Chapter 2

Primitive Data Types and Operations

2.1 Introduction

- You will be introduced to Java **primitive** data types and related subjects, such as variables constants, data types, operators, and expressions.
- You will learn how to write programs using primitive data types, input, and simple calculations.

2.2 Writing Simple Programs

- Writing a program involves designing algorithms and data structures, as well as translating algorithms into programming code.
- An ***Algorithm*** describes how a problem is solved in terms of the actions to be executed, and it specifies the order in which the actions should be executed.
- Computing an area of a circle. The algorithm for this program can be described as follows:
  1. Read in the Radius
  2. Compute the area using the following formula
     Area = radius * radius * ∏
  3. Display the area.
- Java provides data types for representing integers, floating-point numbers, characters, and Boolean types. These types are known as ***primitive data types***.
- When you *code*, you translate an algorithm into a **programming language** understood by the computer.
- The outline of the program is:

```
// ComputeArea.Java: compute the area of a circle Comment

public class ComputeArea  // Class Name
{
  public static void main(String[] args)// Main Method signature
  {
     double radius; // Data type & variable
     double area;

     // Assign a radius
     radius = 20;

     // Compute area
     area = radius * radius * 3.14159; // Expression

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

- The program needs to **declare** a symbol called a variable that will represent the radius. **Variables** are used to store data and computational results in the program.
- Use descriptive names rather than x and y. Use radius for radius, and area for area. Specify their data types to let the compiler know what radius and area are, indicating whether they are integer, float, or something else.
- The program declares radius and area as double-precision variables. The reserved word **double** indicates that radius and area are double-precision floating-point values stored in the computer.
- For the time being, we will assign a fixed number to radius in the program. Then, we will compute the area by assigning the expression radius * radius * 3.14159 to area.
- The program's output is:
  The area for the circle of radius 20.0 is 1256.636
- A string constant should not cross lines in the source code. Use the **concatenation** operator (+) to overcome such problem.

2.3 Identifiers

- Programming languages use special symbols called ***identifiers*** to name such programming entities as variables, constants, methods, classes, and packages.
- The following are the rules for naming 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.
- For example:
    - Legal identifiers are for example: $2, ComputeArea, area, radius, and showMessageDialog.
    - Illegal identifiers are for example: 2A, d+4.
    - Since Java is **case-sensitive**, X and x are different identifiers.

2.4 Variables

- Variables are used to **store** data in a program.
- You can write the code shown below to compute the area for different radii:

```
// 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);
```

2.4.1 Declaring Variables

- Variables are used for representing data of a certain **type**.
- To use a variable, you declare it by telling the compiler the name of the variable as well as what type of data it represents. This is called variable **declaration**.
- Declaring a variable tells the compiler to allocate appropriate memory space for the variable based on its data type. The following are examples of variable declarations:

```
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;
```

- If variables are of the same type, they can be declared together using **short-hand** form:

  Datatype var1, var2, …, varn; ➔ variables are separated by commas

2.5 Assignment Statements and Assignments Expressions

- After a variable is declared, you can assign a value to it by using an assignment statement. The syntax for assignment statement is:

```
variable = expression;

x = 1;                    // Assign 1 to x;  ➔ Thus 1 = x is wrong
radius = 1.0;             // Assign 1.0 to radius;
a = 'A';                  // Assign 'A' to a;
x = 5 * (3 / 2) + 3 * 2; // Assign the value of the expression to x;
x = y + 1;                // Assign the addition of y and 1 to x;
```

- The variable can also be used in the expression.

```
x = x + 1;      // the result of x + 1 is assigned to x;
```

- To assign a value to a variable, the variable name must be on the **left** of the assignment operator.

```
1 = x would be wrong.
```

- In Java, an assignment statement can also be treated as an expression that evaluates to the value being assigned to the variable on the left-hand side of the assignment operator. For this reason, an assignment statement is also known as an **assignment expression**, and the symbol = is referred to as the **assignment operator**.

