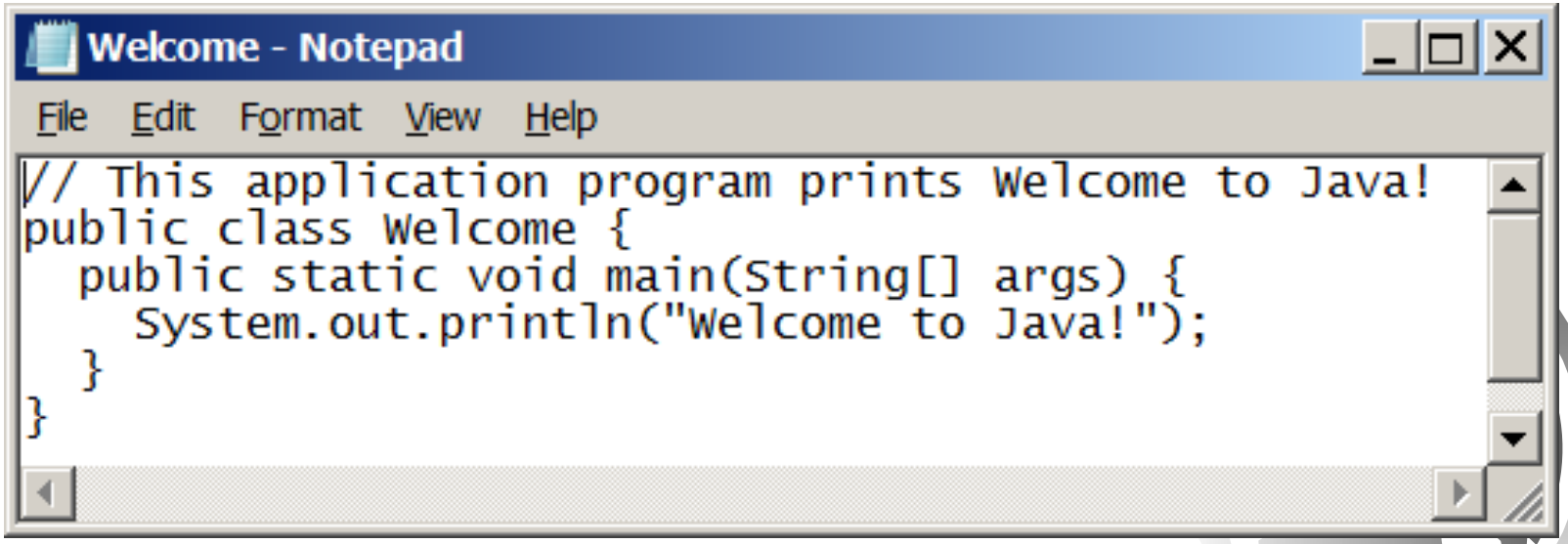
Welcome.java

Creating and Editing Using NotePad

To use NotePad, type

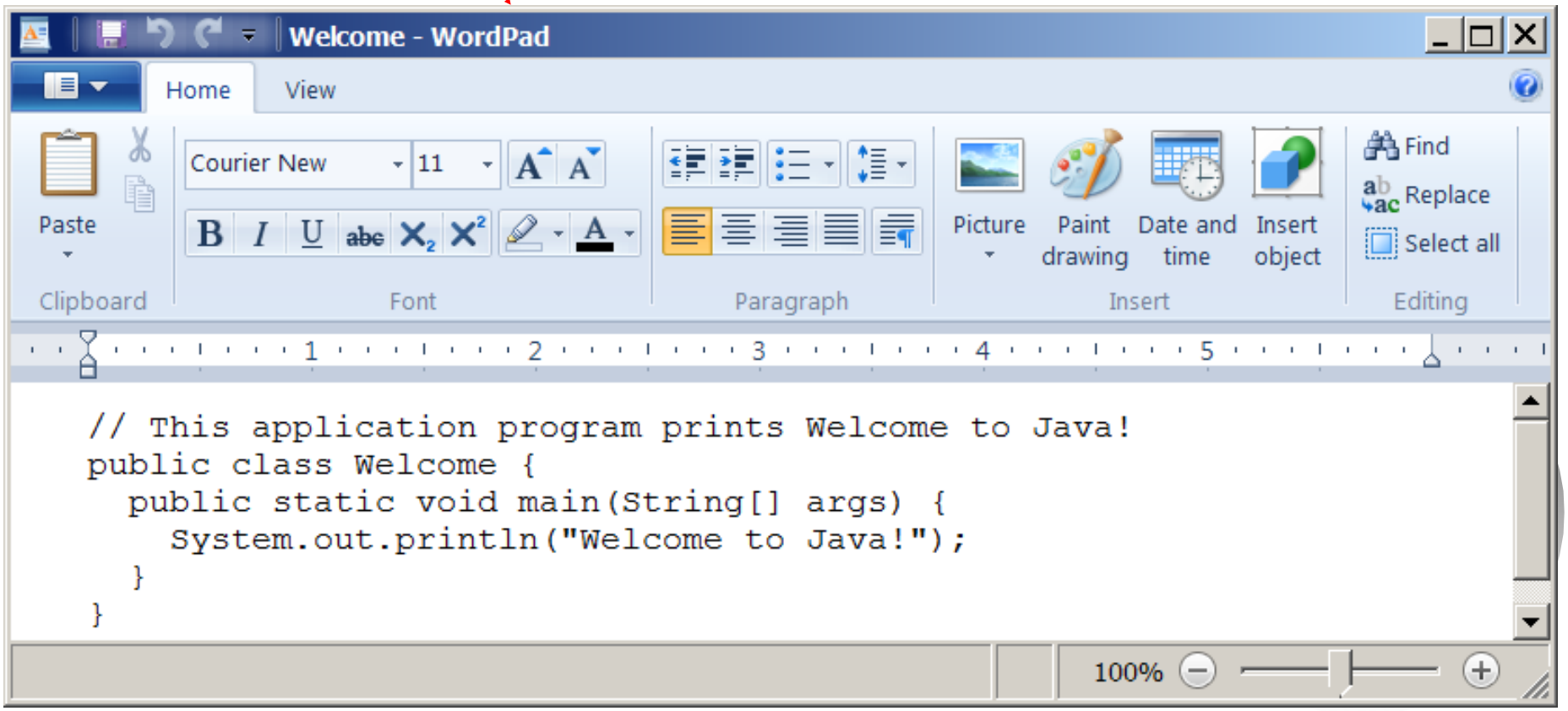
notepad Welcome.java

from the DOS prompt.



Creating and Editing Using WordPad

To use WordPad, type
write Welcome.java
from the DOS prompt.

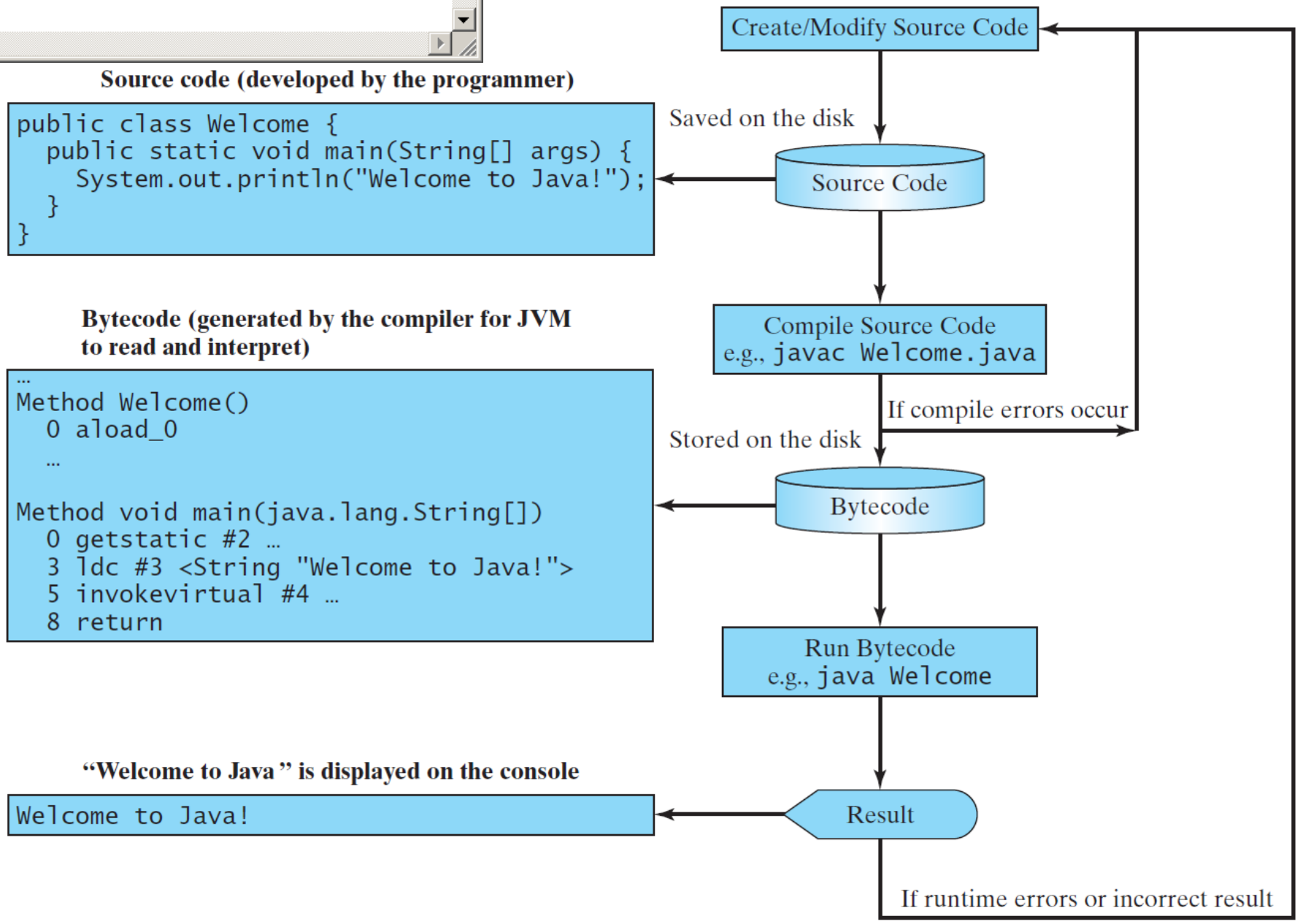


Creating, Compiling, and Running Programs

Welcome - Notepad

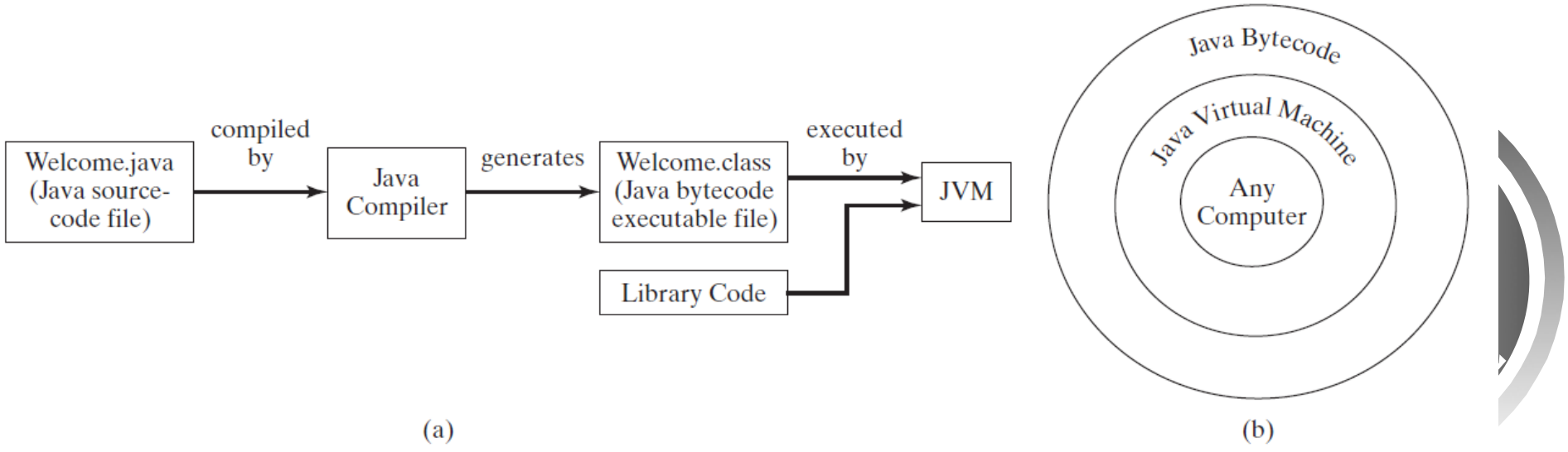
File Edit Format View Help

```
// This application program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```



Compiling Java Source Code

You can port a source program to any machine with appropriate compilers. The source program must be recompiled, however, because the object program can only run on a specific machine. Nowadays computers are networked to work together. Java was designed to run object programs on any platform. With Java, you write the program once, and compile the source program into a special type of object code, known as *bytecode*. The bytecode can then run on any computer with a Java Virtual Machine, as shown below. Java Virtual Machine is a software that interprets Java bytecode.



animation

Trace a Program Execution

Enter main method

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

animation

Trace a Program Execution

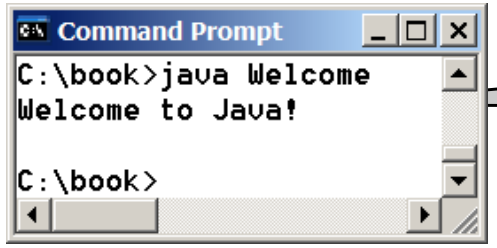
Execute statement

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

animation

Trace a Program Execution

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```



print a message to the console

Two More Simple Examples

