

Chapter 2 Elementary Programming



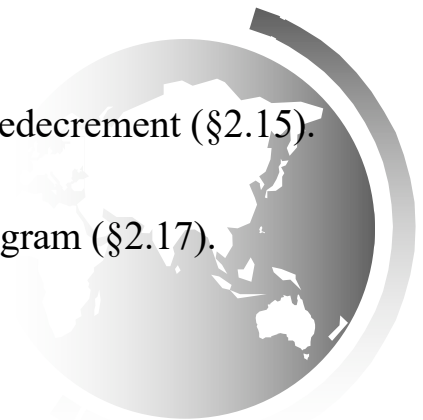
Motivations

In the preceding chapter, you learned how to create, compile, and run a Java program. Starting from this chapter, you will learn how to solve practical problems programmatically. Through these problems, you will learn Java primitive data types and related subjects, such as variables, constants, data types, operators, expressions, and input and output.



Objectives

- ♦ To write Java programs to perform simple computations (§2.2).
- ♦ To obtain input from the console using the **Scanner** class (§2.3).
- ♦ To use identifiers to name variables, constants, methods, and classes (§2.4).
- ♦ To use variables to store data (§§2.5–2.6).
- ♦ To program with assignment statements and assignment expressions (§2.6).
- ♦ To use constants to store permanent data (§2.7).
- ♦ To name classes, methods, variables, and constants by following their naming conventions (§2.8).
- ♦ To explore Java numeric primitive data types: **byte**, **short**, **int**, **long**, **float**, and **double** (§2.9).
- ♦ To read a **byte**, **short**, **int**, **long**, **float**, or **double** value from the keyboard (§2.9.1).
- ♦ To perform operations using operators **+**, **-**, *****, **/**, and **%** (§2.9.2).
- ♦ To perform exponent operations using **Math.pow(a, b)** (§2.9.3).
- ♦ To write integer literals, floating-point literals, and literals in scientific notation (§2.10).
- ♦ To use JShell to quickly test Java code (§2.11).
- ♦ To write and evaluate numeric expressions (§2.12).
- ♦ To obtain the current system time using **System.currentTimeMillis()** (§2.13).
- ♦ To use augmented assignment operators (§2.14).
- ♦ To distinguish between postincrement and preincrement and between postdecrement and predecrement (§2.15).
- ♦ To cast the value of one type to another type (§2.16).
- ♦ To describe the software development process and apply it to develop the loan payment program (§2.17).
- ♦ To write a program that converts a large amount of money into smaller units (§2.18).
- ♦ To avoid common errors and pitfalls in elementary programming (§2.19).



Introducing Programming with an Example

Listing 2.1 Computing the Area of a Circle

This program computes the area of the circle.

ComputeArea

Note: Clicking the green button displays the source code with interactive animation. You can also run the code in a browser. Internet connection is needed for this button.

Trace a Program Execution

```
public class ComputeArea {  
    /** Main method */  
    public static void main(String[] args) {  
        double radius;  
        double area;  
  
        // Assign a radius  
        radius = 20;  
  
        // Compute area  
        area = radius * radius * 3.14159;  
  
        // Display results  
        System.out.println("The area for the circle of radius " +  
            radius + " is " + area);  
    }  
}
```

allocate memory
for radius

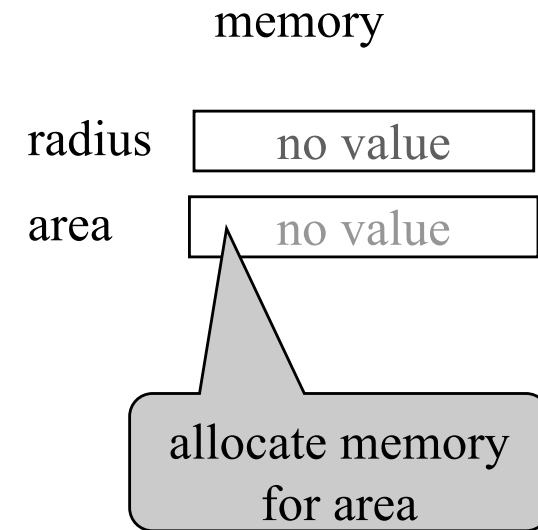
radius

no value



Trace a Program Execution

```
public class ComputeArea {  
    /** Main method */  
    public static void main(String[] args) {  
        double radius;  
        double area;  
  
        // Assign a radius  
        radius = 20;  
  
        // Compute area  
        area = radius * radius * 3.14159;  
  
        // Display results  
        System.out.println("The area for the circle of radius " +  
            radius + " is " + area);  
    }  
}
```



Trace a Program Execution

```
public class ComputeArea {  
    /** Main method */  
    public static void main(String[] args) {  
        double radius;  
        double area;
```

```
        // Assign a radius
```

```
        radius = 20;
```

```
        // Compute area
```

```
        area = radius * radius * 3.14159;
```

```
        // Display results
```

```
        System.out.println("The area for the circle of radius " +  
            radius + " is " + area);
```

```
    }  
}
```

assign 20 to radius

20

radius

area

no value



Trace a Program Execution

```
public class ComputeArea {  
    /** Main method */  
    public static void main(String[] args) {  
        double radius;  
        double area;  
  
        // Assign a radius  
        radius = 20;  
  
        // Compute area  
        area = radius * radius * 3.14159;  
  
        // Display results  
        System.out.println("The area for the circle of radius " +  
            radius + " is " + area);  
    }  
}
```

memory

| | |
|--------|----------|
| radius | 20 |
| area | 1256.636 |

compute area and assign it to variable area



Trace a Program Execution

```
public class ComputeArea {  
    /** Main method */  
    public static void main(String[] args) {  
        double radius;  
        double area;  
  
        // Assign a radius  
        radius = 20;  
  
        // Compute area  
        area = radius * radius * 3.14159;  
  
        // Display results  
        System.out.println("The area for the circle of radius " +  
            radius + " is " + area);  
    }  
}
```

memory

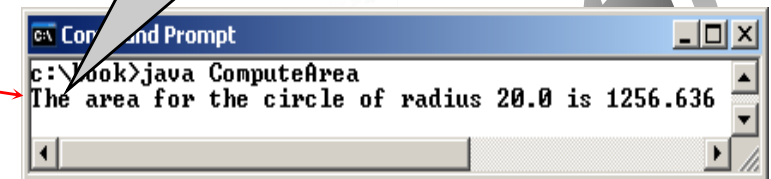
radius

20

area

1256.636

print a message to the
console



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

ComputeAverage

Implicit Import and Explicit Import

```
java.util.* ; // Implicit import
```

```
java.util.Scanner; // Explicit Import
```

No performance difference



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:

- Capitalize the first letter of each word in the name. For example, the class name `ComputeArea`.