```
System.out.println(x = 1);
```

which is equivalent to

```
x = 1;
System.out.println(x);
```

The following statment is also correct:

```
i = j = k = 1;
```

which is equivalent to

```
k = 1; j = k; i = j;
```

2.5.1 Declaring and Initializing Variables in One Step

- You can declare a variable and initialize it in one step.

```
  int x = 1;

This is equivalent to the next two statements:

  int x;
  x = 1;

// shorthand form to declare and initialize vars of same type
int i = 1, j = 2;
```

- **Tip**: A variable must be declared **before** it can be assigned a value.

2.6 Constants

- The value of a variable may change during the execution of the program, but a constant represents permanent data that **never** change.
- The syntax for declaring a constant:

```
final datatype CONSTANTNAME = VALUE;

final double PI = 3.14159;  ➔ // Declare a constant
final int SIZE = 3;
```

- A constant **must** be declared and initialized before it can be used. You **cannot** change a constant's value once it is declared. By convention, constants are named in **uppercase**.

```
// ComputeArea.Java: compute the area of a circle Comment

public class ComputeArea       // Class Name
{
  public static void main(String[] args) // Main Method signature
  {
     final double PI = 3.14159;      // declare a constant
     double radius = 20;         // assign a radius

     // Compute area
     double area = radius * radius * PI; // Expression

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

- **Note:** There are three benefits of using constants:
  - You don't have to **repeatedly** type the same value.
  - The value can be changed in a **single** location.
  - The program is easy to **read**.

2.7 Numerical Data Types and Operations

- Every data type has a range of **values**. The compiler allocates memory space to store each variable or constant according to its data type.
- Java has six numeric types: four for integers and two for floating-point numbers.

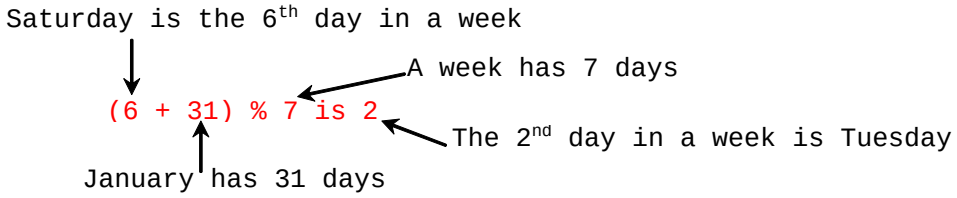
Name	*Storage Size*	*Range*
byte	8 bits	-2^7 (-128) to $2^7 - 1$ (127)
short	16 bits	-2^{15} (-32768) to $2^{15} - 1$ (32767)
int	**32 bits**	-2^{32} (-2147483648) to $2^{31} - 1$ (2147483647)
long	64 bits	-2^{63} to $2^{63} - 1$
float	**32 bits**	6 – 7 significant digits of accuracy
double	64 bits	14 – 15 significant digits of accuracy

2.7.1 Numerical Operators

+, -, *, /, and %

```
5/2         yields an integer          2
5.0/2       yields a double value      2.5
-5/2        yields an integer value    -2
-5.0/2      yields a double value      -2.5

5 % 2       yields 1 (the remainder of the division.)
-7 % 3      yields -1
-12 % 4     yields 0
-26 % -8    yields -2
20 % -13    yields 7
```

- **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 you know January 1, 2005 is **Saturday**, you can find that the day for February 1, 2005 is Tuesday using the following expression:



- A unary operator has only **one** operand. A binary operator has **two** operands.
- **NOTE**
  Calculations involving floating-point numbers are **approximated** because these numbers are not stored with complete accuracy. For example,
  `System.out.println(1 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1);`
  displays 0.5000000000000001, not 0.5, and

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

displays 0.09999999999999998, not 0.1.

Integers are stored **precisely**. Therefore, calculations with integers yield a precise integer result.

2.7.2 Numeric Literals

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

```
int i = 34;
long l = 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 (lowercase L).
- For example, the following code display the decimal value 65535 for hexadecimal number FFFF.