```
public class ComputeExpression {
  public static void main(String[] args) {
    System.out.println((10.5 + 2 * 3) / (45 - 3.5));
  }
}
```

ComputeExpression .java

Companion Website

Supplements on the Companion Website

- See Supplement I.B for installing and configuring JDK
- See Supplement I.C for compiling and running Java from the command window for details

Supplements are available on (require registration):

www.cs.armstrong.edu/liang/intro10e

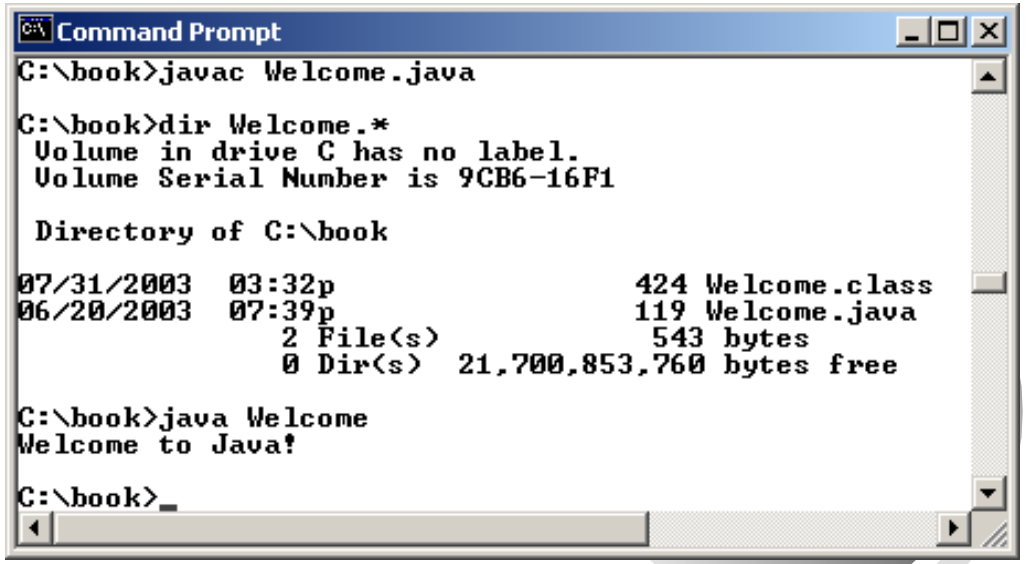
Supplements for the 9th edition don't require registration:

http://www.cs.armstrong.edu/liang/intro9e/supplement.html

Companion Website

Compiling and Running Java from the Command Window

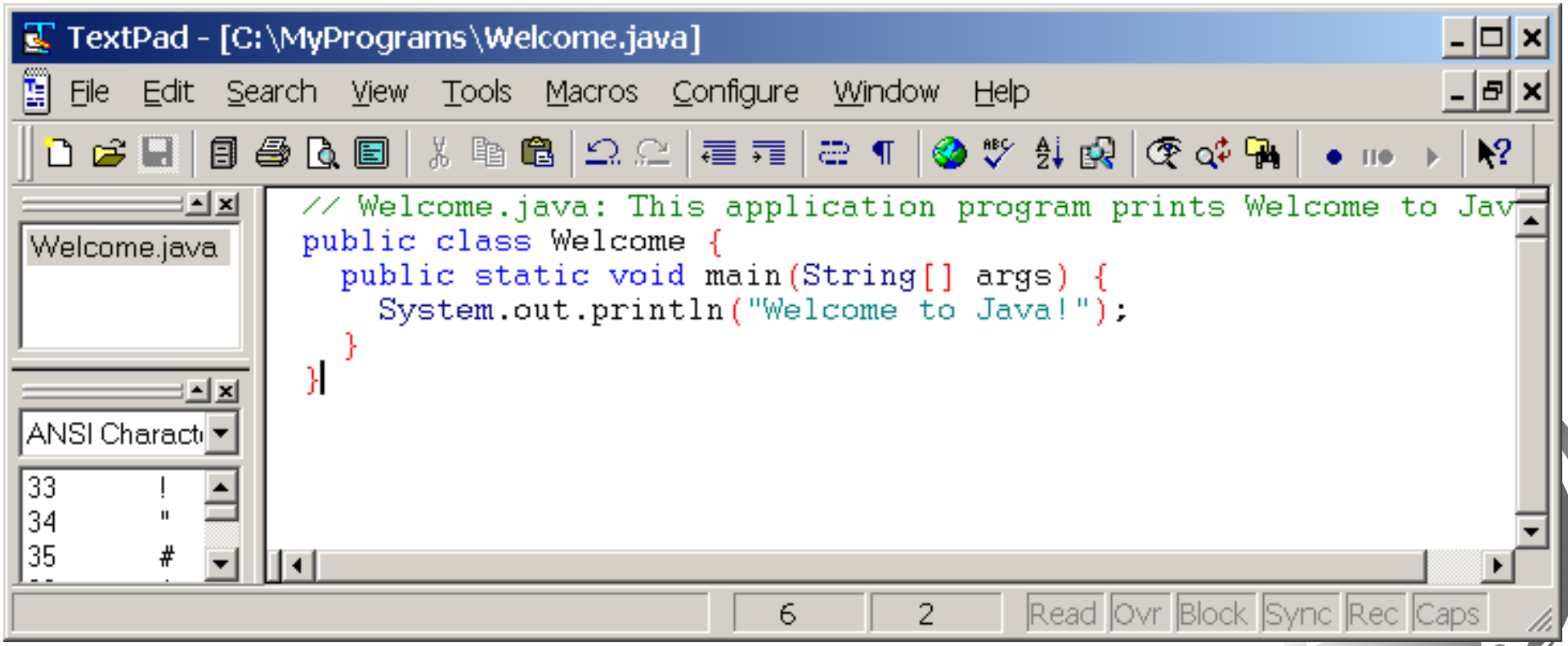
- Set path to JDK bin directory
  - set path=c:\Program Files\java\jdk1.8.0\bin
- Set classpath to include the current directory
  - set classpath=.
- Compile
  - javac Welcome.java
- Run
  - java Welcome



Compiling and Running Java from TextPad

Companion Website

- See Supplement II.A on the Website for details



Anatomy of a Java Program

- Class name
- Main method
- Statements
- Statement terminator
- Reserved words
- Comments
- Blocks

Class Name

Every Java program must have at least one class. Each class has a name. By convention, class names start with an uppercase letter. In this example, the class name is Welcome.

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Main Method

Line 2 defines the main method. In order to run a class, the class must contain a method named main. The program is executed from the main method.

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Statement

A statement represents an action or a sequence of actions. The statement System.out.println("Welcome to Java!") in the program in Listing 1.1 is a statement to display the greeting "Welcome to Java!".

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Statement Terminator

Every statement in Java ends with a semicolon (;).

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

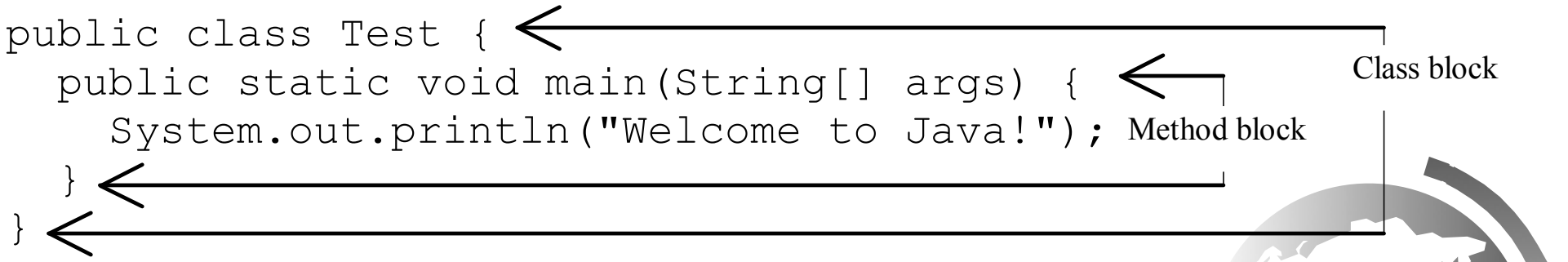
Reserved words

Reserved words or keywords are words that have a specific meaning to the compiler and cannot be used for other purposes in the program. For example, when the compiler sees the word class, it understands that the word after class is the name for the class.

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Blocks

A pair of braces in a program forms a block that groups components of a program.



Special Symbols

Character	Name	Description
{}	Opening and closing braces	Denotes a block to enclose statements.
()	Opening and closing parentheses	Used with methods.
[]	Opening and closing brackets	Denotes an array.
//	Double slashes	Precedes a comment line.
" "	Opening and closing quotation marks	Enclosing a string (i.e., sequence of characters).
;	Semicolon	Marks the end of a statement.

{ ... }

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

(...)

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

;

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

```
// ...
```

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

" "
...

```
// This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Programming Style and Documentation

- Appropriate Comments
- Naming Conventions
- Proper Indentation and Spacing Lines
- Block Styles

Appropriate Comments

Include a summary at the beginning of the program to explain what the program does, its key features, its supporting data structures, and any unique techniques it uses.

Include your name, class section, instructor, date, and a brief description at the beginning of the program.

Naming Conventions

- Choose meaningful and descriptive names.
- Class names:
  - Capitalize the first letter of each word in the name. For example, the class name `ComputeExpression`.

Proper Indentation and Spacing

- Indentation
  - Indent two spaces.

- Spacing
  - Use blank line to separate segments of the code.

Block Styles

Use end-of-line style for braces.

Next-line style

```
public class Test
{
  public static void main(String[] args)
  {
    System.out.println("Block Styles");
  }
}
```

End-of-line style

```
public class Test {
  public static void main(String[] args) {
    System.out.println("Block Styles");
  }
}
```

Programming Errors

- Syntax Errors
  – Detected by the compiler
- Runtime Errors
  – Causes the program to abort
- Logic Errors
  – Produces incorrect result

Syntax Errors

```
public class ShowSyntaxErrors {
  public static main(String[] args) {
    System.out.println("Welcome to Java);
  }
}
```

Return type for the method is missing

String literal is not properly closed by a double-quote

ShowSyntaxErrors.java

Runtime Errors

```
public class ShowRuntimeErrors {
  public static void main(String[] args) {
    System.out.println(1 / 0);
  }
}
```

Exception in thread "main" java.lang.ArithmeticException: / by zero
at chapter1.ShowRuntimeErrors.main(ShowRuntimeErrors.java:6)

ShowRuntimeErrors.java

Logic Errors

```
public class ShowLogicErrors {
  public static void main(String[] args) {
    System.out.println("Celsius 35 is Fahrenheit degree ");
    System.out.println((9 / 5) * 35 + 32);
  }
}
```

This program compute Fahrenheit as 67, and it should be 95, find out what is wrong.

ShowLogicErrors.java

Companion Website

Compiling and Running Java from NetBeans

- See Supplement I.D on the Website for details

Companion Website

Compiling and Running Java from Eclipse

- See Supplement II.D on the Website for details

Chapter 2 Elementary Programming

Reading Input from the Console

1. Create a Scanner object

```
Scanner input = new Scanner(System.in);
```

2. Use the method nextDouble() to obtain to a double value. For example,

```
System.out.print("Enter a double value: ");
Scanner input = new Scanner(System.in);
double d = input.nextDouble();
```

ComputeAreaWithConsoleInput.java

ComputeAverage.java

Identifiers

- An identifier is a sequence of characters that consist of letters, digits, underscores (_), and dollar signs ($).
- An identifier must start with a letter, an underscore (_), or a dollar sign ($). It cannot start with a digit.
- An identifier cannot be a reserved word. (See Appendix A, "Java Keywords," for a list of reserved words).
- An identifier cannot be `true`, `false`, or `null`.
- An identifier can be of any length.

Variables

```
// Compute the first area
radius = 1.0;
area = radius * radius * 3.14159;
System.out.println("The area is " +
  area + " for radius "+radius);

// Compute the second area
radius = 2.0;
area = radius * radius * 3.14159;
System.out.println("The area is " +
  area + " for radius "+radius);
```

Declaring Variables

```
int x;            // Declare x to be an
                  // integer variable;
double radius;    // Declare radius to
                  // be a double variable;
char a;           // Declare a to be a
                  // character variable;
```

Assignment Statements

```
x = 1;              // Assign 1 to x;

radius = 1.0;       // Assign 1.0 to radius;

a = 'A';            // Assign 'A' to a;
```

Declaring and Initializing in One Step

```
int x = 1;

double d = 1.4;
```

Named Constants

```
final datatype CONSTANTNAME = VALUE;
```

```
final double PI = 3.14159;
final int SIZE = 3;
```

Naming Conventions

- Choose meaningful and descriptive names.
- Variables and method names:
  - Use lowercase. If the name consists of several words, concatenate all in one, use lowercase for the first word, and capitalize the first letter of each subsequent word in the name. For example, the variables `radius` and `area`, and the method `computeArea`.

Naming Conventions, cont.

- Class names:
  - Capitalise the first letter of each word in the name. For example, the class name `ComputeArea`.

- Constants:
  - Capitalise all letters in constants, and use underscores to connect words. For example, the constant `PI and` MAX_VALUE

Numerical Data Types

Name	Range	Storage Size
`byte`	-2^7 to $2^7 - 1$ (-128 to 127)	8-bit signed
`short`	-2^{15} to $2^{15} - 1$ (-32768 to 32767)	16-bit signed
`int`	-2^{31} to $2^{31} - 1$ (-2147483648 to 2147483647)	32-bit signed
`long`	-2^{63} to $2^{63} - 1$ (i.e., -9223372036854775808 to 9223372036854775807)	64-bit signed
`float`	Negative range: -3.4028235E+38 to -1.4E-45 Positive range: 1.4E-45 to 3.4028235E+38	32-bit IEEE 754
`double`	Negative range: -1.7976931348623157E+308 to -4.9E-324 Positive range: 4.9E-324 to 1.7976931348623157E+308	64-bit IEEE 754

Java data type sizes are platform independent

Top four are integer, bottom two are floating point

Variables of these types declared like

short a,b,c; or initialised when declared

double x = 1.502;

Reading Numbers from the Keyboard

```
Scanner input = new Scanner(System.in);
int value = input.nextInt();
```

Method	Description
`nextByte()`	reads an integer of the `byte` type.
`nextShort()`	reads an integer of the `short` type.
`nextInt()`	reads an integer of the `int` type.
`nextLong()`	reads an integer of the `long` type.
`nextFloat()`	reads a number of the `float` type.
`nextDouble()`	reads a number of the `double` type.

Numeric Operators

Name	Meaning	Example	Result
+	Addition	34 + 1	35
-	Subtraction	34.0 - 0.1	33.9
*	Multiplication	300 * 30	9000
/	Division	1.0 / 2.0	0.5
%	Remainder	20 % 3	2

Integer Division

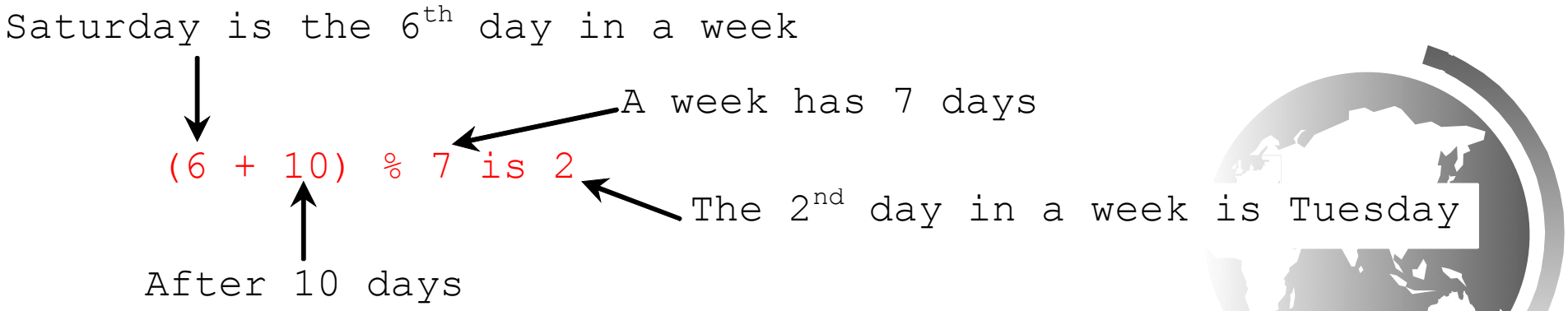
+, -, *, /, and %

5 / 2 yields an integer 2.
5.0 / 2 yields a double value 2.5

5 % 2 yields 1 (the remainder of the division)

Remainder Operator

Remainder is very useful in programming. For example, an even number % 2 is always 0 and an odd number % 2 is always 1. So you can use this property to determine whether a number is even or odd. Suppose today is Saturday and you and your friends are going to meet in 10 days. What day is in 10 days? You can find that day is Tuesday using the following expression:



Exponent Operations

```
System.out.println(Math.pow(2, 3));
// Displays 8.0
System.out.println(Math.pow(4, 0.5));
// Displays 2.0
System.out.println(Math.pow(2.5, 2));
// Displays 6.25
System.out.println(Math.pow(2.5, -2));
// Displays 0.16
```

Number Literals

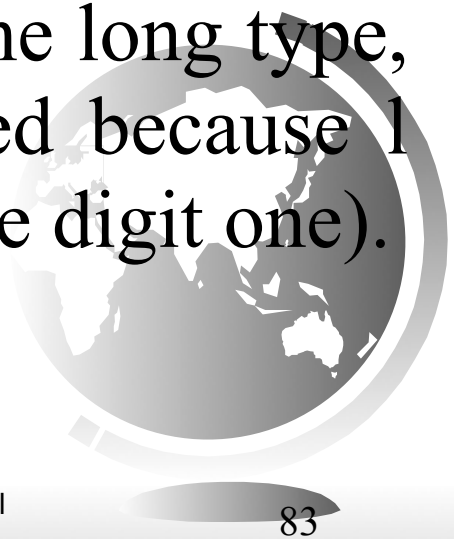
A *literal* is a constant value that appears directly in the program. For example, 34, 1,000,000, and 5.0 are literals in the following statements:

```
int i = 34;
long x = 1000000;
double d = 5.0;
```

Integer Literals

An integer literal can be assigned to an integer variable as long as it can fit into the variable. A compilation error would occur if the literal were too large for the variable to hold. For example, the statement byte b = 1000 would cause a compilation error, because 1000 cannot be stored in a variable of the byte type.

An integer literal is assumed to be of the int type, whose value is between -2^{31} (-2147483648) to $2^{31}-1$ (2147483647). To denote an integer literal of the long type, append it with the letter L or l. L is preferred because l (lowercase L) can easily be confused with 1 (the digit one).



Floating-Point Literals

Floating-point literals are written with a decimal point. By default, a floating-point literal is treated as a double type value. For example, 5.0 is considered a double value, not a float value. You can make a number a float by appending the letter f or F, and make a number a double by appending the letter d or D. For example, you can use 100.2f or 100.2F for a float number, and 100.2d or 100.2D for a double number.

double vs. float

The double type values are more accurate than the float type values. For example,

```
System.out.println("1.0 / 3.0 is " + 1.0 / 3.0);
```

displays `1.0 / 3.0 is 0.3333333333333333`

16 digits

```
System.out.println("1.0F / 3.0F is " + 1.0F / 3.0F);
```

displays `1.0F / 3.0F is 0.33333334`

7 digits

Arithmetic Expressions

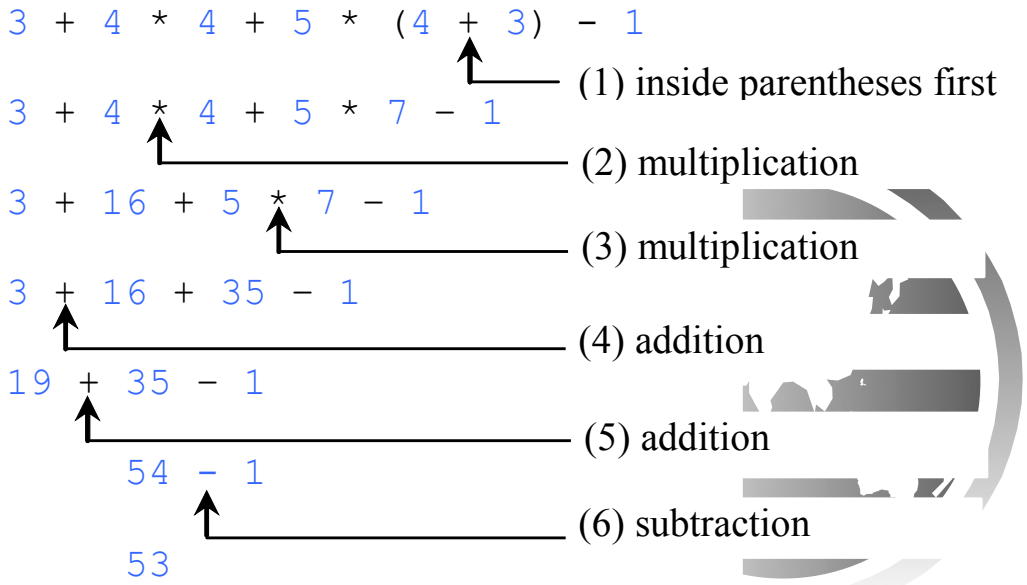
$$\frac{3+4x}{5} - \frac{10(y-5)(a+b+c)}{x} + 9\left(\frac{4}{x} + \frac{9+x}{y}\right)$$

is translated to

```
(3+4*x)/5 – 10*(y-5)*(a+b+c)/x + 9*(4/x + (9+x)/y)
```

How to Evaluate an Expression

Though Java has its own way to evaluate an expression behind the scene, the result of a Java expression and its corresponding arithmetic expression are the same. Therefore, you can safely apply the arithmetic rule for evaluating a Java expression.