♦ Constants:

- Capitalize 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 |



Reading Numbers from the Keyboard

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

| Method | Description |
|---------------------------|--|
| <code>nextByte()</code> | reads an integer of the byte type. |
| <code>nextShort()</code> | reads an integer of the short type. |
| <code>nextInt()</code> | reads an integer of the int type. |
| <code>nextLong()</code> | reads an integer of the long type. |
| <code>nextFloat()</code> | reads a number of the float type. |
| <code>nextDouble()</code> | 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

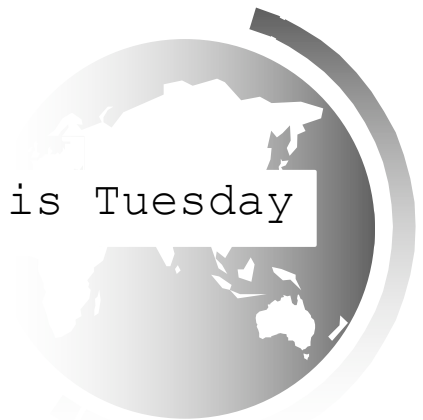
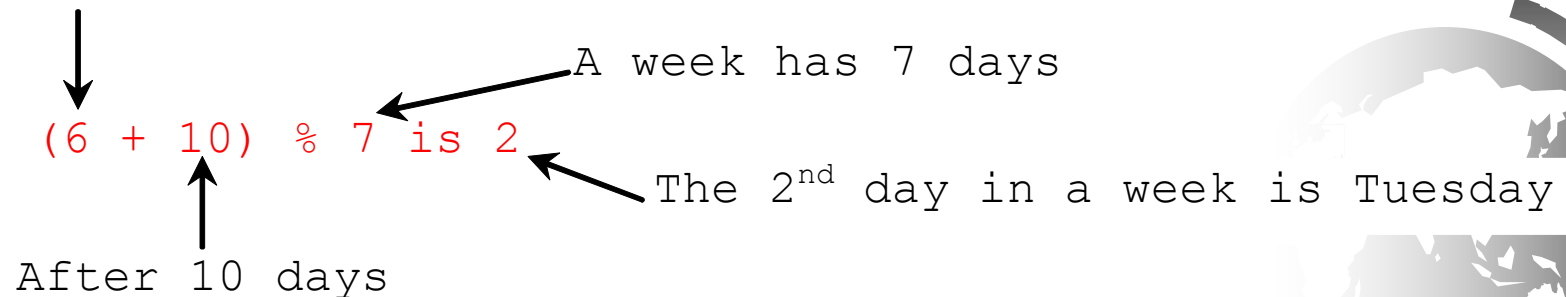
$5 \% 2$ yields 1 (the remainder of the division)



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:

Saturday is the 6th day in a week



Problem: Displaying Time

Write a program that obtains minutes and remaining seconds from seconds.

DisplayTime



NOTE

Calculations involving floating-point numbers are approximated because these numbers are not stored with complete accuracy. For example,

```
System.out.println(1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1);
```

displays 0.50000000000000000001, not 0.5, and

```
System.out.println(1.0 - 0.9);
```

displays 0.099999999999999999998, not 0.1. Integers are stored precisely. Therefore, calculations with integers yield a precise integer result.



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



Scientific Notation

Floating-point literals can also be specified in scientific notation, for example, $1.23456e+2$, same as $1.23456e2$, is equivalent to 123.456 , and $1.23456e-2$ is equivalent to 0.0123456 . E (or e) represents an exponent and it can be either in lowercase or uppercase.



JShell

JShell is a command line interactive tool introduced in Java 9. JShell enables you to type a single Java statement and get it executed to see the result right away without having to write a complete class. This feature is commonly known as REPL (Read-Evaluate-Print Loop), which evaluates expressions and executes statements as they are entered and shows the result immediately.



Arithmetic Expressions

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

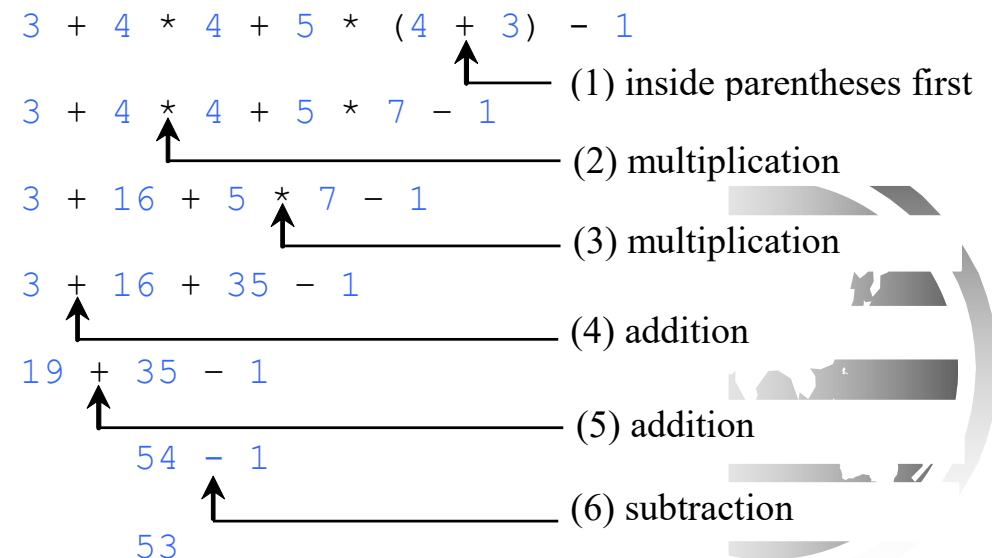
is translated to

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



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.