```
System.out.println(0xFFFF);
```

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.
- The double type values are **more accurate** than float type values.

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

displays 1.0 / 3.0 is 0.3333333333333333

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

displays 1.0F / 3.0F is 0.33333334

Scientific Notations

- 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.

2.7.3 Arithmetic Expressions

- For example, the arithmetic expression

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

  can be translated into a Java expression as:

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

- Operators contained within pairs of **parentheses** are evaluated first.
- Parentheses can be **nested**, in which case the expression in the **inner** parentheses is evaluated first.
- Multiplication, division, and remainder operators are applied next. Order of operation is applied from left to right. Addition and subtraction are applied last.

2.7.4 Shortcut Operators

Table 2.2 Shortcut Operators

Operator	*Example*	*Equivalent*
+=	i+=8	i = i+8
-=	f-=8.0	f = f-8.0
*=	i*=8	i = i*8
/=	i/=8	i = i/8
%=	i%=8	i = i%8

- There are two more shortcut operators for incrementing and decrementing a variable by 1. These two operators are ++, and --. They can be used in prefix or suffix notations.

suffix →
```
x++; // Same as x = x + 1;
```
prefix →
```
++x; // Same as x = x + 1;
```
suffix →
```
x--; // Same as x = x - 1;
```
prefix →
```
--x; // Same as x = x - 1;
```

Table 2.3 Increment and Decrement Operators

Operator	*Name*	*Description*
++var	preincrement	The expression (++var) increments var by 1 and evaluates to the ***new*** value in var ***after*** the increment.
var++	postincrement	The expression (var++) evaluates to the *original* value in var and increments var by 1.
--var	predecrement	The expression (--var) decrements var by 1 and evaluates to the *new* value in var *after* the decrement.
var--	postdecrement	The expression (var--) evaluates to the *original* value in var and decrements var by 1.

```
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;
```

Ex:

```
double x = 1.0;
double y = 5.0;
double z = x-- + (++y);
```

After execution, y = 6.0, **z = 7.0**, and x = 0.0;

- Using increment and decrement operators make expressions short; 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.

2.8 Numeric Type Conversions

- Consider the following statements:

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

  Are these statements correct?

- 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.

- Thus the result of 1 / 2 is **0**, and the result of 1.0 / 2 is **0.5**.
- **Type Casting** is an operation that converts a value of one data type into a value of another data type.
- Casting a variable of a type with a small range to variable with a larger range is known as **widening** a type. Widening a type can be performed **automatically** without explicit casting.
- Casting a variable of a type with a large range to variable with a smaller range is known as **narrowing** a type. Narrowing a type must be performed **explicitly**.
- **Caution:** Casting is necessary if you are assigning a value to a variable of a smaller type range. A compilation **error** will occur if casting is not used in situations of this kind. Be careful when using casting. **Lost** information might lead to inaccurate results.

```
float f = (float) 10.1;
int i = (int) f;

double d = 4.5;
int i =(int)d;    // d is not changed
System.out.println("d " + d + " i " + i); // answer is d 4.5 i 4
```

Implicit casting

```
double d = 3;     // type widening
```

Explicit casting

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

What is wrong?

```
int i = 1;
byte b = i;       // Error because explicit casting is required
```

2.9 Character Data Type and Operations

- The character data type, char, is used to represent a single character.
- A character literal is enclosed in **single** quotation marks.

```
char letter = 'A';   // Assigns A to char variable letter (ASCII)
char numChar = '4';  // Assigns numeric character 4 to numChar (ASCII)
```

- **Caution:** A string literal must be enclosed in quotation marks. A character literal is a single chaaracter enclosed in single quotation marks. So **"A" is a string, and 'A' is a character**.

2.9.1 Unicode and ASCII code

- Java uses Unicode, a **16-bit** encoding scheme established by the Unicode Consortium to support the interchange, processing, and display of written texts in the world's diverse languages (See the Unicdoe Web sit at www.unicode.org for more information.)
- Unicode takes **two** bytes, precoded by \u, expressed in four hexdecimal digits that run from '\u0000' to '\uFFFF'. For example, the "coffee" is translated into Chinese using two characters. The Unicode of these two characters are "\u5496\u5561".