Operator Precedence

- 2 * 3 + 4 is 10 not 14
- 2*(3+4) is 14
- Highest ++ --

  * / %

  + -

  < <= > >=

  == !=

  &&

  ||

  Lowest = += -= *= /= %=

  Use brackets when in doubt

Augmented Assignment Operators

Operator	*Name*	*Example*	*Equivalent*
`+=`	Addition assignment	`i += 8`	`i = i + 8`
`-=`	Subtraction assignment	`i -= 8`	`i = i - 8`
`*=`	Multiplication assignment	`i *= 8`	`i = i * 8`
`/=`	Division assignment	`i /= 8`	`i = i / 8`
`%=`	Remainder assignment	`i %= 8`	`i = i % 8`

Increment and Decrement Operators

Operator	*Name*	*Description*	*Example (assume i = 1)*
`++var`	preincrement	Increment `var` by `1`, and use the new `var` value in the statement	`int j = ++i;` `// j is 2, i is 2`
`var++`	postincrement	Increment `var` by `1`, but use the original `var` value in the statement	`int j = i++;` `// j is 1, i is 2`
`--var`	predecrement	Decrement `var` by `1`, and use the new `var` value in the statement	`int j = --i;` `// j is 0, i is 0`
`var--`	postdecrement	Decrement `var` by `1`, and use the original `var` value in the statement	`int j = i--;` `// j is 1, i is 0`

Increment and Decrement Operators, cont.

```
int i = 10;
int newNum = 10 * i++;
```

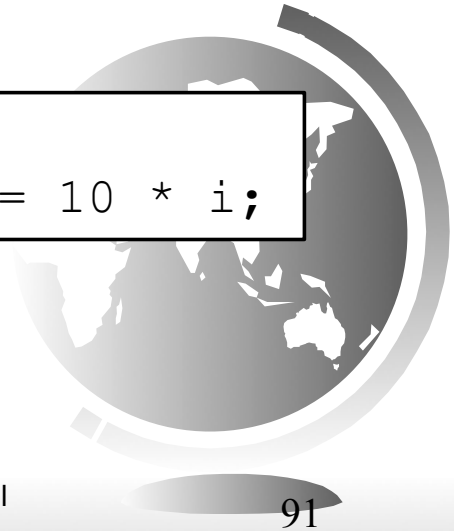
Same effect as

```
int newNum = 10 * i;
i = i + 1;
```

```
int i = 10;
int newNum = 10 * (++i);
```

Same effect as

```
i = i + 1;
int newNum = 10 * i;
```



Assignment Expressions and Assignment Statements

Prior to Java 2, all the expressions can be used as statements. Since Java 2, only the following types of expressions can be statements:

variable op= expression; // Where op is +, -, *, /, or %

++variable;

variable++;

--variable;

variable--;

bitwise operators

- & is bitwise AND (like both)

  | is bitwise OR (like either)

  ^ is XOR (like not equal)

  ~ is NOT

- eg if x = 9 1001

and y = 10 1010

- x & y is 8 1000
- x | y is 11 1011
- x ^ y is 3 0011
- (~ 0000 0001) is 1 inverting it results in: 1111 1110

bit shift operators

- >> is shift right
  eg if x = 7 or in binary 0000 0111
  x >> 1 is 0000 0011
- << is shift left so
  x << 1 is 0000 1110 = 14

Bit shift exercise

- Try out this code:

```
int i = 6;
System.out.println(i&1);
i>>=1;
System.out.println(i&1);
i>>=1;
System.out.println(i&1);
```

- Explain what you get

Numeric Type Conversion

Consider the following statements:

```
byte i = 100;
long k = i * 3 + 4;
double d = i * 3.1 + k / 2;
```

Char type

- char is for a single character, like
- char c = ‘A’; // note single quotes
- c++; makes c = ‘B’
- Strings are different - will see later
- Java uses Unicode not ASCII - 16 bits per character.

```
import java.applet.*;
import java.awt.*;

public class TestApplet extends Applet {
      public void paint(Graphics g) {

            char c;
            Font f = new Font("Arial Unicode
            MS",Font.PLAIN,20);
            g.setFont(f);
            c = '\u098a';          // Unicode constant
            g.drawString("Some Bengali: " + c,10,30 );
      }
}
```

Boolean Type

- If a variable is declared to be boolean, it is restricted to 2 values - true and false:
  - boolean result;
  - result = true;
  - result = (x > y);
    result is true if x is greater than y
- also < <= >= == != **== not the same as =**
- **&&** is and || is or **!** is not
- result = (x > y) && (y < 5);
  result is true if x is greater than y and y is less than 5
- && and || are short-cut operators

Conversion Rules

When performing a binary operation involving two operands of different types, Java automatically converts the operand based on the following rules:

1. If one of the operands is double, the other is converted into double.
2. Otherwise, if one of the operands is float, the other is converted into float.
3. Otherwise, if one of the operands is long, the other is converted into long.
4. Otherwise, both operands are converted into int.

Type Casting

Implicit casting

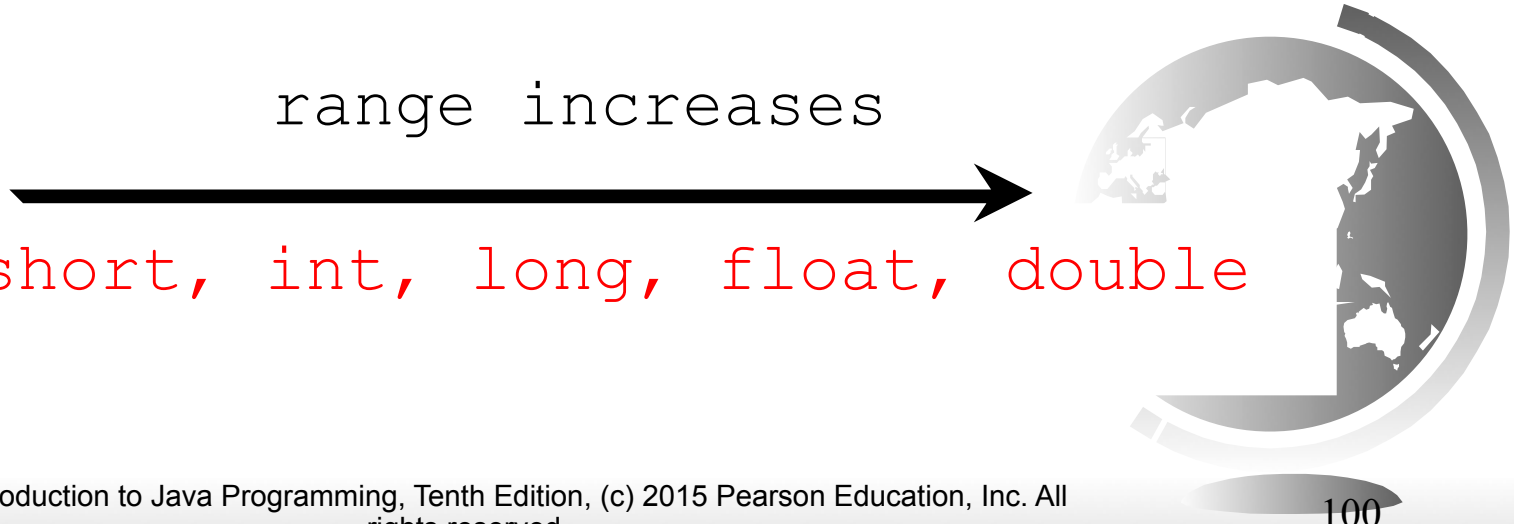
```
double d = 3;
```
(type widening)

Explicit casting

```
int i = (int)3.0;
```
(type narrowing)

```
int i = (int)3.9;
```
(Fraction part is truncated)

What is wrong? int x = 5 / 2.0;



Control - if

for example

```
if ( x== 5 ) {
        y = 2;
        a++;
}
else
        c++;
```

- round brackets around boolean expression
- indentation
- no then as in Visual Basic
- block { } around several steps to do
- no block if just one step -

```
if (x<4)
        a=4;
```

- else can be omitted if not needed

if example - validation

- for example

```
if ( ( age>0 )  &&  ( age < 130 )  )
    System.out.println('age is valid');
else
    {
    System.out.println('age is invalid');
    ..
    code to deal with error
    ..
    }
```

- beware of

```
if ( x==5 );
    y = 2;
```

switch - I

- used where many alternative actions are possible
- example -

```
switch (y) {
   case 5:       a = 7;
   case 9:       b = 3;
   case 4:       a = 8;
   default:      z = 2;
}
```

- y can be expression (like x + 4) but must be integral
- the 5, 9, 4 etc must be constants
- default is optional

switch - II

- The action ‘falls through’ - when one case is triggered, all the following options execute to the end of the switch
- So often combine with break – example:

```
switch (y) {
      case 5:          a = 7;      break;
      case 9:          b = 3;      break;
      case 4:          a = 8;      break;
  }
```

- include final break - not essential but good practice, since if add further option do not need to go back and add break to previous

Conditional operator ? ;

- Example:
  ```
  x =  ( y > 4 ) ? 7 : 3;
  ```
  if y is greater than 4, x becomes 7, and otherwise, it becomes 3
- in general:
  ```
  a ? b : c
  ```
  b is evaluated if a is true, c if it is not
- Example:
  ```
  int  x =9, y = 10 , a;
  a = (x > 9) ? x++ :  y++ ;
  ```
- after this a = 10, y is 11, x is still 9

loops - while

- loops repeat blocks of code - called iteration

Example - output the numbers 3, 6, 9, ... 99

```
x = 3;
while ( x<102 ){
    System.out.println( x );
    x += 3;
}
```

- in general:
  while (boolean expression)
  statement or block to repeat

- need to initialise variables

- may loop zero times if false first time

- use indentation

loops - do while

- example - output the numbers 3, 6, 9, ... 99

```
x = 3;
do {
    System.out.println( x );
    x += 3;
} while ( x<102 )
```

- in general,

```
do
  statement or block to repeat
while (boolean expression)
```

- unlike a while, it will execute the loop at least once

loops - for

- example - output the numbers 3, 6, 9, ... 99

```
for ( x = 3;  x<102;  x+=3  )
    System.out.println(x);
```

- in general:
  for (<initialisation> ; <loop while true>; <change every time>)
  < statement or block to repeat >
- may loop zero times

add up the integers 1 + 2 + 3 + ...100

```
int t = 0;  int x;
for (  x = 1; x<101;  x++)
    t += x;
System.out.println( t );
```

loops - for - II

- can use statement list, like:

```
int t;
int x;
for ( x = 1, t = 0;  x<101;  x++)
    t+=x;
System.out.println(t);
```

- can omit any part, (retain separating ;) like:

```
int t = 0;
int x = 1;
for ( ; x<101; x++)
    t+=x;
System.out.println(t);
```

- for (; ;) loops forever

loops - for - III

- can declare variable in for, like:

```
int t = 0;
for ( int x = 1;  x<101;  x++)
    t+=x;
System.out.println(t);
```

do not do this -

- in this case the scope of the variable is limited to the for statement

```
for ( int x = 1;  x<101;  x++);
                  t+=x;
```

Arrays - I

- An array is a set of boxes (elements) each labelled with a number (index)
- Arrays are declared and created as
  int [ ] numbers = new int [100];
  which makes an array of 100 integers called numbers
- or do it in 2 steps
  int [ ] numbers;   //declare it
  numbers = new int [100];   // create it
- or initialise it
  int [ ] numbers = { 4, 2, 1, 3, 5 };
- can have arrays of anything

Arrays - II

- Array elements referred to like
  numbers [4] = 18;
- Multi-dimensional arrays created and used like
  int [ ] [ ] table = new int [5] [10];
- table[3][4]=7;
- Array element numbering starts at 0

- int [ ] numbers = new int [100];
  creates 100 elements, from numbers[0] to numbers[99]
- array bounds are checked at compile time and run time

Arrays - sorting

```
int [] numbers = new int [5];

//.. put some numbers in the array, then...sort them

// a bubble sort..
 for (int i = 0; i < 5; i++)
  for (int j = 0; j < 4-i; j++)
    if (numbers[ j ] > numbers[ j+1]) {
        // swap them
       int temp;
        temp = numbers [j];
        numbers[j] = numbers[j+1];
        numbers[j+1] = temp;
   };
```

Array exercise

- Declare an array of 100 doubles
- Fill the array with random numbers (use Math.random();)
- Print them out

Common Errors and Pitfalls

- Common Error 1: Undeclared/Uninitialised Variables and Unused Variables
- Common Error 2: Integer Overflow
- Common Error 3: Round-off Errors
- Common Error 4: Unintended Integer Division
- Common Error 5: Redundant Input Objects

- Common Pitfall 1: Redundant Input Objects

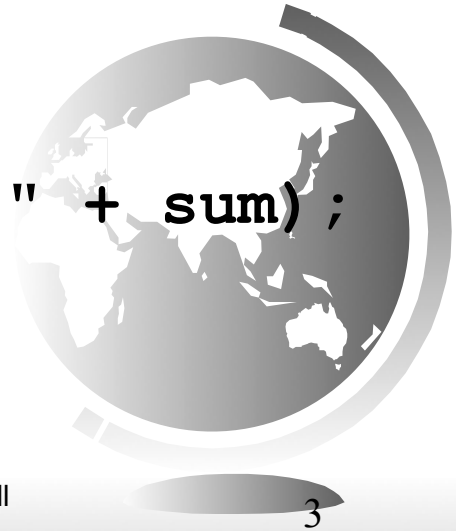
Chapter 6 Methods

Opening Problem

Find the sum of integers from 1 to 10, from 20 to 30, and from 35 to 45, respectively.

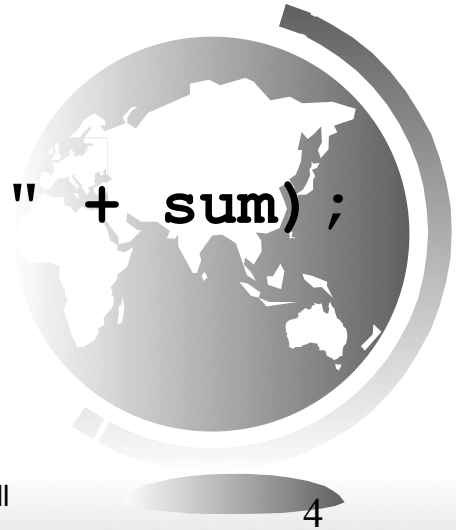
Problem

```
int sum = 0;
for (int i = 1; i <= 10; i++)
  sum += i;
System.out.println("Sum from 1 to 10 is " + sum);

sum = 0;
for (int i = 20; i <= 30; i++)
  sum += i;
System.out.println("Sum from 20 to 30 is " + sum);

sum = 0;
for (int i = 35; i <= 45; i++)
  sum += i;
System.out.println("Sum from 35 to 45 is " + sum);
```



Problem

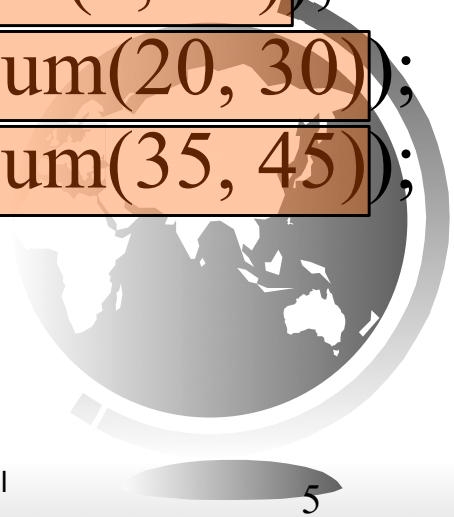
```
int sum = 0;
for (int i = 1; i <= 10; i++)
  sum += i;
System.out.println("Sum from 1 to 10 is " + sum);

sum = 0;
for (int i = 20; i <= 30; i++)
  sum += i;
System.out.println("Sum from 20 to 30 is " + sum);

sum = 0;
for (int i = 35; i <= 45; i++)
  sum += i;
System.out.println("Sum from 35 to 45 is " + sum);
```



Solution

```
public static int sum(int i1, int i2) {
  int sum = 0;
  for (int i = i1; i <= i2; i++)
    sum += i;
  return sum;
}
```

```
public static void main(String[] args) {
  System.out.println("Sum from 1 to 10 is " + sum(1, 10));
  System.out.println("Sum from 20 to 30 is " + sum(20, 30));
  System.out.println("Sum from 35 to 45 is " + sum(35, 45));
}
```



Objectives

- To define methods with formal parameters (§6.2).
- To invoke methods with actual parameters (i.e., arguments) (§6.2).
- To define methods with a return value (§6.3).
- To define methods without a return value (§6.4).
- To pass arguments by value (§6.5).
- To develop reusable code that is modular, easy to read, easy to debug, and easy to maintain (§6.6).
- To write a method that converts hexadecimals to decimals (§6.7).
- To use method overloading and understand ambiguous overloading (§6.8).
- To determine the scope of variables (§6.9).
- To apply the concept of method abstraction in software development (§6.10).
- To design and implement methods using stepwise refinement (§6.10).