Problem: Converting Temperatures

Write a program that converts a Fahrenheit degree to Celsius using the formula:

$$celsius = (\frac{5}{9})(fahrenheit - 32)$$

Note: you have to write

$$celsius = (5.0 / 9) * (fahrenheit - 32)$$

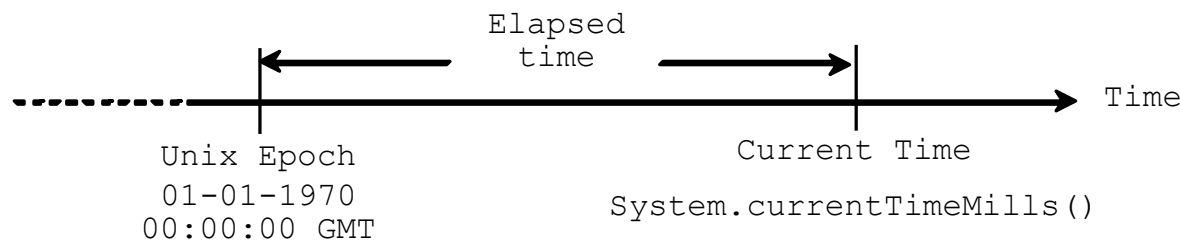
FahrenheitToCelsius



Problem: Displaying Current Time

Write a program that displays current time in GMT in the format hour:minute:second such as 1:45:19.

The `currentTimeMillis` method in the `System` class returns the current time in milliseconds since the midnight, January 1, 1970 GMT. (1970 was the year when the Unix operating system was formally introduced.) You can use this method to obtain the current time, and then compute the current second, minute, and hour as follows.



ShowCurrentTime

Augmented Assignment Operators

| <i>Operator</i> | <i>Name</i> | <i>Example</i> | <i>Equivalent</i> |
|-----------------|---------------------------|---------------------|------------------------|
| <code>+=</code> | Addition assignment | <code>i += 8</code> | <code>i = i + 8</code> |
| <code>-=</code> | Subtraction assignment | <code>i -= 8</code> | <code>i = i - 8</code> |
| <code>*=</code> | Multiplication assignment | <code>i *= 8</code> | <code>i = i * 8</code> |
| <code>/=</code> | Division assignment | <code>i /= 8</code> | <code>i = i / 8</code> |
| <code>%=</code> | Remainder assignment | <code>i %= 8</code> | <code>i = i % 8</code> |



Increment and Decrement Operators

| <i>Operator</i> | <i>Name</i> | <i>Description</i> | <i>Example (assume i = 1)</i> |
|-----------------|---------------|---|--|
| ++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;`

Increment and Decrement Operators, cont.

Using increment and decrement operators makes expressions short, but it also makes them complex and difficult to read. Avoid using these operators in expressions that modify multiple variables, or the same variable for multiple times such as this: `int k = ++i + 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--;`



Numeric Type Conversion

Consider the following statements:

```
byte i = 100;
```

```
long k = i * 3 + 4;
```

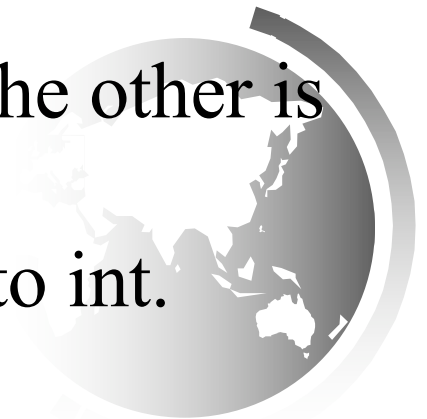
```
double d = i * 3.1 + k / 2;
```



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;`

range increases
→
byte, short, int, long, float, double



Problem: Keeping Two Digits After Decimal Points

Write a program that displays the sales tax with two digits after the decimal point.

SalesTax



Casting in an Augmented Expression

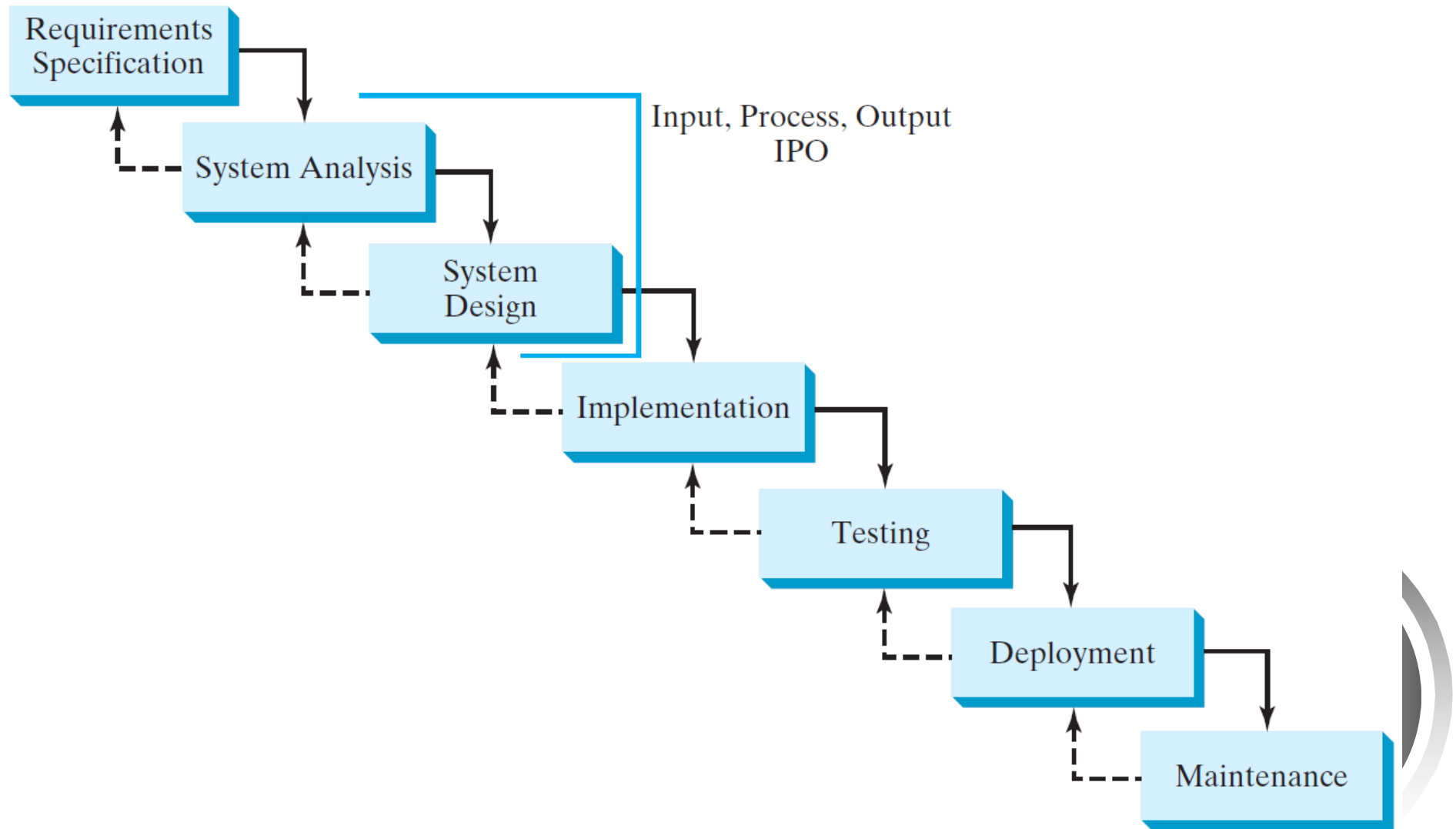
In Java, an augmented expression of the form **x1 op= x2** is implemented as **x1 = (T)(x1 op x2)**, where **T** is the type for **x1**. Therefore, the following code is correct.

```
int sum = 0;
```

```
sum += 4.5; // sum becomes 4 after this statement
```