```
char letter = '\u0041'; (Unicode ➔ 16-bit encoding scheme)
char numChar = '\u0034'; (Unicode)
```

- Unicode can represent 65,536 characters, since FFFF in hexdecimal is 65535.
- Most computer ASCII (American Standard Code for Information Interchange), a **7-bit** encoding scheme for reprsenting all uppercase and lowcase letter, digits, puctuation marks, and control characters.
- Unicode includes ASCII code with '\u0000' to '\u007F' corresponding to **128** ASCII characters. (See Appendix B).
- **Note:** The increment and decrement operators can also be used on char variables to get the next or preceding Unicode character.
- For example, the following statements display character **b**:

```
char ch = 'a';
System.out.println(++ch);
```

TABLE B.1 ASCII Character Set in the Decimal Index

	0	1	2	3	4	5	6	7	8	9
0	nul	soh	stx	etx	eot	enq	ack	bel	bs	ht
1	nl	vt	ff	cr	so	si	dle	dcl	dc2	dc3
2	dc4	nak	syn	etb	can	em	sub	esc	fs	gs
3	rs	us	sp	!	"	#	$	%	&	'
4	(	)	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[	\	]	^	_	`	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{	|	}	~	del		

2.9.2 Escape Sequences for Special Characters

Description	*Escape Sequence*	*Unicode*
Backspace	\b	\u0008
Tab	\t	\u0009
Linefeed	\n	\u000A
Carriage return	\r	\u000D
Backslash	\\	\u005C
Single Quote	\'	\u0027
Double Quote	\"	\u0022

- Suppose you want to print the **quoted** message show below:

  He said “Java is fun”

  `Here is how to write the statement:`

  System.out.println(“He said \”Java is fun\””);

2.9.3 Casting between char and Numeric Types

- A char can be cast into **any** numeric type, and vice versa.
- Implicit casting can be used if the result of a casting **fits** into the target variable. Otherwise expicit casting must be used.
- **All** numeric operation 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.
- If the other operand is a string, the character is concatenated with the string.

```
int i = 'a'; // Same as int i = (int)'a'; // (int) a is 97

char c = 99; // Same as char c = (char)99;

int i = '1' + '2';// (int) 1 is 49 and (int) 2 is 50
System.out.println("i is " + i);

int j = 1 + 'a'; // (int) a is 97
System.out.println("j is " + 98);
System.out.println(j + " is the Unicode for character " + (char) j);
System.out.println("Chapter " + 2);
```

Output is:

```
i is 99
j is 98
98 is the Unicode for character b
Chapter 2
```

2.10 The String Type

- The char type only represents **one character**. To represent a string of **characters**, use the data type called String. For example,

```
String message = "Welcome to Java";
```

- String is actually a **predefined class** in the Java library just like the System class and JOptionPane class.
- The String type is not a **primitive** type. It is known as a **reference** type. Any Java class can be used as a reference type for a variable.
- Reference data types will be thoroughly discussed in Chapter 6, "Classes and Objects." For the time being, you just need to know how to declare a String variable, how to assign a string to the variable, and how to concatenate strings.

String Concatenation

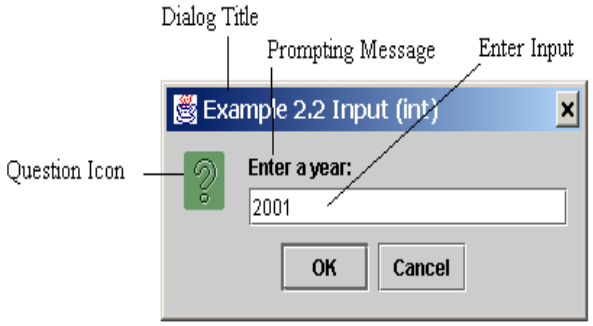
- The plus sign (+) is the **concatenation** operator if one of the operands is a string.
- If one of the operands is a non-string (e.g. a number), the non-string value is **converted** into a string and concatenated with the other string.