Defining Methods

A method is a collection of statements that are grouped together to perform an operation.

Define a method

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

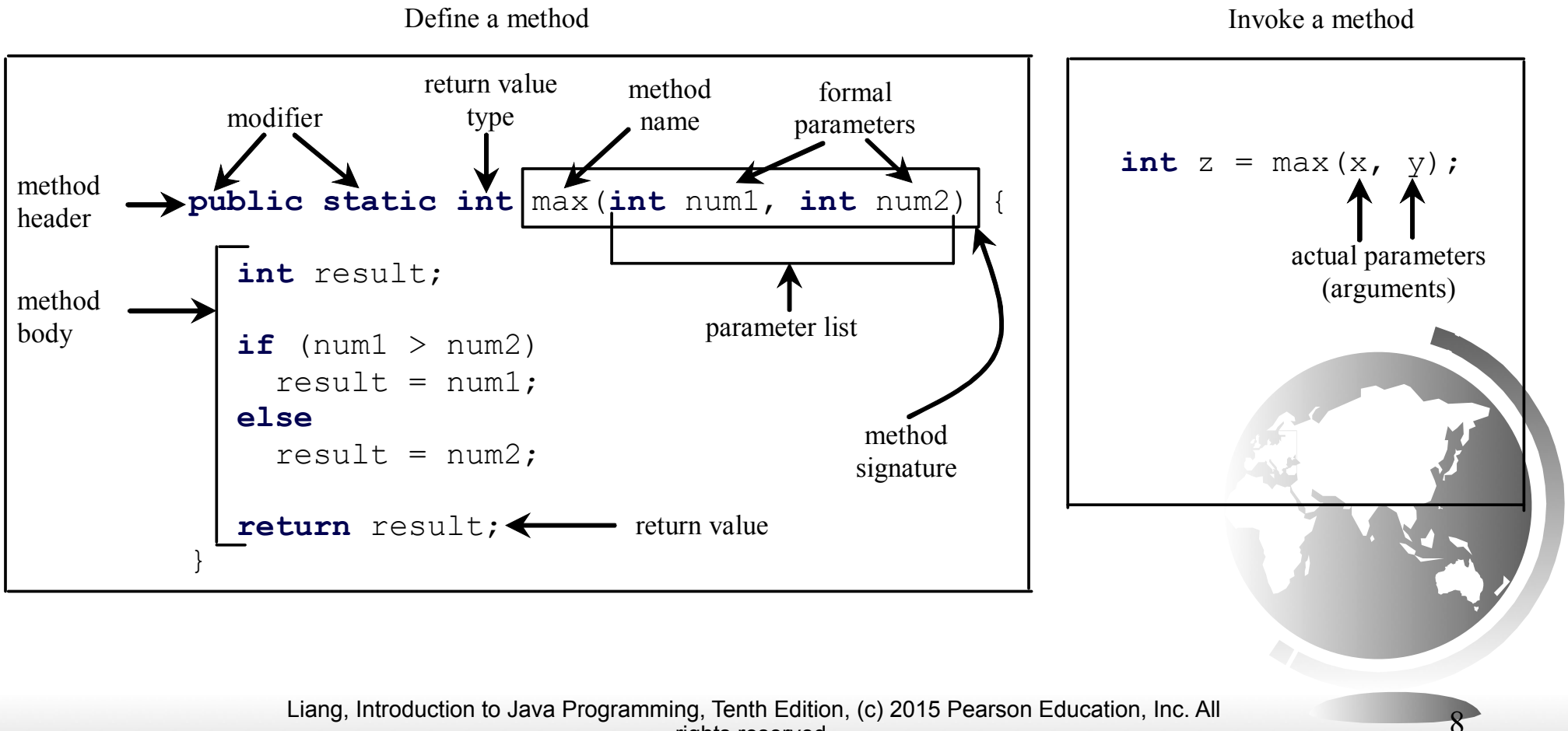
Invoke a method

```
int z = max(x, y);
```

actual parameters (arguments)

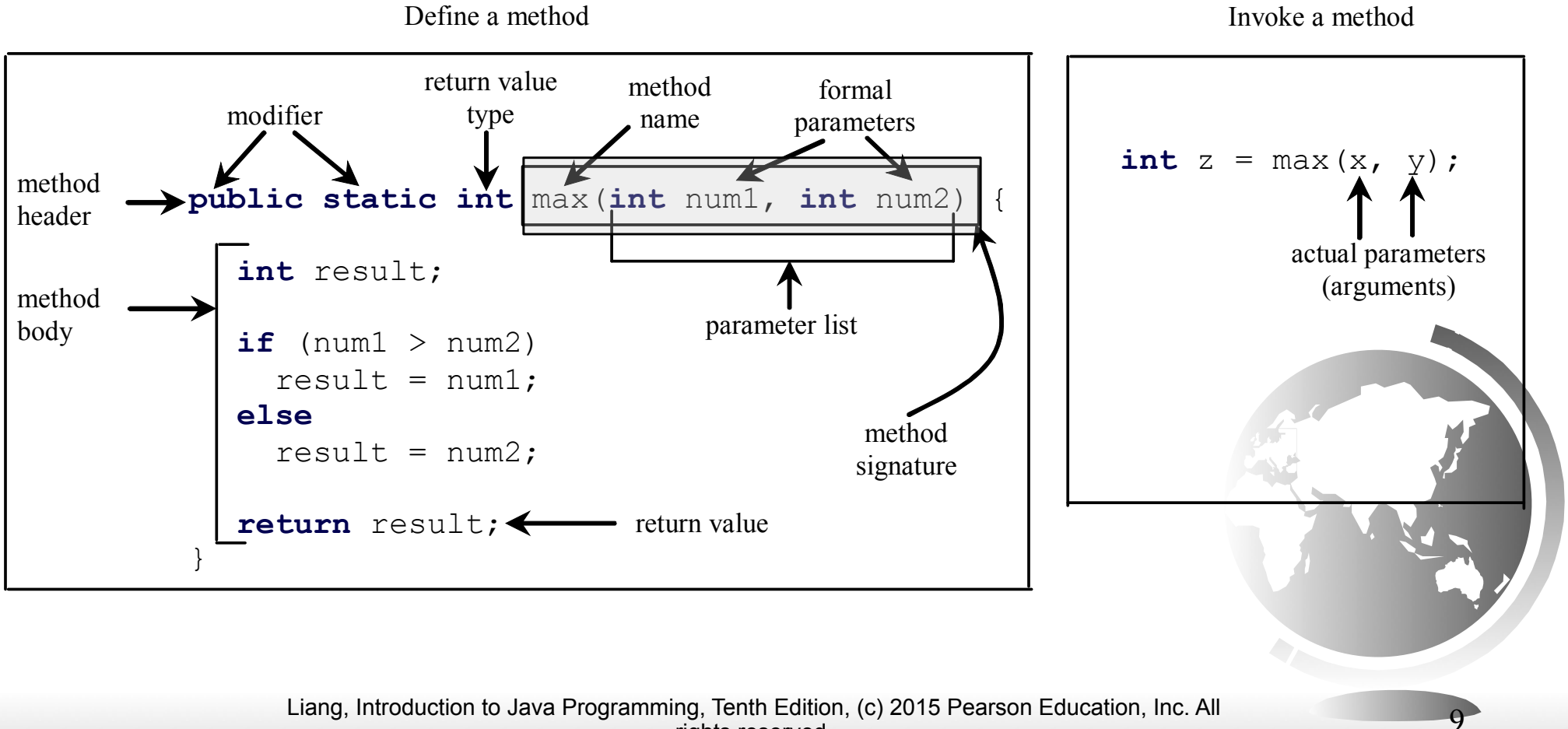
Defining Methods

A method is a collection of statements that are grouped together to perform an operation.



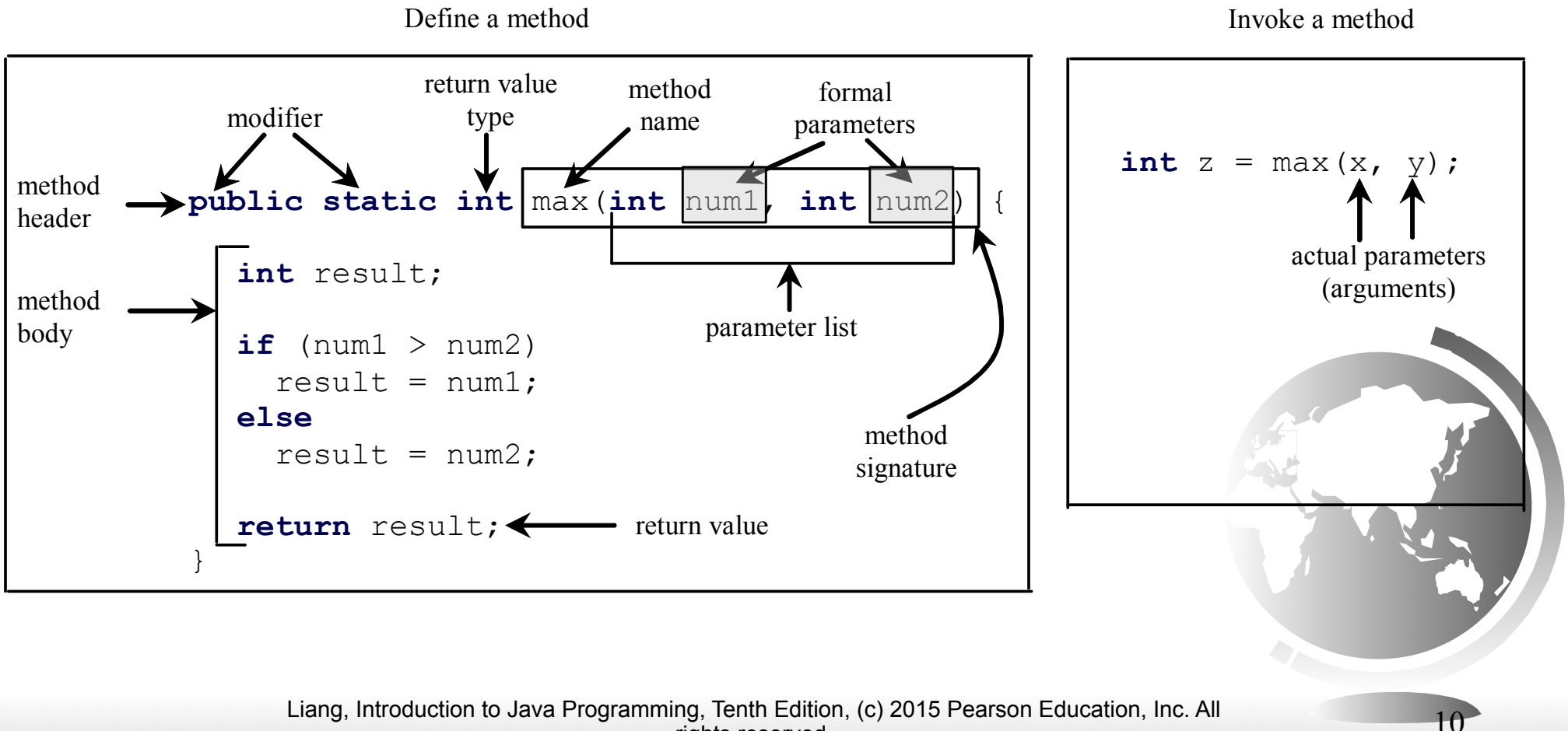
Method Signature

Method signature is the combination of the method name and the parameter list.



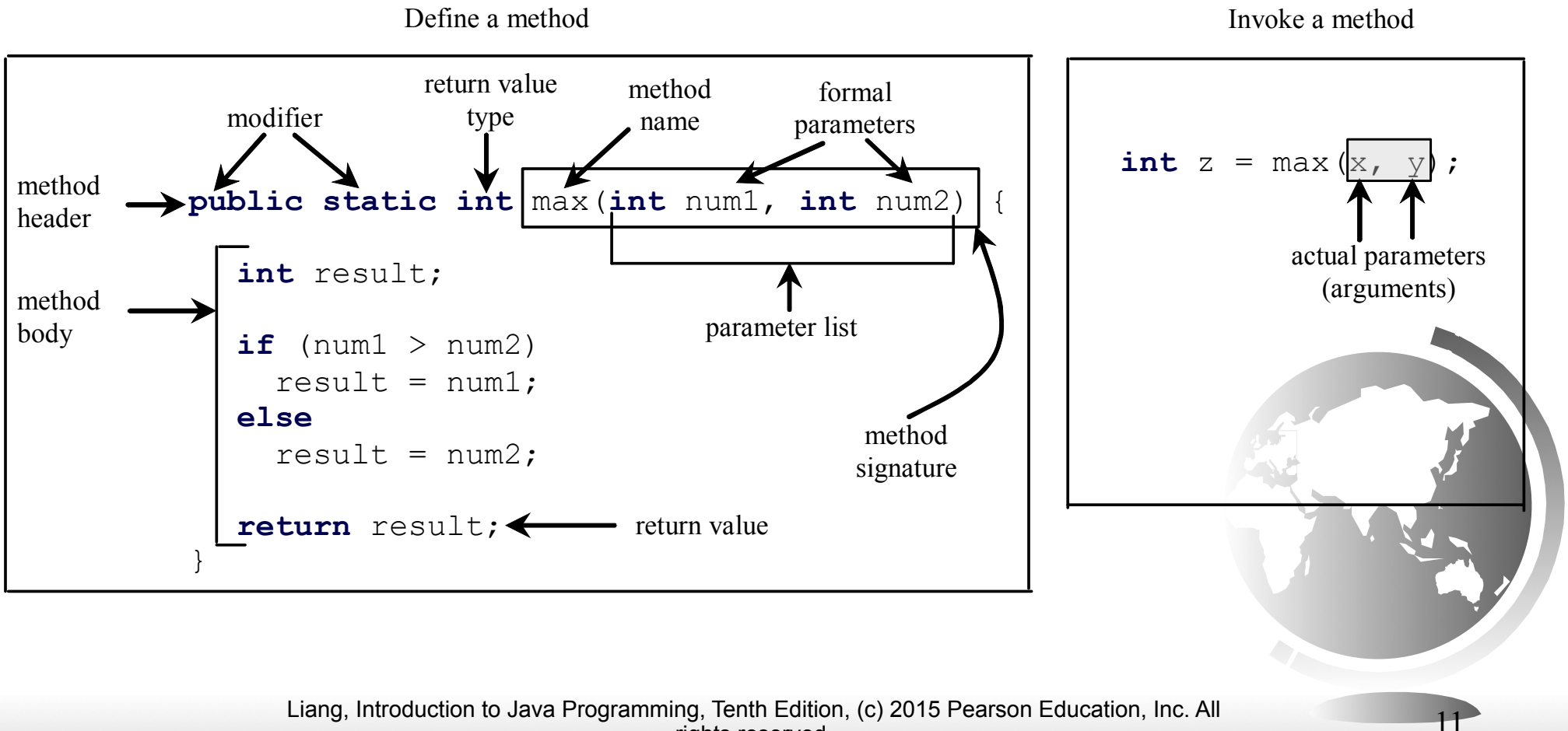
Formal Parameters

The variables defined in the method header are known as *formal parameters*.