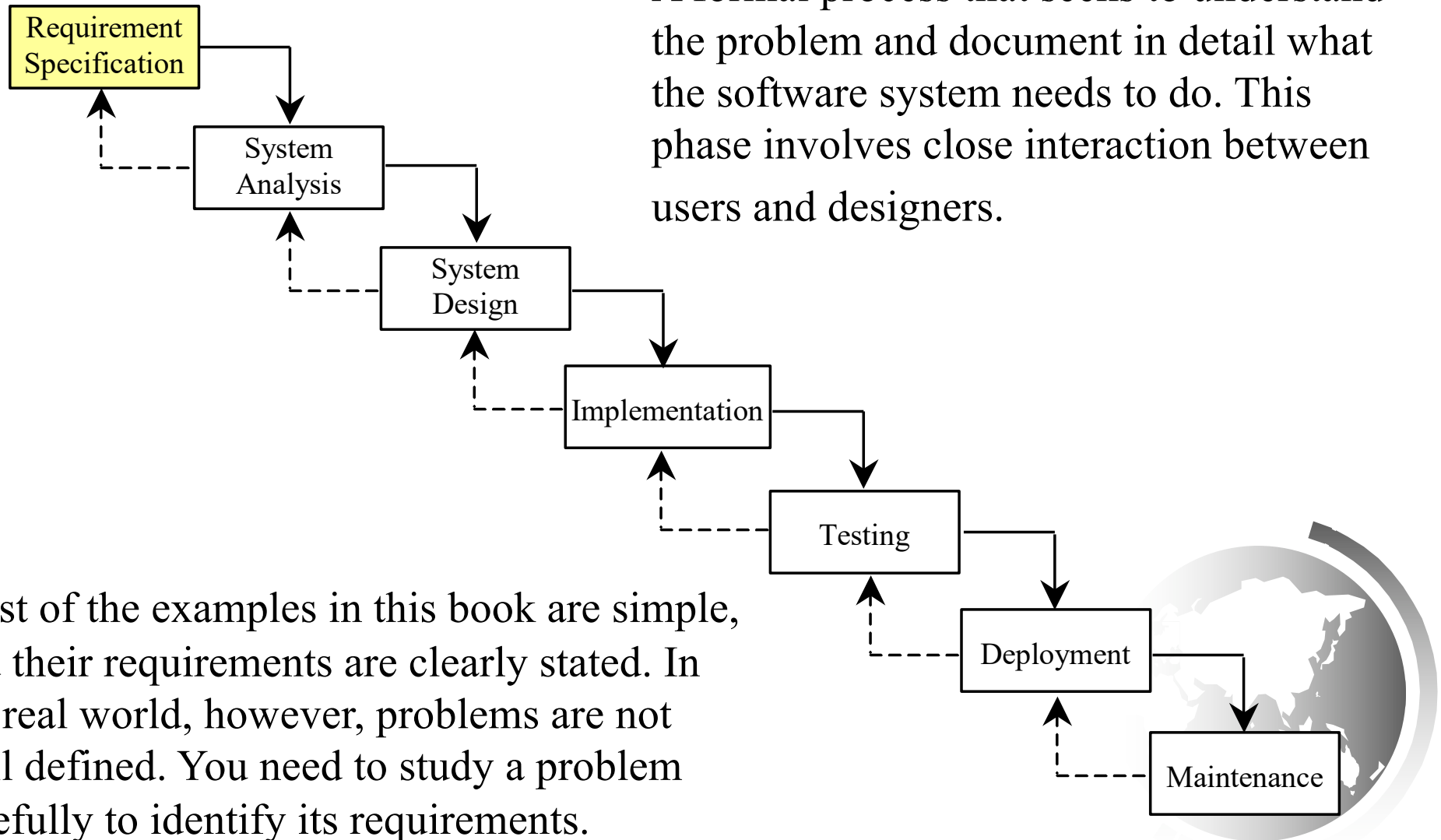
```
sum += 4.5 is equivalent to sum = (int)(sum + 4.5).
```

Software Development Process



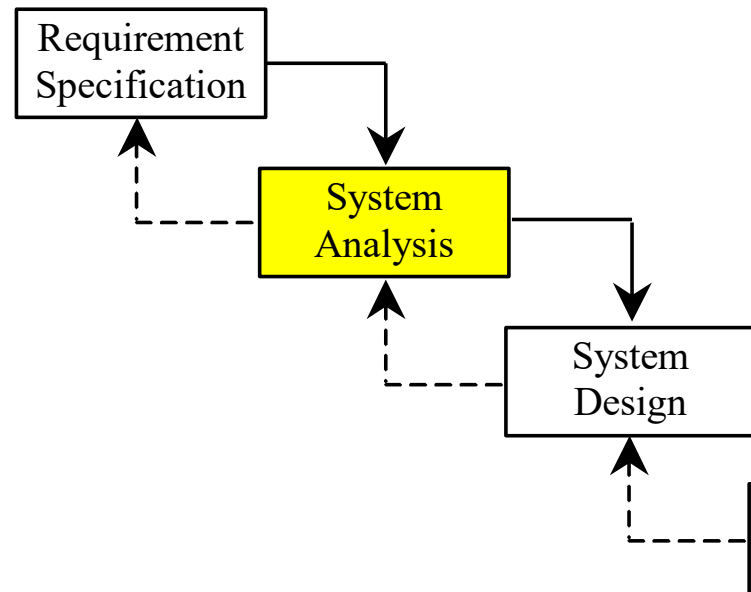
Requirement Specification

A formal process that seeks to understand the problem and document in detail what the software system needs to do. This phase involves close interaction between users and designers.