```
// Three strings are concatenated
String message = "Welcome " + "to " + "Java";
message += " and Java is fun"; // message = Welcome to Java and Java is fun


 // String Chapter is concatenated with number 2
String s = "Chapter" + 2;        // s becomes Chapter2

 // String Supplement is concatenated with character B
String s1 = "Supplement" + 'B'; // s becomes SupplementB

i = 1; j = 3;
System.out.println("i + j is " + i + j);  ➔ i + j is 13
System.out.println("i + j is " + (i + j));➔ i + j is 4
```

2.11 Getting Input from Input Dialog Boxes

```
String string = JOptionPane.showInputDialog(
   null, "Prompt Message", "Dialog Title",
   JOptionPane.QUESTION_MESSAGE);

String string = JOptionPane.showInputDialog(
   null, x, y, JOptionPane.QUESTION_MESSAGE);
```

where x is a string for the prompting message and y is a string for the title of the input dialog box. ""



- **Note**: There are several ways to use the showInputDialog method. For the time being, you only need to know two ways to invoke it.
  One is to use a statement as shown in the example:

  ```
  String string = JOptionPane.showInputDialog(null, x,
    y, JOptionPane.QUESTION_MESSAGE);
  ```

  where x is a string for the prompting message, and y is a string for the title of the input dialog box.

  The other is to use a statement like this:

  ```
  JOptionPane.showMessageDialog(x);
  ```

  where x is a string for the prompting message.

2.11.1 Converting String to Numbers

Converting Strings to Integers

- The input returned from the input dialog box is a **string**. If you enter a numeric value such as 123, it returns "123". To obtain the input as a number, you have to convert a string into a number.

- To convert a string into an **int** value, you can use the **static parseInt** method in the **Integer** class as follows:

```
int intValue = Integer.parseInt(intString);
```

  where intString is a numeric string such as "123".

Converting Strings to Doubles

- To convert a string into a **double** value, you can use the **static parseDouble** method in the **Double** class as follows:

```
double doubleValue = Double.parseDouble(doubleString);
```

  where doubleString is a numeric string such as "123.45".

2.13 Getting Input from the Console

Getting Input Using Scanner

- Create a Scanner object

  Scanner scanner = new Scanner(System.in);

- Use the methods next( ), nextByte( ), nextShort( ), nextInt( ), nextLong( ), nextFloat( ), nextDouble( ), or nextBoolean( ) to obtain to a string, byte, short, int, long, float, double, or boolean value. For example,

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

- Listing 2.9 TestScanner.java

```
import java.util.Scanner; // Scanner is in java.util

public class TestScanner {
  public static void main(String args[]) {
    // Create a Scanner
    Scanner scanner = new Scanner(System.in);

    // Prompt the user to enter an integer
    System.out.print("Enter an integer: ");
    int intValue = scanner.nextInt();
    System.out.println("You entered the integer " + intValue);

    // Prompt the user to enter a double value
    System.out.print("Enter a double value: ");
    double doubleValue = scanner.nextDouble();
    System.out.println("You entered the double value "
      + doubleValue);