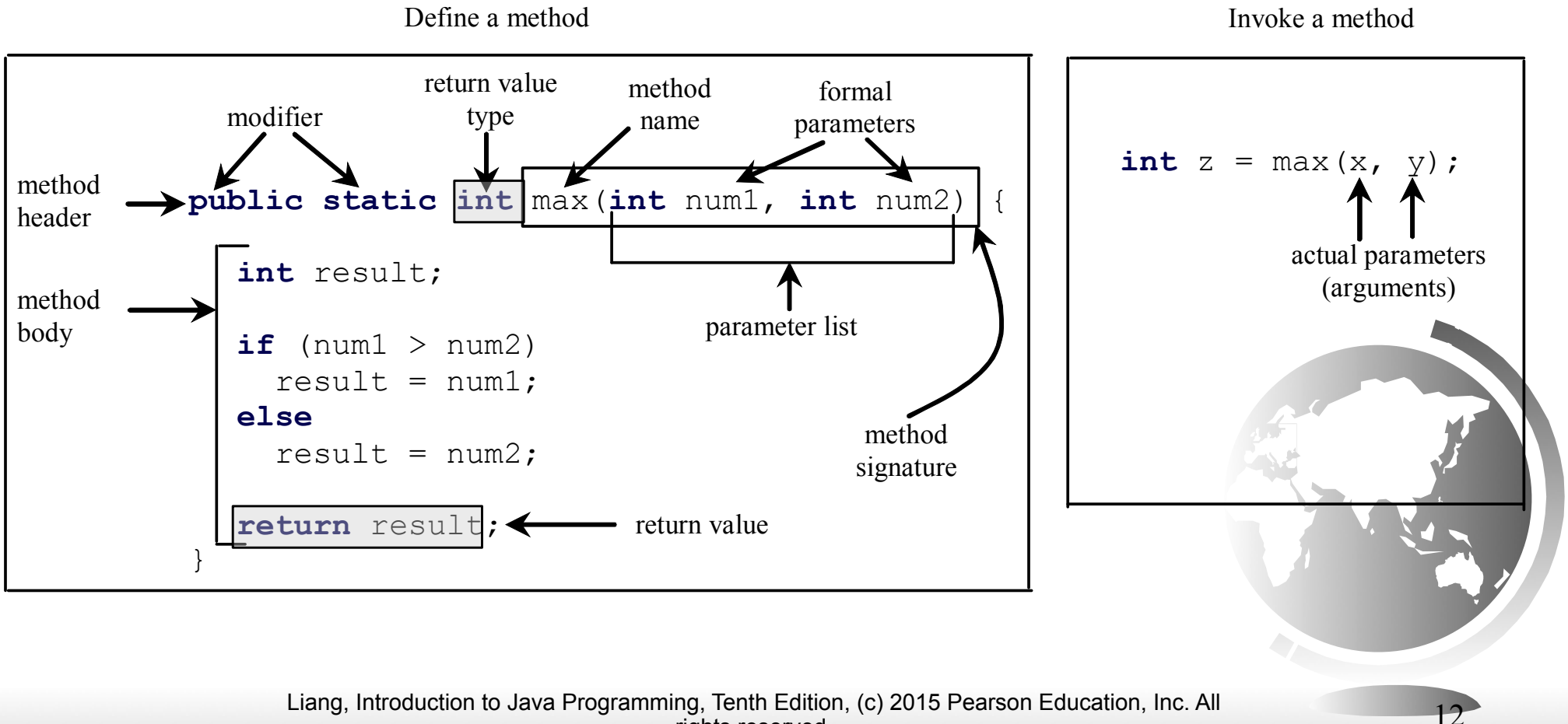
Actual Parameters

When a method is invoked, you pass a value to the parameter. This value is referred to as *actual parameter or argument*.



Return Value Type

A method may return a value. The returnValueType is the data type of the value the method returns. If the method does not return a value, the returnValueType is the keyword void. For example, the returnValueType in the main method is void.



Calling Methods

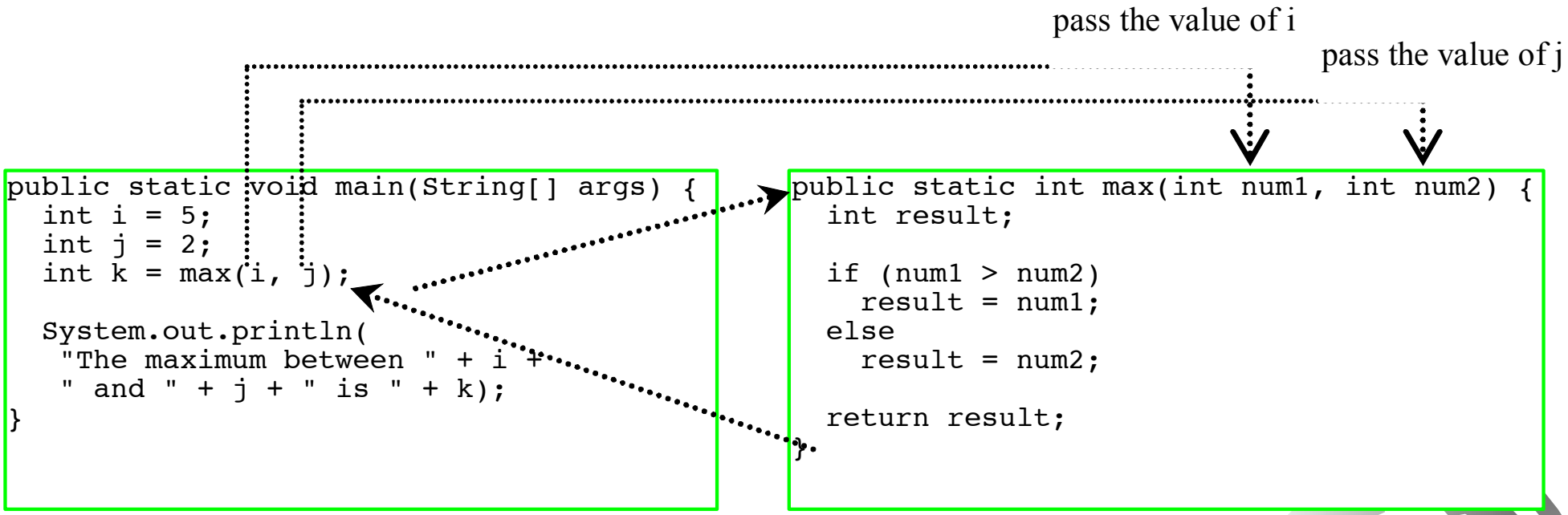
Testing the `max` method

This program demonstrates calling a method max to return the largest of the `int` values

TestMax.java

animation

Calling Methods, cont.



animation

Trace Method Invocation

i is now 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

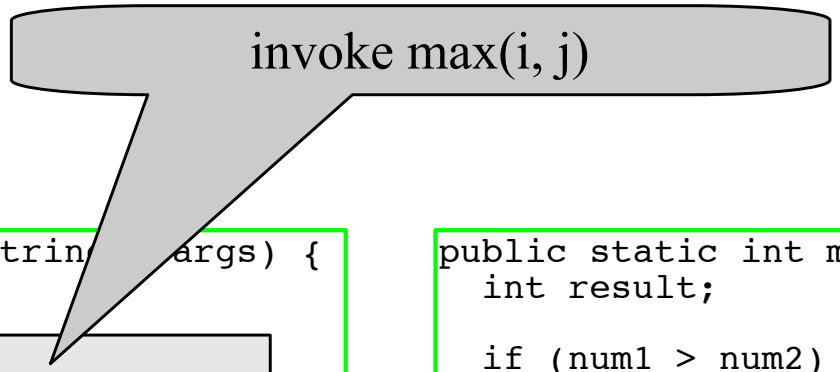
j is now 2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation




```
public static void main(Strin    args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

invoke max(i, j)
Pass the value of i to num1
Pass the value of j to num2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

declare variable result

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

(num1 > num2) is true since num1 is 5 and num2 is 2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

result is now 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

return result, which is 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
pu      tatic int max(int num1, int num2) {
        esult;

    num1 > num2)
    esult = num1;
  se
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

return max(i, j) and assign the return value to k

```
public static void main(Strin    args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

animation

Trace Method Invocation

Execute the print statement

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

CAUTION

A return statement is required for a value-returning method. The method shown below in (a) is logically correct, but it has a compilation error because the Java compiler thinks it possible that this method does not return any value.

```
public static int sign(int n) {
  if (n > 0)
    return 1;
  else if (n == 0)
    return 0;
  else if (n < 0)
    return -1;
}
```

(a)

Should be

```
public static int sign(int n) {
  if (n > 0)
    return 1;
  else if (n == 0)
    return 0;
  else
    return -1;
}
```

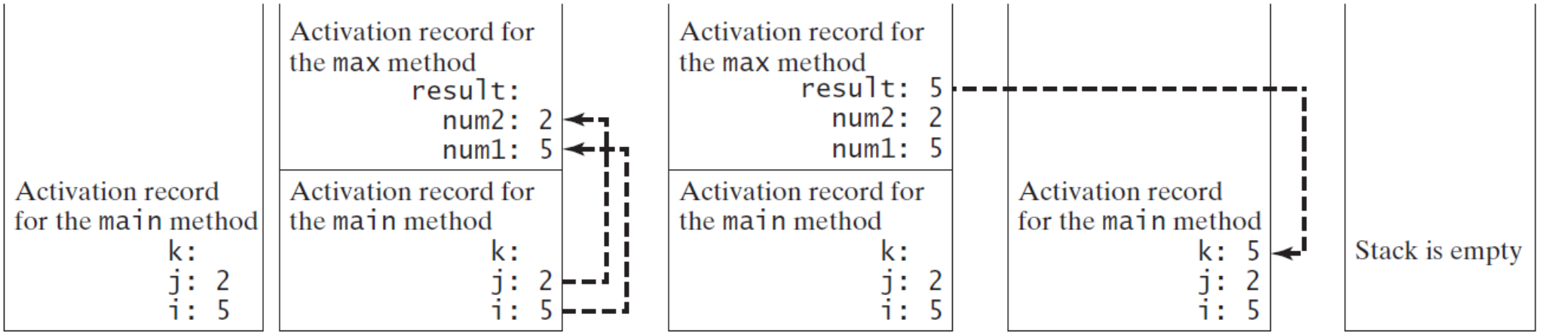
(b)

To fix this problem, delete *if (n < 0)* in (a), so that the compiler will see a return statement to be reached regardless of how the if statement is evaluated.

Reuse Methods from Other Classes

NOTE: One of the benefits of methods is for reuse. The max method can be invoked from any class besides TestMax. If you create a new class Test, you can invoke the max method using ClassName.methodName (e.g., TestMax.max).

Call Stacks



(a) The `main` method is invoked.

(b) The `max` method is invoked.

(c) The `max` method is being executed.

(d) The `max` method is finished and the return value is sent to `k`.

(e) The `main` method is finished.

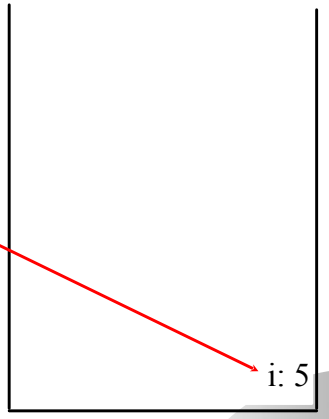
animation

Trace Call Stack

i is declared and initialized

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```



The main method is invoked.

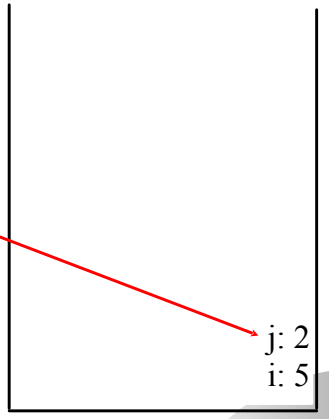
animation

Trace Call Stack

j is declared and initialized

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```



The main method is invoked.