Most of the examples in this book are simple, and their requirements are clearly stated. In the real world, however, problems are not well defined. You need to study a problem carefully to identify its requirements.

System Analysis

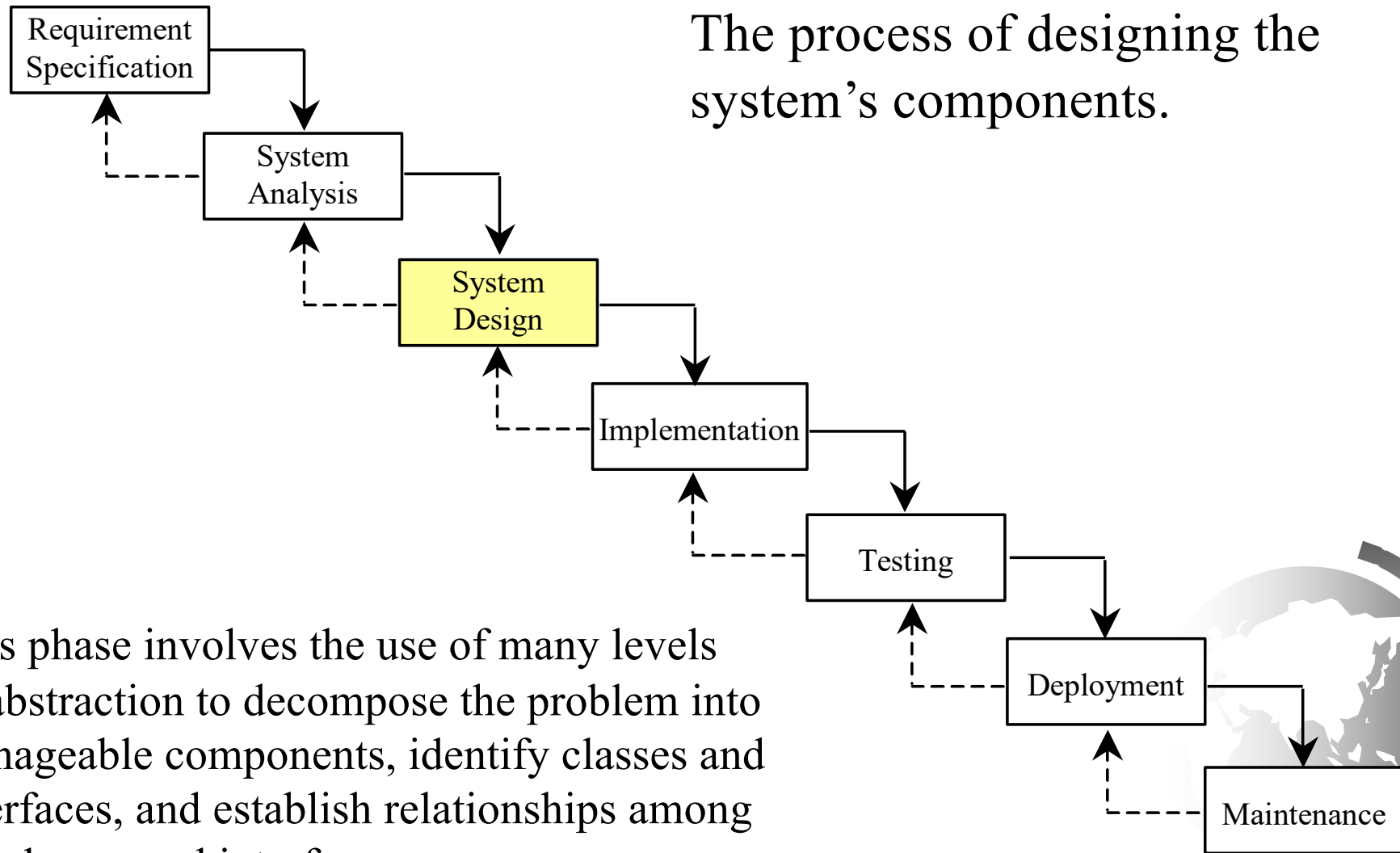


Seeks to analyze the business process in terms of data flow, and to identify the system's input and output.

Part of the analysis entails modeling the system's behavior. The model is intended to capture the essential elements of the system and to define services to the system.