    // Prompt the user to enter a string
    System.out.print("Enter a string without space: ");
    String string = scanner.next();
    System.out.println("You entered the string " + string);
  }
}
```

- **Tip**

  One benefit of using the console input is that you can store the input values in a text file and pass the file from the command line using the following command:

  java TestScanner < input.txt

  You can also save the output into a file using the following command:

  java TestScanner < input.txt > out.txt

- **Caution**

  By default a Scanner object reads a string separated by **whitespaces** (i.e. ' ', '\t', '\f', '\r', and '\n').

2.14 Programming Style and Documentation

- Programming Style deals with what programs look like.
- Documentation is the body of explanatory remarks and comments pertaining to a program.
- Programming style and documentation are as important as coding. They make the programs easy to read.

2.14.1 Appropriate Comments and Comments Style

- Include a summary at the beginning of the program to explain what the program does, its key features, its supporting data structures, and unique techniques it uses.
- In a long program, you should also include comments that introduce each major step and explain anything that is difficult to read.
- Make your comments concise to they do not crowd the program or make it difficult to read.
- Include your **name**, **class section**, **date**, **instruction**, and a brief **description** at the beginning of the program.

2.14.2 Naming Conventions

- Use **lowercase** for variables and methods. If a 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. Ex: showInputDialog.
- Choose **meaningful** and descriptive names. For example, the variables radius and area, and the method computeArea.
- **Capitalize** the first letter of each word in the **class** name. For example, the class name ComputeArea.
- Capitalize all letters in **constants**. For example, the constant PI.
- Do **not** use class names that are already used in Java library. For example, the constants PI and MAX_VALUE.

2.14.3 Proper Indentation and Spacing Lines

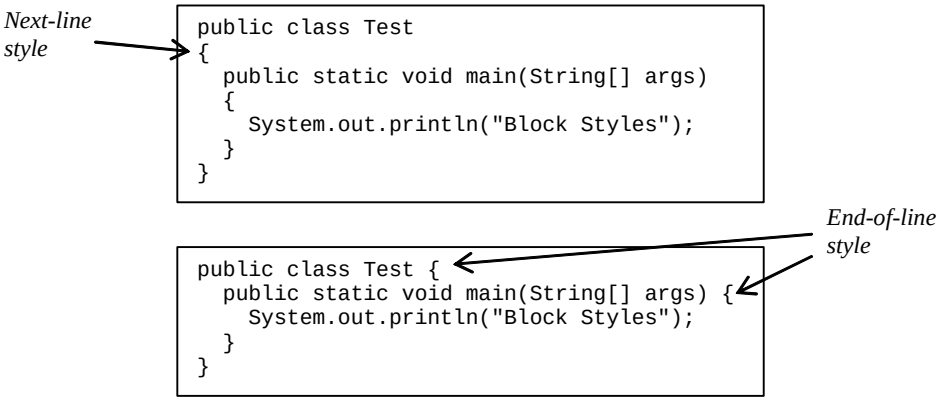
- **Indentation** is used to illustrate the structural relationships between program's components or statements.
- Indent two spaces in each subcomponent more than the structure which it is nested.
- Use a single space on both sides of a binary operator.

```
boolean b = 3 + 4 * 4 > 5 * (4 + 3)
```

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

2.14.4 Block Styles

- A block is a group of statements surrounded by braces. Use end-of-line style for braces or next-line style.



2.15 Programming Errors

2.15.1 Syntax Errors "Compilation Error"

- Errors that occur duing **compilation** are called **syntax errors** or **compilation errors**.
- Syntax errors result from errors in code construction, such as mistyping a keyword, omitting some necessary punctuation, or using an opening brace without a corresponding closing brace.
- These errors are easily detected, because the compiler tells you where they are and the reasons for them.

```
public class ShowSyntaxErrors {
  public static void main(String[] args) {
    i = 30;
    System.out.println(i+4);
  }
}
```

2.15.2 Runtime Errors

- Runtime errors are erros that cause a program to terminate **abnormally**.
- Runtime errors occur while an application is running where the environment detects an operation that is impossible to carry out.
- For instance, an input error occurs when the user enters an unexpected input value that the program can't handle. To prevent input errors, the program should prompt the user to enter the correct type of values.
- Another example of a run time error is division by zero.

```
public class ShowRuntimeErrors {
  public static void main(String[] args) {
    int i = 1 / 0;
  }
}
```

2.15.3 Logic Errors

- Logic errors occur when a program **doesn't** perform the way it was intended to.
- For example, the program doesn't have syntax or runtime errors, but it does not print the correct result.

```
// ShowLogicErrors.java: The program contains a logic error
// Suppose you wrote the following program to add number1 to number2
import javax.swing.JOptionPane;

public class ShowLogicErrors {
  public static void main(String[] args) {
   // Add number1 to number2
   int number1 = 3;
   int number2 = 3;
   number2 += number1 + number2;
   System.out.println("number2 is " + number2);
  }
}
```

2.16 Debugging

- Finding logic errors "***bugs***" is challenging and the process of finding and correcting errors is called ***debugging***.
- You can ***hand-trace*** the program or you can insert print statements in order to show the values of the variables or the execution flow of the program.
- For a large, complex program, the most effective approach for debugging is to use a debugger **utility**.