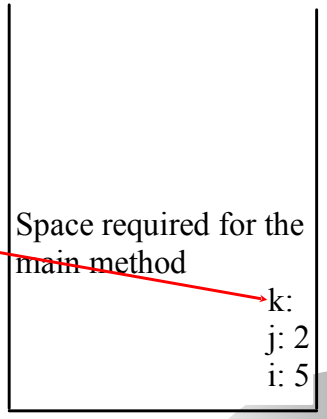
animation

Trace Call Stack

Declare k

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

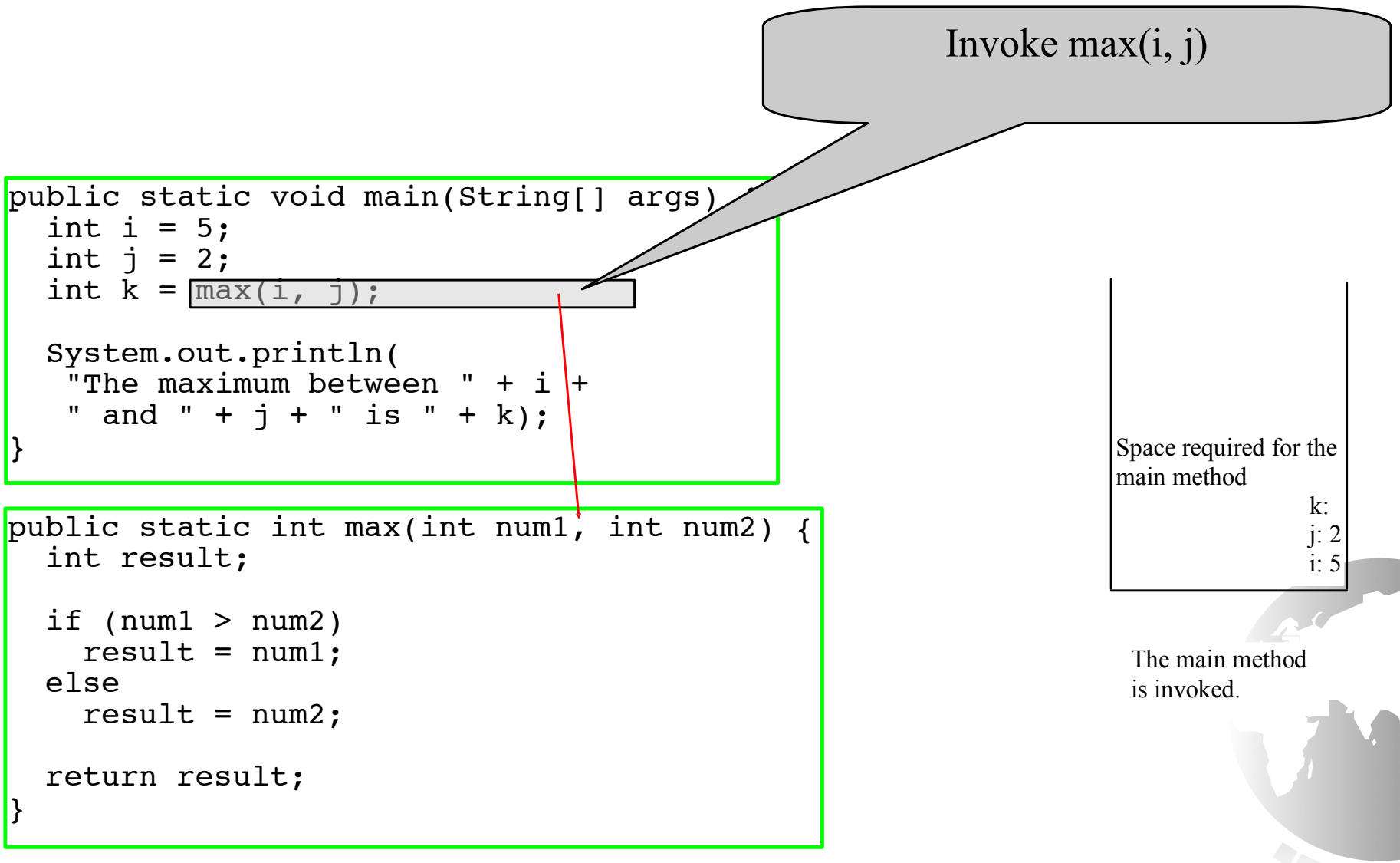
```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```



The main method is invoked.

animation

Trace Call Stack



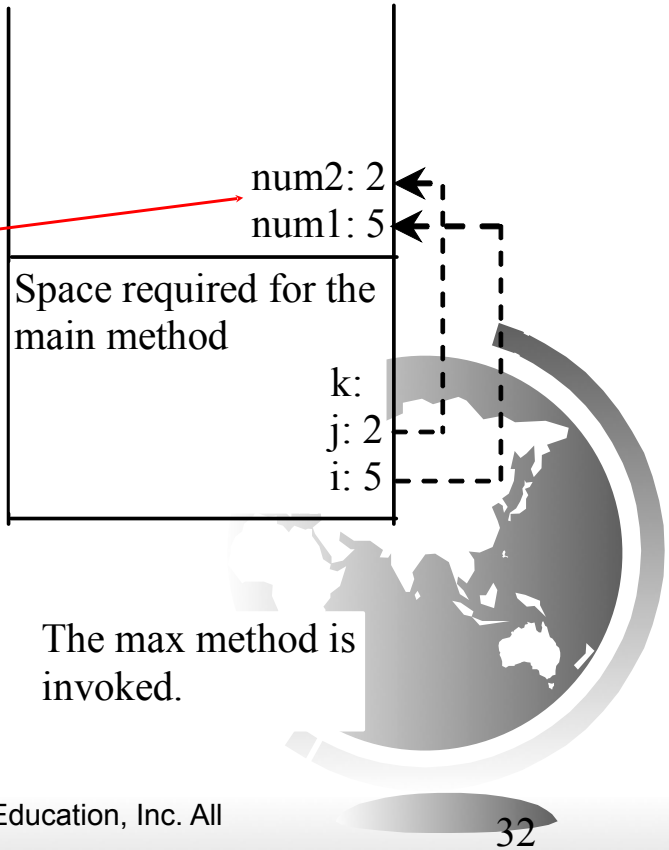
animation

Trace Call Stack

pass the values of i and j to num1 and num2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```



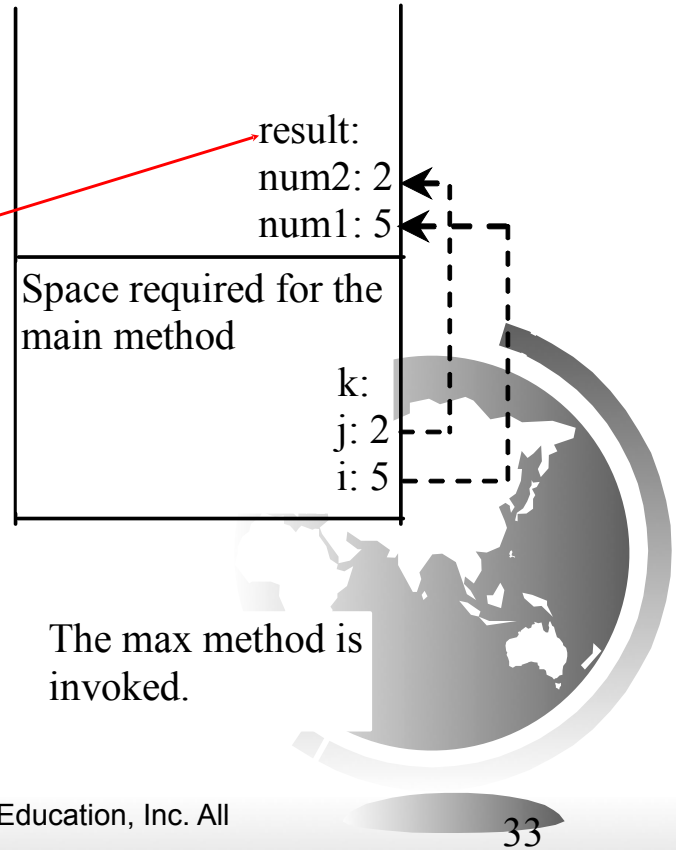
animation

Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Declare result



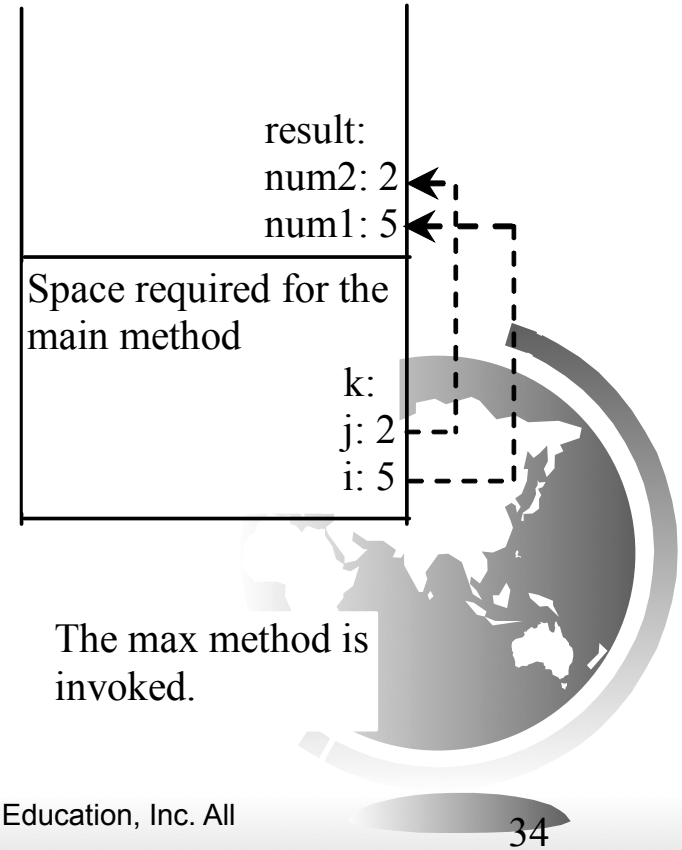
animation

Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

(num1 > num2) is true



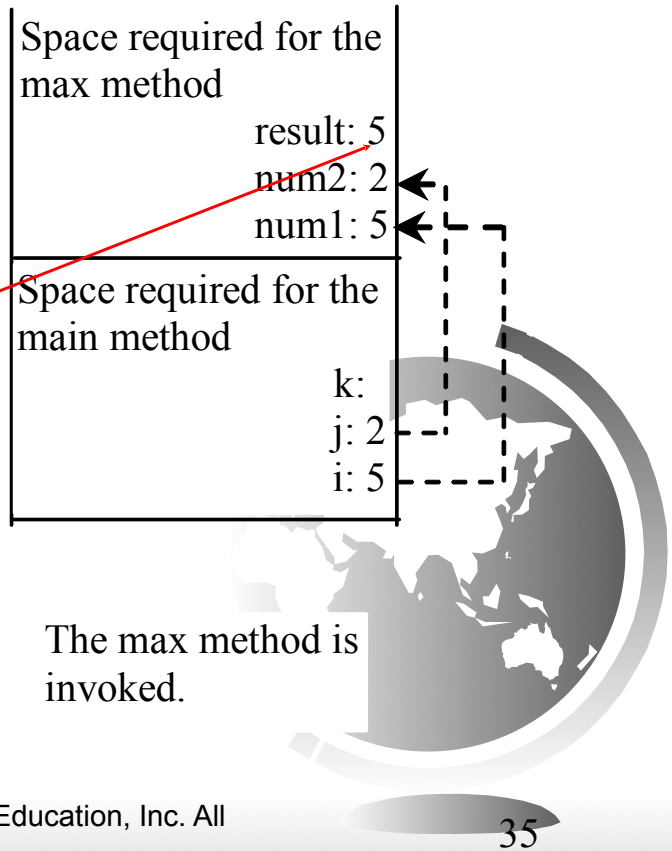
animation

Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
    "The maximum between " + i +
    " and " + j + " is " + k);
}
```

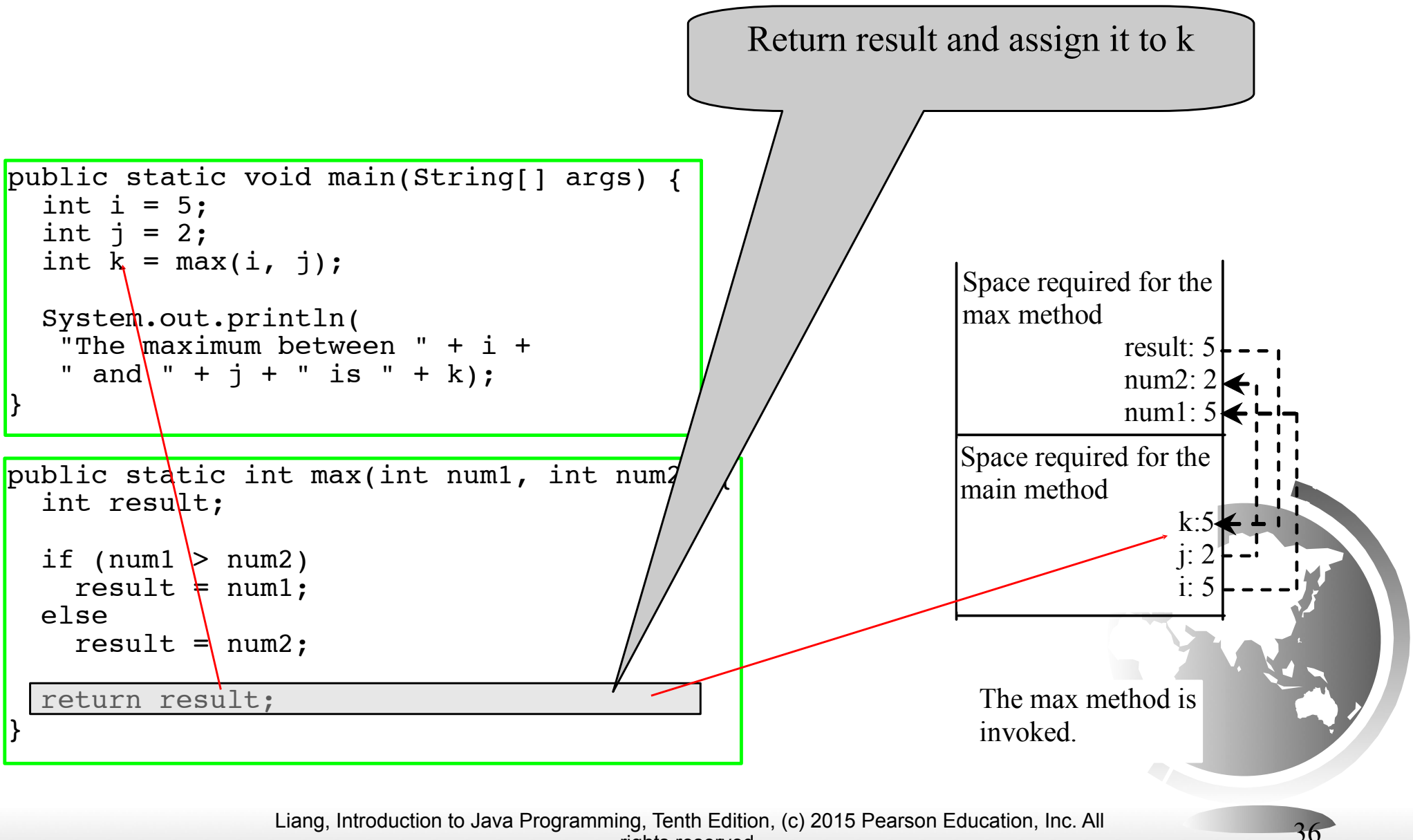
```
public static int max(int num1, int num2)
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Assign num1 to result



animation

Trace Call Stack



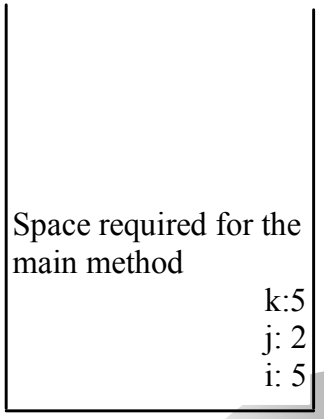
animation

Trace Call Stack

Execute print statement

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```



The main method is invoked.

void Method Example

This type of method does not return a value. The method performs some actions.

TestVoidMethod.java

TestReturnGradeMethod.java

Passing Parameters

```
public static void nPrintln(String message, int n) {
  for (int i = 0; i < n; i++)
    System.out.println(message);
}
```

Suppose you invoke the method using

nPrintln("Welcome to Java", 5);

What is the output?

Suppose you invoke the method using

nPrintln("Computer Science", 15);

What is the output?

Can you invoke the method using

nPrintln(15, "Computer Science");

Pass by Value

This program demonstrates passing values to the methods.

Increment.java

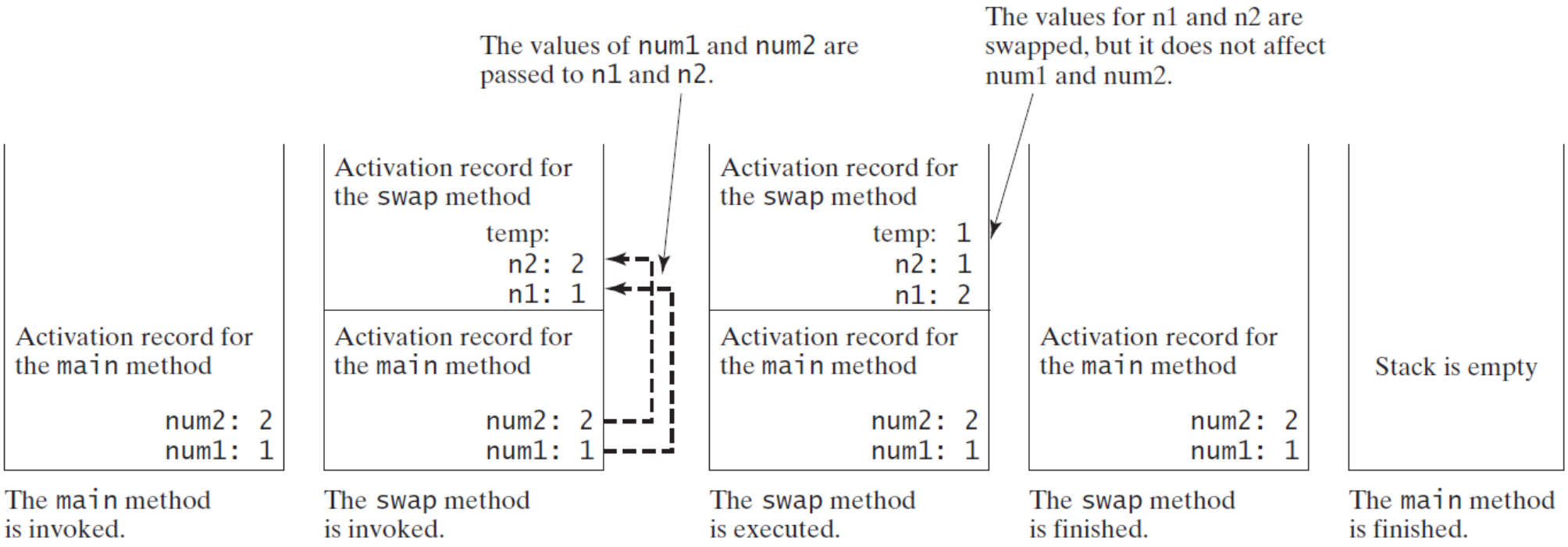
Pass by Value

Testing Pass by value

This program demonstrates passing values to the methods.

TestPassByValue.java

Pass by Value, cont.



Modularising Code

Methods can be used to reduce redundant coding and enable code reuse. Methods can also be used to modularise code and improve the quality of the program.

GreatestCommonDivisorMethod.java

PrimeNumberMethod.java

Case Study: Converting Hexadecimals to Decimals

Write a method that converts a hexadecimal number into a decimal number.

ABCD =>

A*16^3 + B*16^2 + C*16^1+ D*16^0

= ((A*16 + B)*16 + C)*16+D

= ((10*16 + 11)*16 + 12)*16+13 = ?

Hex2Dec.java

Overloading Methods

Overloading the `max` Method

```
public static double max(double num1, double
  num2) {
   if (num1 > num2)
     return num1;
   else
     return num2;
}
```

TestMethodOverloading.java

Ambiguous Invocation

Sometimes there may be two or more possible matches for an invocation of a method, but the compiler cannot determine the most specific match. This is referred to as *ambiguous invocation*. Ambiguous invocation is a compile error.

Ambiguous Invocation

```
public class AmbiguousOverloading {
  public static void main(String[] args) {
    System.out.println(max(1, 2));
  }

  public static double max(int num1, double num2) {
    if (num1 > num2)
      return num1;
    else
      return num2;
  }

  public static double max(double num1, int num2) {
    if (num1 > num2)
      return num1;
    else
      return num2;
  }
}
```

Scope of Local Variables

A local variable: a variable defined inside a method.

Scope: the part of the program where the variable can be referenced.

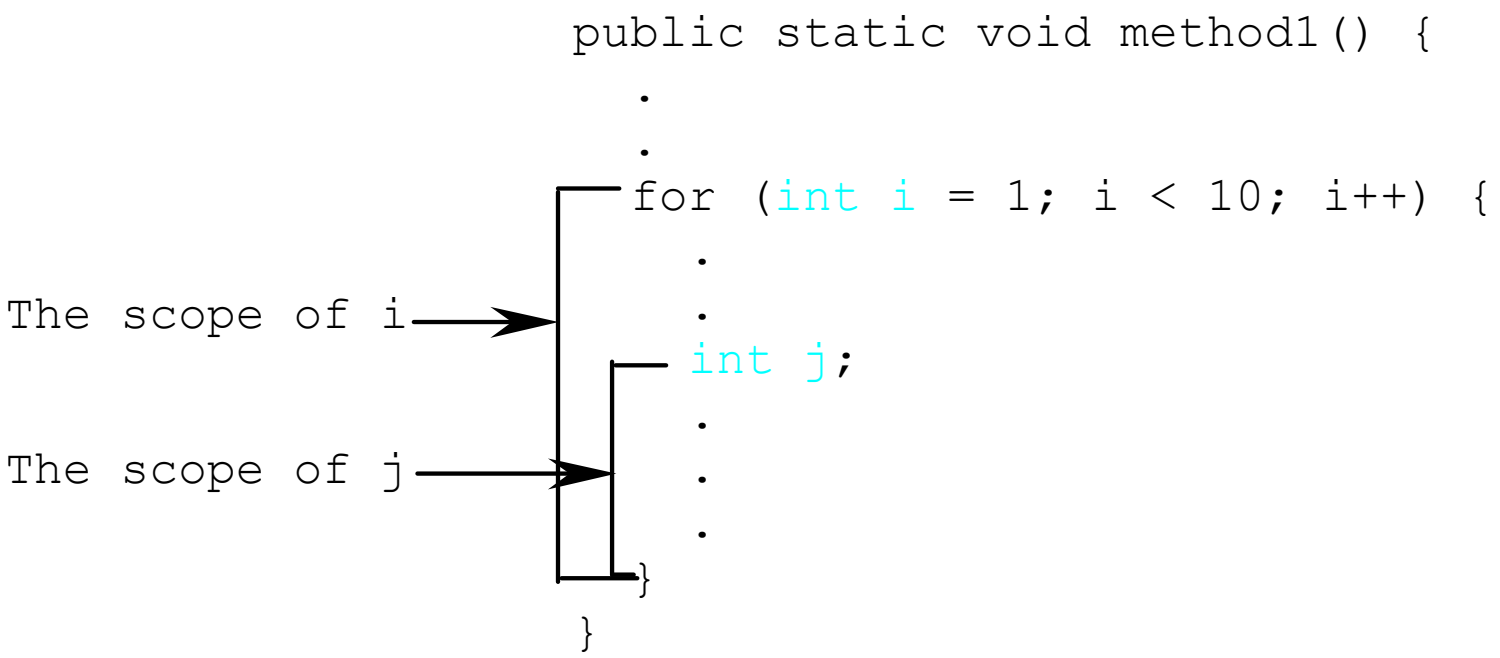
The scope of a local variable starts from its declaration and continues to the end of the block that contains the variable. A local variable must be declared before it can be used.

Scope of Local Variables, cont.

You can declare a local variable with the same name multiple times in different non-nesting blocks in a method, but you cannot declare a local variable twice in nested blocks.

Scope of Local Variables, cont.

A variable declared in the initial action part of a for loop header has its scope in the entire loop. But a variable declared inside a for loop body has its scope limited in the loop body from its declaration and to the end of the block that contains the variable.



Scope of Local Variables, cont.

It is fine to declare i in two non-nesting blocks