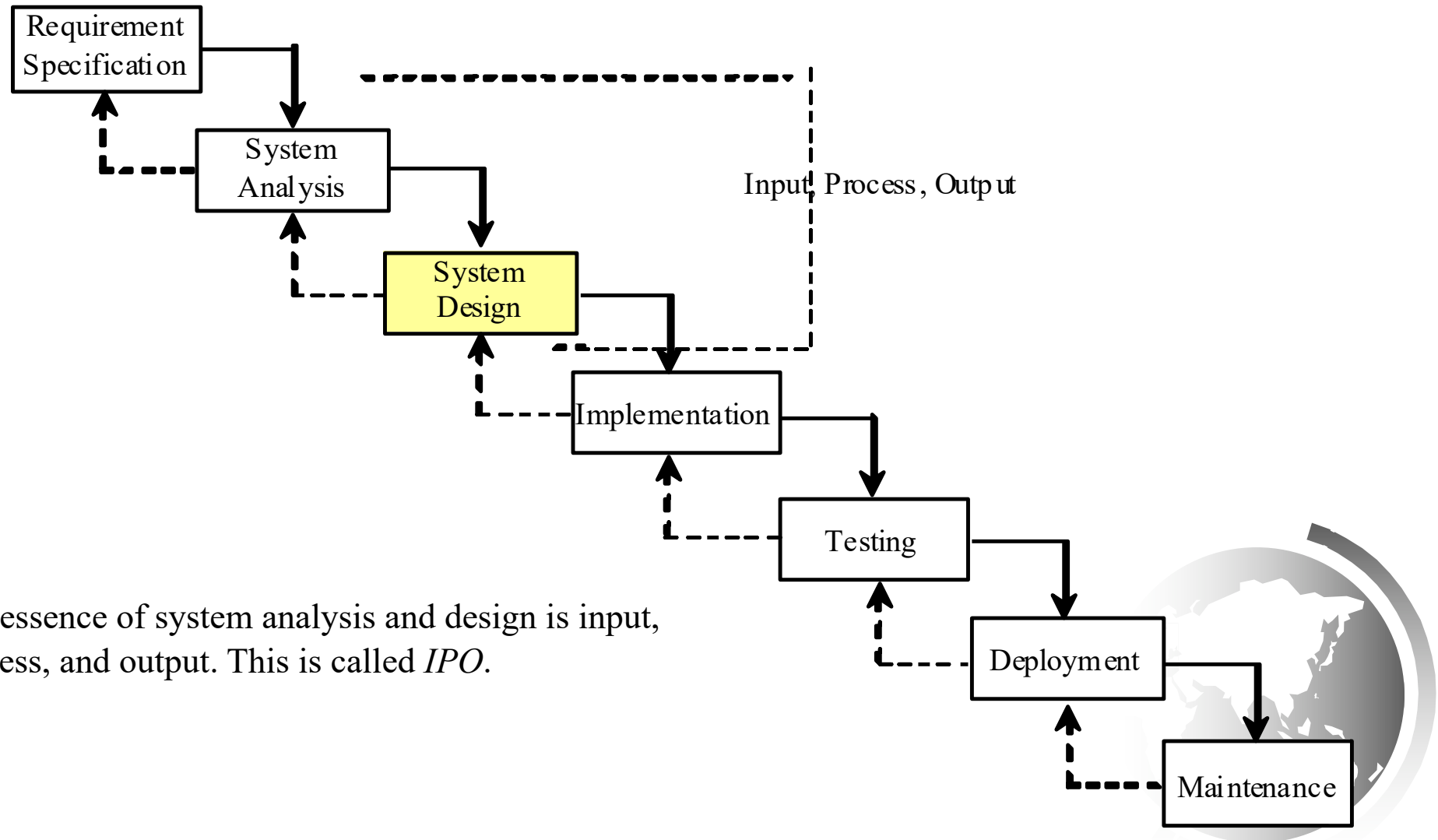
System Design

The process of designing the system's components.



This phase involves the use of many levels of abstraction to decompose the problem into manageable components, identify classes and interfaces, and establish relationships among the classes and interfaces.

IPO

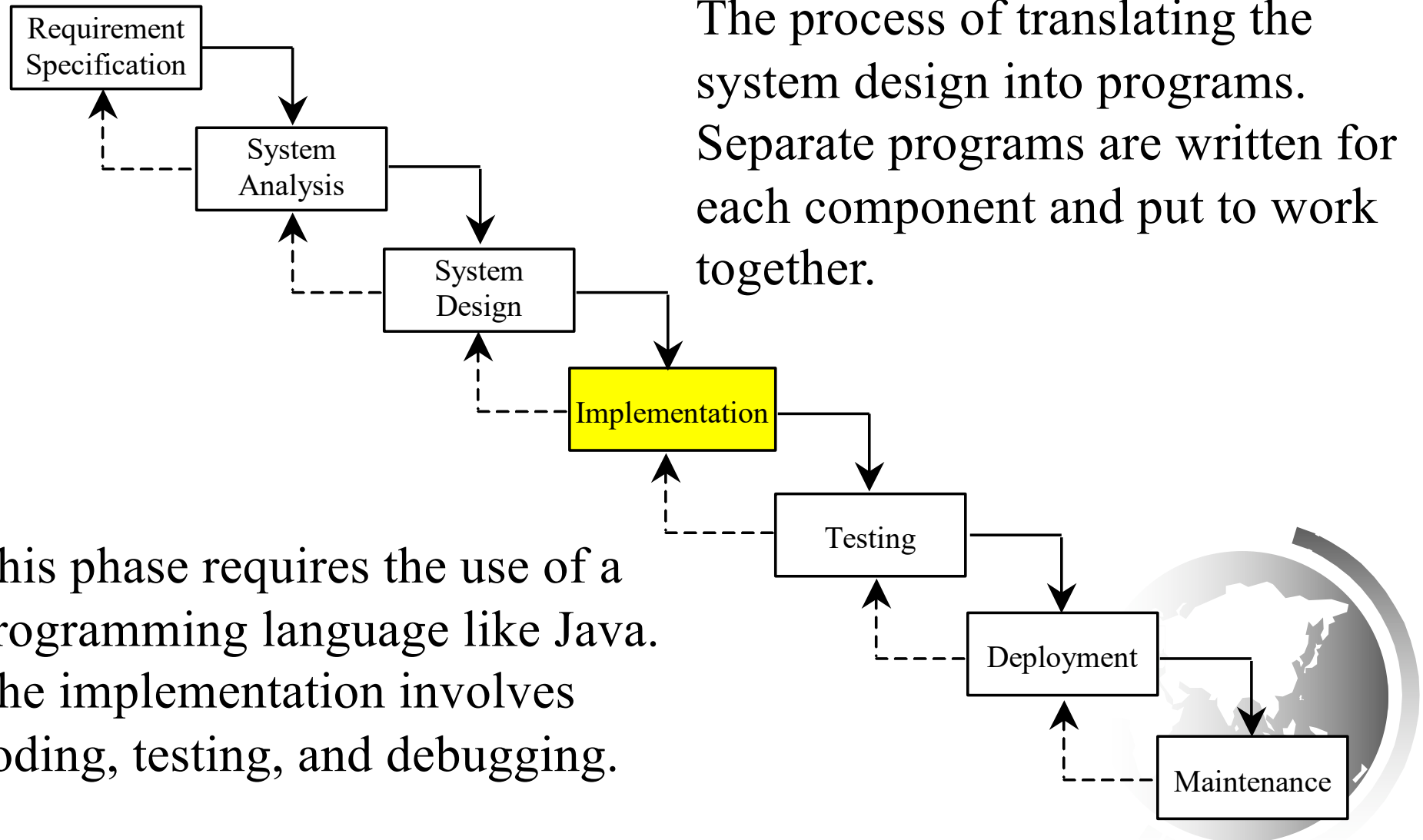


The essence of system analysis and design is input, process, and output. This is called *IPO*.