```
public static void method1() {
  int x = 1;
  int y = 1;

  for (int i = 1; i < 10; i++) {
    x += i;
  }

  for (int i = 1; i < 10; i++) {
    y += i;
  }
}
```

It is wrong to declare i in two nesting blocks

```
public static void method2() {

  int i = 1;
  int sum = 0;

  for (int i = 1; i < 10; i++)
    sum += i;
  }
}
```

Scope of Local Variables, cont.

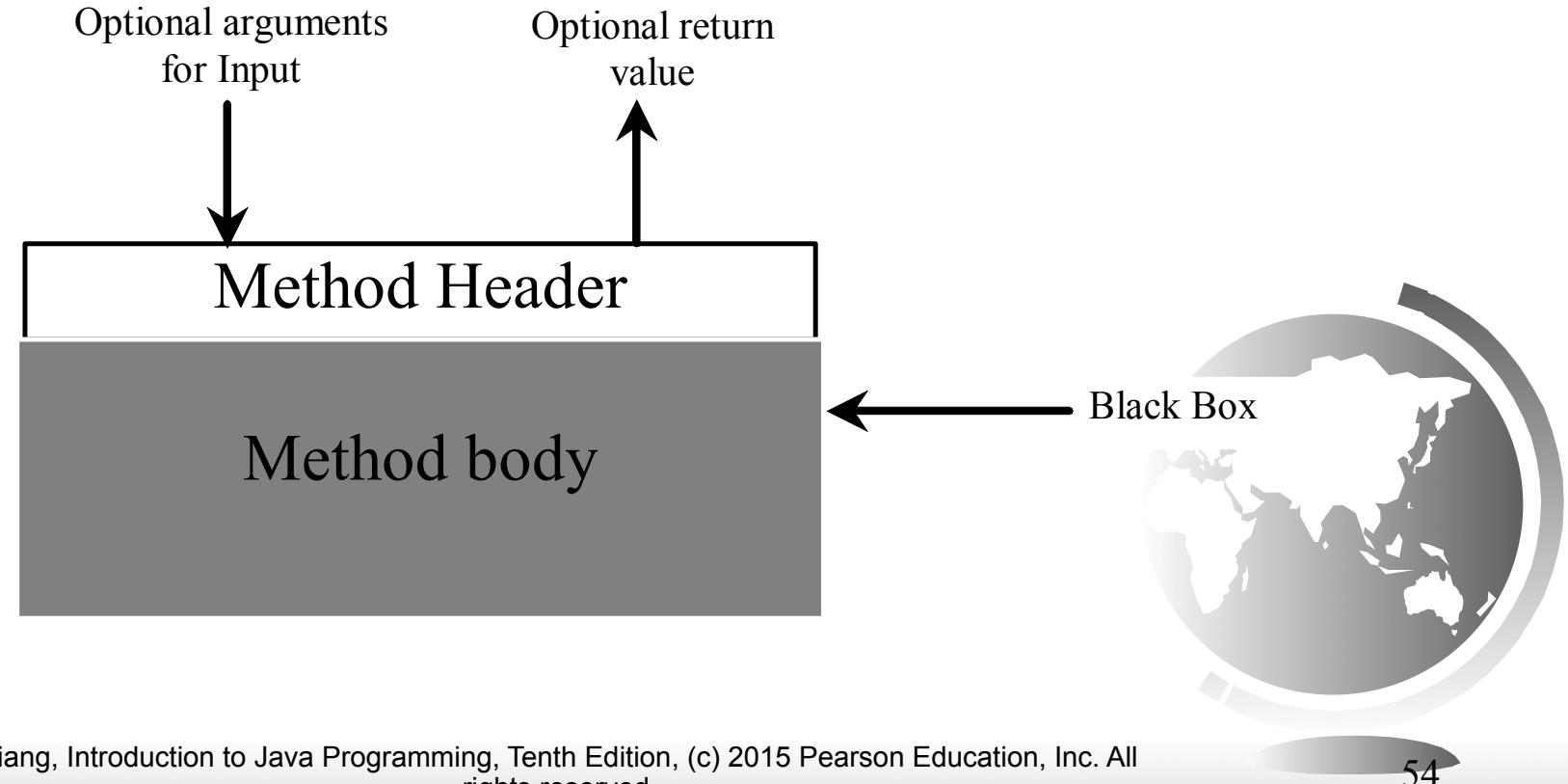
```
// Fine with no errors
public static void correctMethod() {
  int x = 1;
  int y = 1;
  // i is declared
  for (int i = 1; i < 10; i++) {
    x += i;
  }
  // i is declared again
  for (int i = 1; i < 10; i++) {
    y += i;
  }
}
```

Scope of Local Variables, cont.

```
// With errors
public static void incorrectMethod() {
  int x = 1;
  int y = 1;
  for (int i = 1; i < 10; i++) {
    int x = 0;
    x += i;
  }
}
```

Method Abstraction

You can think of the method body as a black box that contains the detailed implementation for the method.



Benefits of Methods

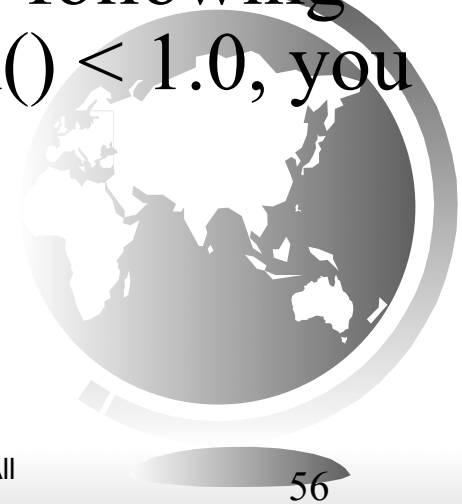
- Write a method once and reuse it anywhere.
- Information hiding. Hide the implementation from the user.
- Reduce complexity.

Case Study: Generating Random Characters

Computer programs process numerical data and characters. You have seen many examples that involve numerical data. It is also important to understand characters and how to process them.

As introduced in Section 2.9, each character has a unique Unicode between 0 and FFFF in hexadecimal (65535 in decimal). To generate a random character is to generate a random integer between 0 and 65535 using the following expression: (note that since 0 <= Math.random() < 1.0, you have to add 1 to 65535.)

```
(int)(Math.random() * (65535 + 1))
```



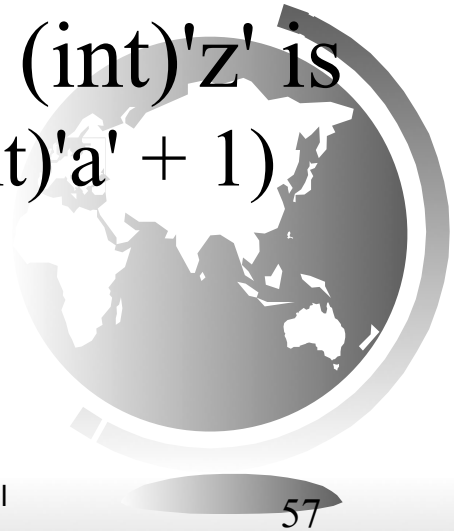
Case Study: Generating Random Characters, cont.

Now let us consider how to generate a random lowercase letter. The Unicode for lowercase letters are consecutive integers starting from the Unicode for 'a', then for 'b', 'c', ..., and 'z'. The Unicode for 'a' is

```
(int)'a'
```

So, a random integer between (int)'a' and (int)'z' is

```
(int)((int)'a' + Math.random() * ((int)'z' - (int)'a' + 1)
```



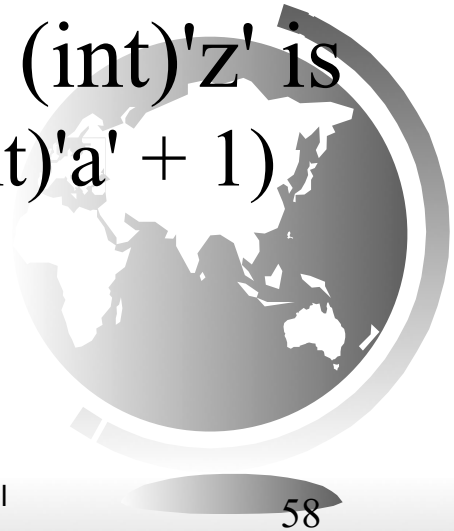
Case Study: Generating Random Characters, cont.

Now let us consider how to generate a random lowercase letter. The Unicode for lowercase letters are consecutive integers starting from the Unicode for 'a', then for 'b', 'c', ..., and 'z'. The Unicode for 'a' is

```
(int)'a'
```

So, a random integer between (int)'a' and (int)'z' is

```
(int)((int)'a' + Math.random() * ((int)'z' - (int)'a' + 1)
```



Case Study: Generating Random Characters, cont.

As discussed in Chapter 2., all numeric operators can be applied to the char operands. The char operand is cast into a number if the other operand is a number or a character. So, the preceding expression can be simplified as follows:

```
'a' + Math.random() * ('z' - 'a' + 1)
```

So a random lowercase letter is

```
(char)('a' + Math.random() * ('z' - 'a' + 1))
```

Case Study: Generating Random Characters, cont.

To generalise the foregoing discussion, a random character between any two characters ch1 and ch2 with ch1 < ch2 can be generated as follows:

```
(char)(ch1 + Math.random() * (ch2 – ch1 + 1))
```

The RandomCharacter Class

```
// RandomCharacter.java: Generate random characters
public class RandomCharacter {
  /** Generate a random character between ch1 and ch2 */
  public static char getRandomCharacter(char ch1, char ch2) {
    return (char)(ch1 + Math.random() * (ch2 - ch1 + 1));
  }

  /** Generate a random lowercase letter */
  public static char getRandomLowerCaseLetter() {
    return getRandomCharacter('a', 'z');
  }

  /** Generate a random uppercase letter */
  public static char getRandomUpperCaseLetter() {
    return getRandomCharacter('A', 'Z');
  }

  /** Generate a random digit character */
  public static char getRandomDigitCharacter() {
    return getRandomCharacter('0', '9');
  }

  /** Generate a random character */
  public static char getRandomCharacter() {
    return getRandomCharacter('\u0000', '\uFFFF');
  }
}
```

RandomCharacter.java

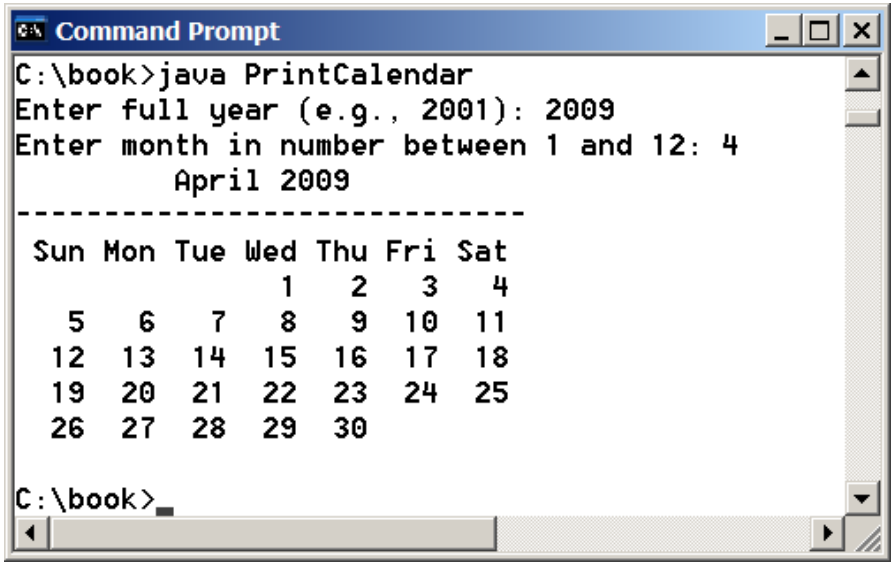
TestRandomCharacter.java

Stepwise Refinement (Optional)

The concept of method abstraction can be applied to the process of developing programs. When writing a large program, you can use the "divide and conquer" strategy, also known as *stepwise refinement*, to decompose it into subproblems. The subproblems can be further decomposed into smaller, more manageable problems.

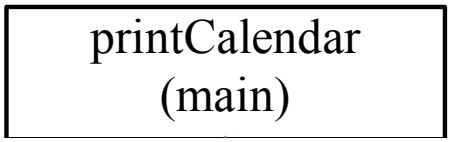
PrintCalender Case Study

Let us use the PrintCalendar example to demonstrate the stepwise refinement approach.

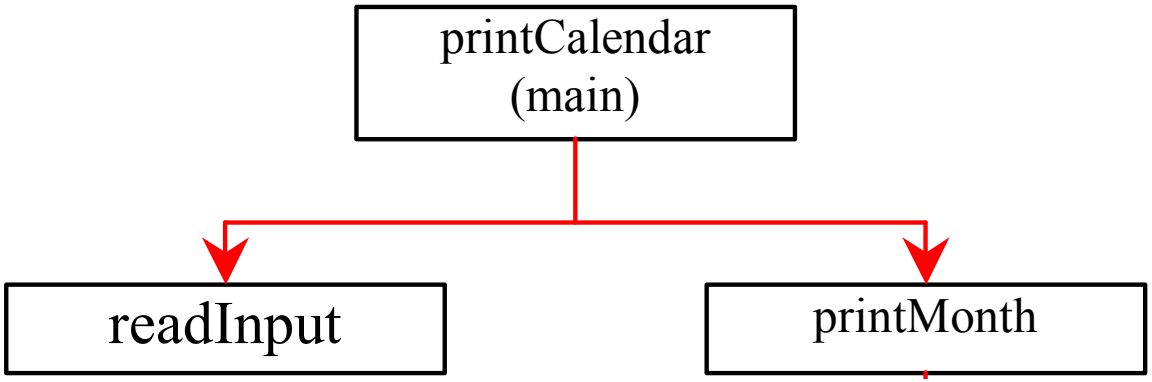


PrintCalendar.java

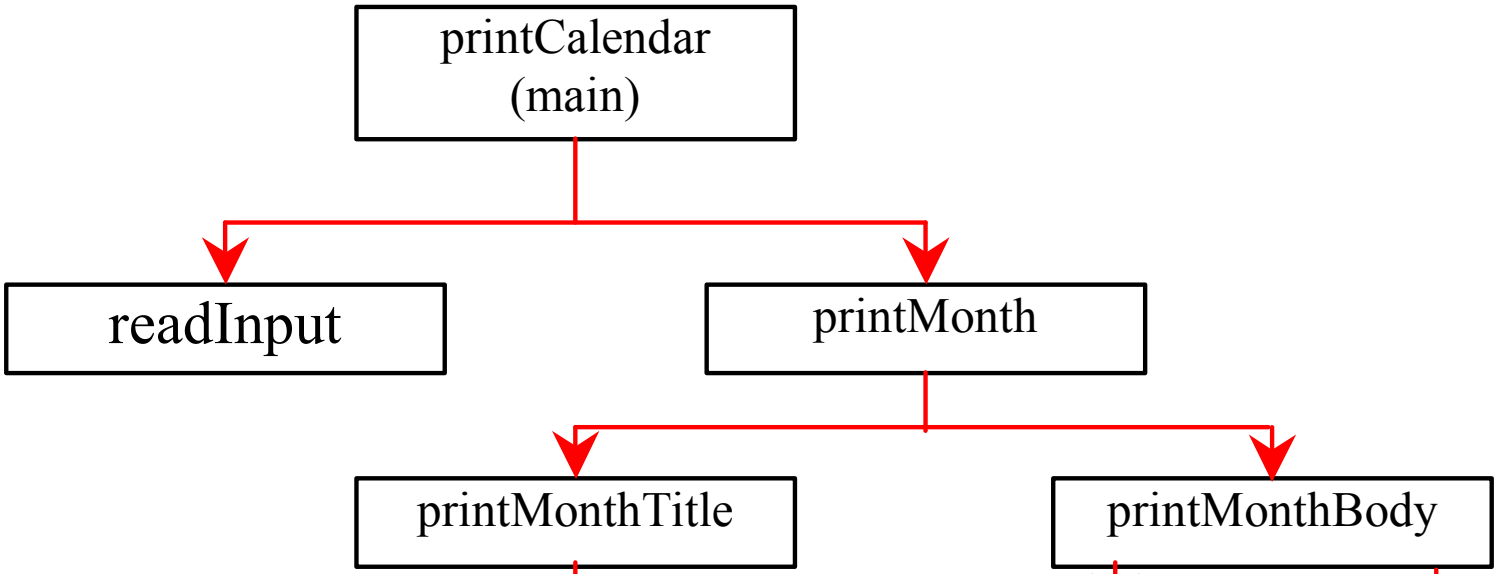
Design Diagram



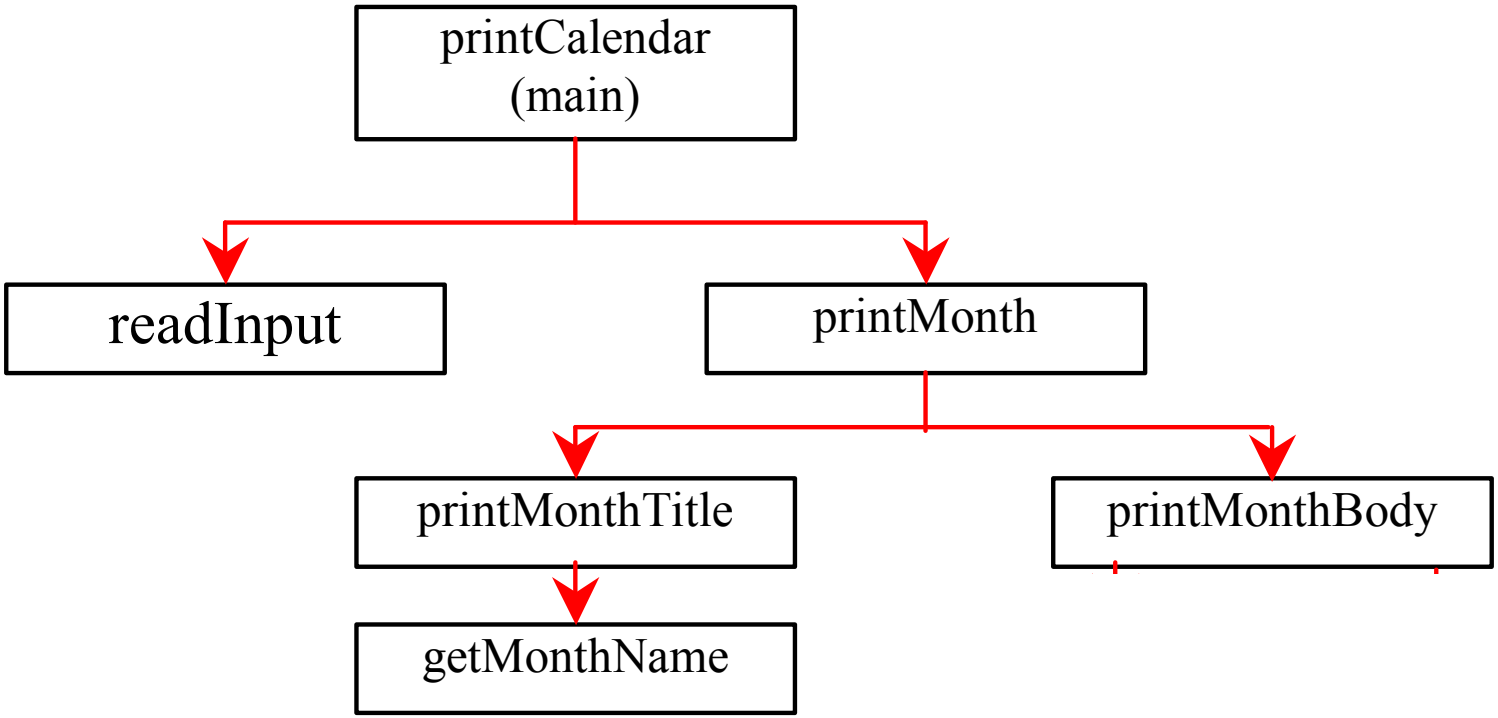
Design Diagram



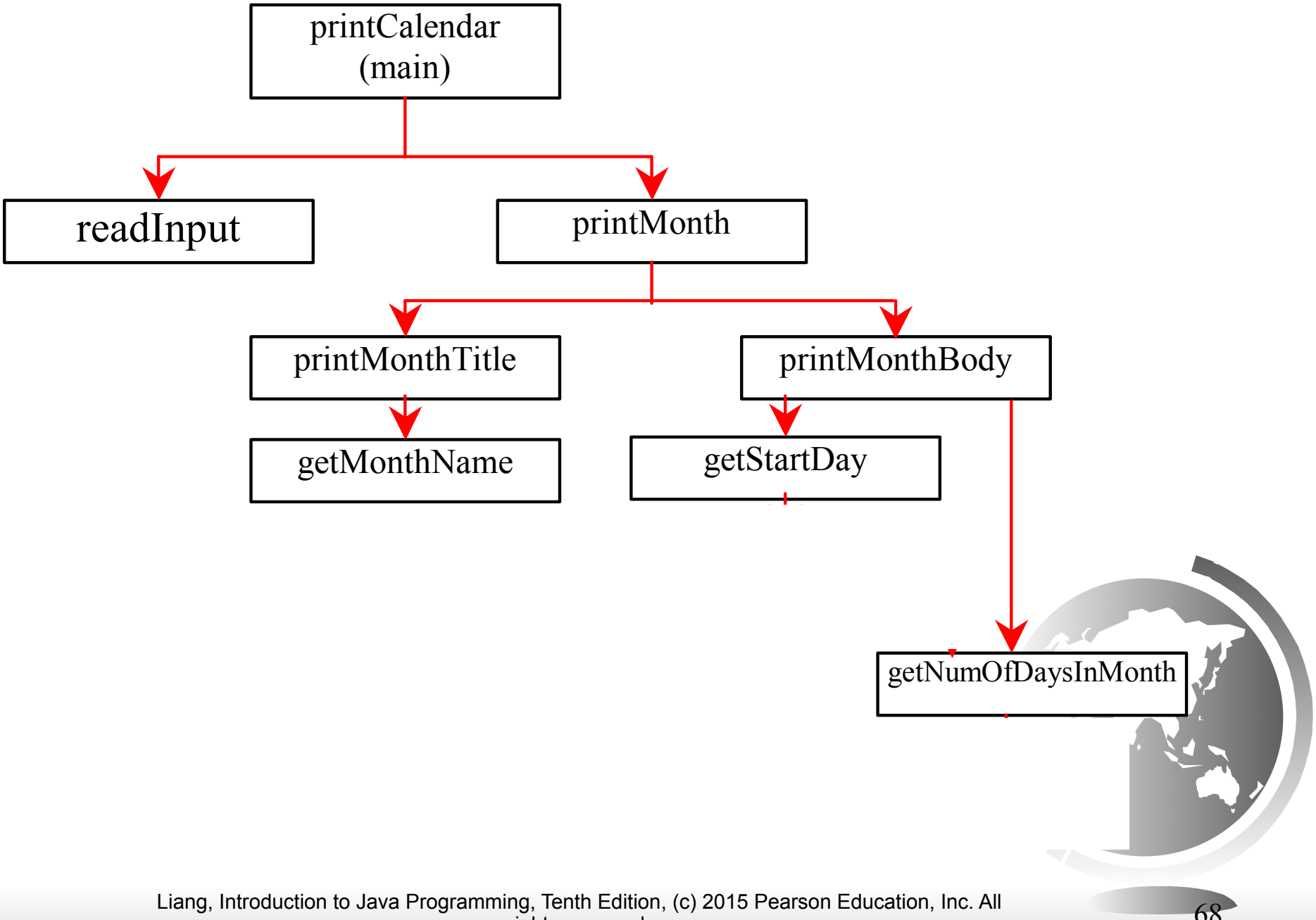
Design Diagram



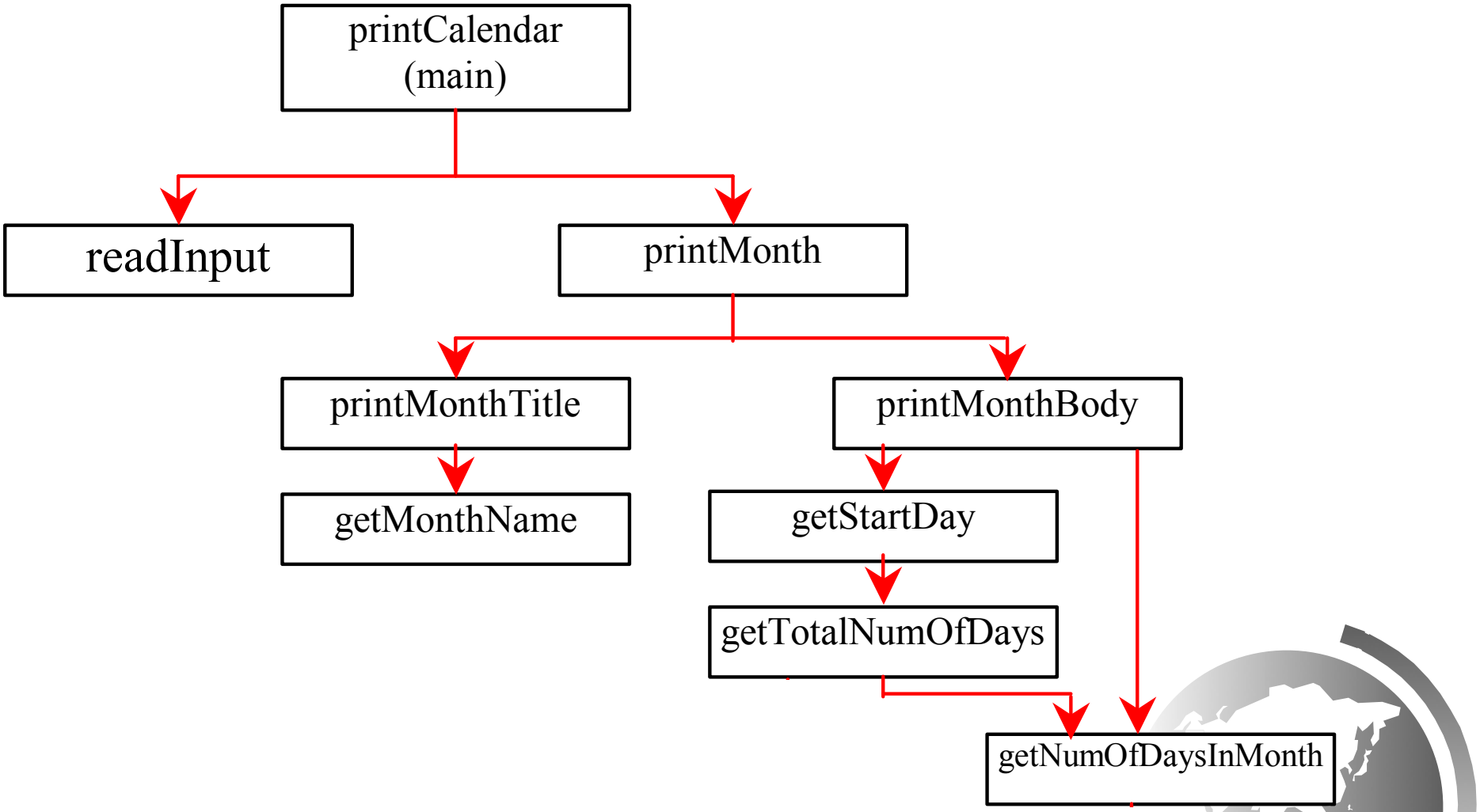
Design Diagram



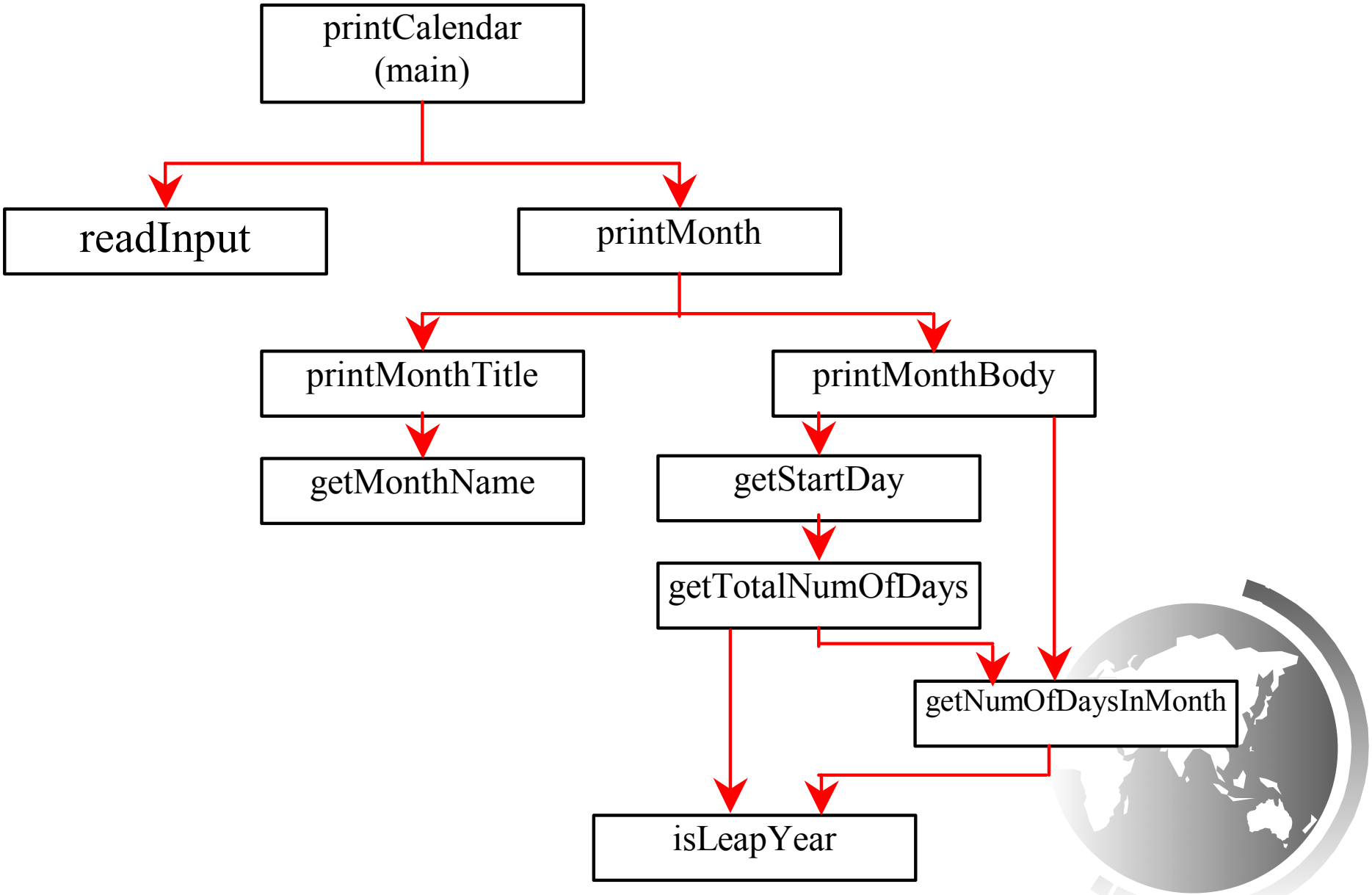
Design Diagram



Design Diagram



Design Diagram



Implementation: Top-Down

Top-down approach is to implement one method in the structure chart at a time from the top to the bottom. Stubs can be used for the methods waiting to be implemented. A stub is a simple but incomplete version of a method. The use of stubs enables you to test invoking the method from a caller. Implement the main method first and then use a stub for the printMonth method. For example, let printMonth display the year and the month in the stub. Thus, your program may begin like this:

A Skeleton for printCalendar.java

Implementation: Bottom-Up

Bottom-up approach is to implement one method in the structure chart at a time from the bottom to the top. For each method implemented, write a test program to test it. Both top-down and bottom-up methods are fine. Both approaches implement the methods incrementally and help to isolate programming errors and makes debugging easy. Sometimes, they can be used together.

Benefits of Stepwise Refinement

Simpler Program

Reusing Methods

Easier Developing, Debugging, and Testing

Better Facilitating Teamwork