Implementation

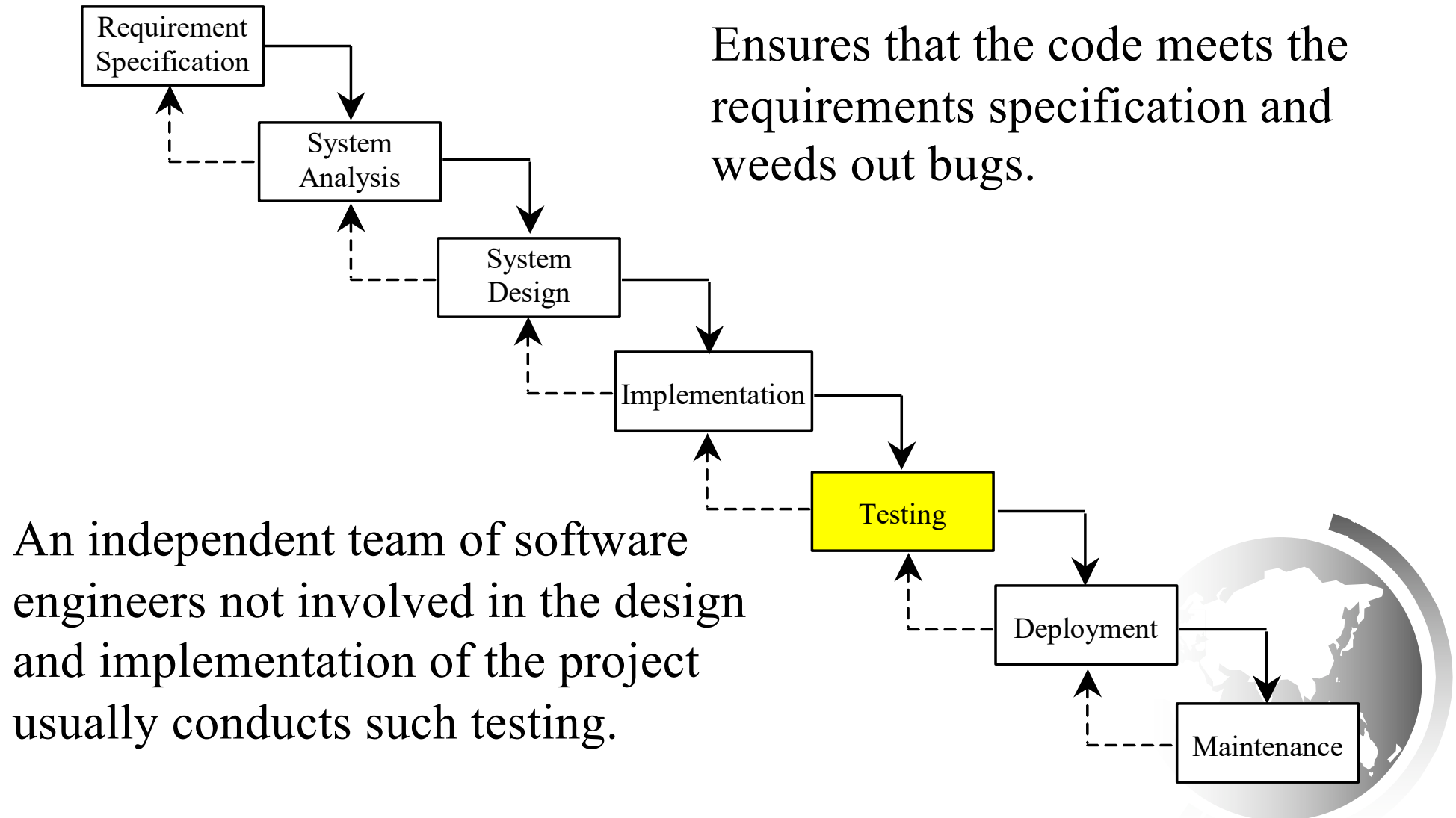
The process of translating the system design into programs. Separate programs are written for each component and put to work together.

This phase requires the use of a programming language like Java. The implementation involves coding, testing, and debugging.



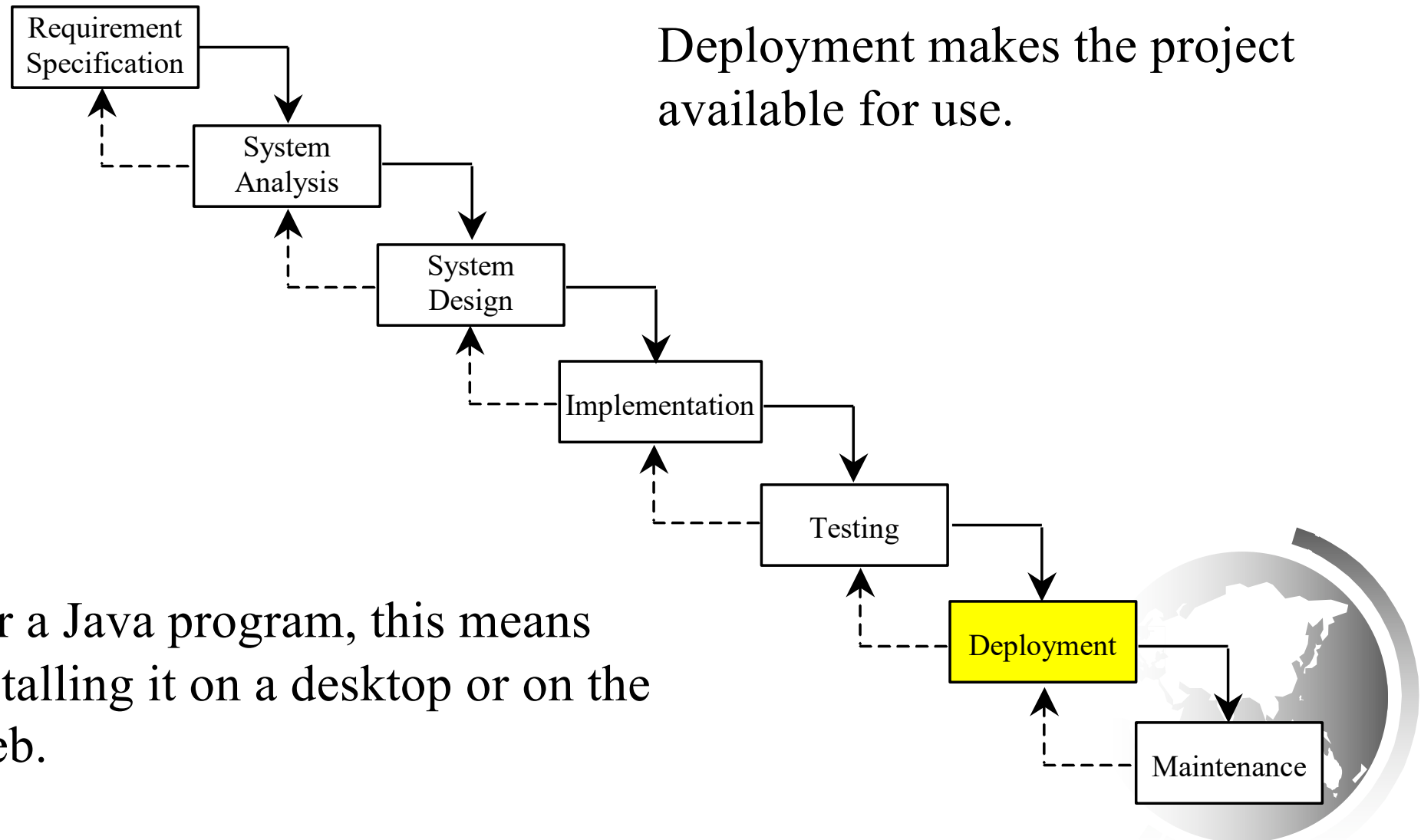
Testing

Ensures that the code meets the requirements specification and weeds out bugs.



Deployment

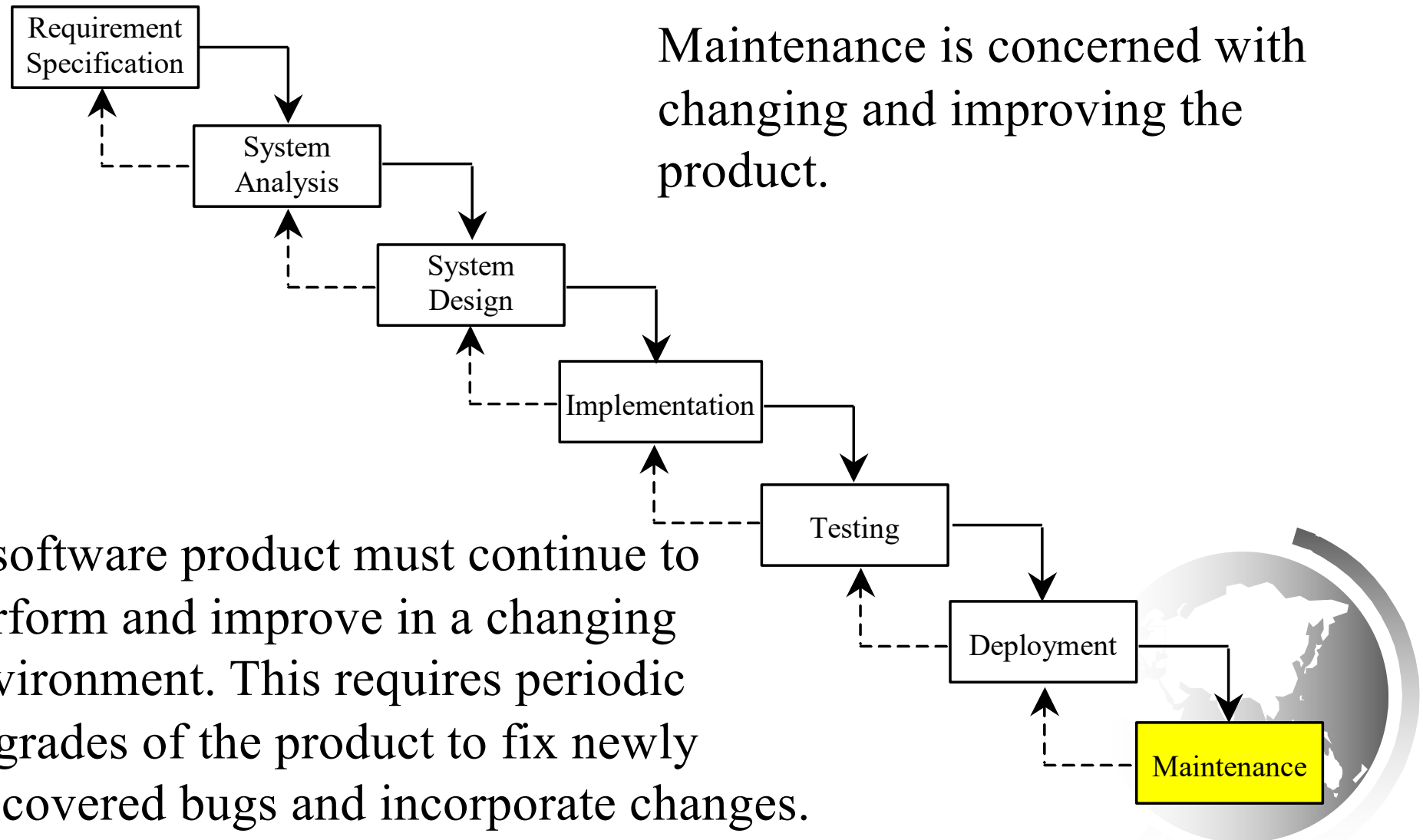
Deployment makes the project available for use.



For a Java program, this means installing it on a desktop or on the Web.

Maintenance

Maintenance is concerned with changing and improving the product.



Problem:

Computing Loan Payments

This program lets the user enter the interest rate, number of years, and loan amount, and computes monthly payment and total payment.

$$\text{monthlyPayment} = \frac{\text{loanAmount} \times \text{monthlyInterestRate}}{1 - \frac{1}{(1 + \text{monthlyInterestRate})^{\text{numberOfYears} \times 12}}}$$



ComputeLoan

Problem: Monetary Units

This program lets the user enter the amount in decimal representing dollars and cents and output a report listing the monetary equivalent in single dollars, quarters, dimes, nickels, and pennies.

Your program should report maximum number of dollars, then the maximum number of quarters, and so on, in this order.

ComputeChange



Common Errors and Pitfalls

- ♦ Common Error 1: Undeclared/Uninitialized 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



Common Error 1: Undeclared/Uninitialized Variables and Unused Variables

```
double interestRate = 0.05;  
double interest = interestrate * 45;
```



Common Error 2: Integer Overflow

```
int value = 2147483647 + 1;  
// value will actually be -2147483648
```



Common Error 3: Round-off Errors

```
System.out.println(1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1);
```

```
System.out.println(1.0 - 0.9);
```



Common Error 4: Unintended Integer Division

```
int number1 = 1;  
int number2 = 2;  
double average = (number1 + number2) / 2;  
System.out.println(average);
```

(a)

```
int number1 = 1;  
int number2 = 2;  
double average = (number1 + number2) / 2.0;  
System.out.println(average);
```

(b)



Common Pitfall 1: Redundant Input Objects

```
Scanner input = new Scanner(System.in);  
System.out.print("Enter an integer: ");  
int v1 = input.nextInt();
```

```
Scanner input1 = new Scanner(System.in);  
System.out.print("Enter a double value: ");  
double v2 = input1.nextDouble();
```

