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Preface

Welcome to *Starting Out with Java: From Control Structures through Data Structures, Fourth Edition*. This book is intended for a traditional two-semester CS1/CS2 sequence of courses. The first half of the book, intended for a CS1 class, teaches fundamental programming and problem-solving concepts using Java. The second half of the book, intended for a CS2 class, teaches advanced concepts and provides an introduction to algorithms and data structures. The book is written for students with no prior programming background, but experienced students will also benefit from its depth of detail.

Control Structures First, Then Objects, Then Data Structures

The text introduces students to the fundamentals of data types, input/output, control structures, methods, and objects created from standard library classes. Next, students learn to use arrays. Then, a series of more advanced topics are presented, including inheritance, polymorphism, GUI development, recursion, searching, sorting, algorithm analysis, and generics. Finally, students are introduced to the world of data structures, beginning with an overview of the Java Collections Framework (JCF), and continuing through a series of chapters in which students learn to develop their own data structures, including linked lists, stacks, queues, priority queues, binary trees, and AVL trees. Students are shown how to implement data structures either with or without generics, which gives instructors a great deal of flexibility in presenting the material.

As with all the books in the *Starting Out With* series, the hallmark of the text is its clear, friendly, and easy-to-understand writing. In addition, it is rich in concise, practical example programs.

Changes in This Edition

This book's pedagogy, organization, and clear writing style remain the same as in the previous edition. The most significant change in this edition is the switch from Swing to JavaFX in the chapters that focus on GUI development. Although Swing is not officially deprecated, Oracle has announced that JavaFX has replaced Swing as the standard GUI library for Java[1].

[1] http://www.oracle.com/technetwork/java/javafx/overview/faq-1446554.html#6

In this edition, we have added the following new chapters:

- **Chapter 12 JavaFX: GUI Programming and Basic Controls:** This chapter presents the basics of developing graphical user interface (GUI) applications with JavaFX. Fundamental controls, layout containers, and the basic concepts of event-driven programming are covered.
- **Chapter 13 JavaFX: Advanced Controls:** This chapter discusses CSS styling and advanced user interface controls.
- **Chapter 14 JavaFX: Graphics, Effects, and Media:** This chapter discusses 2D shapes, animation, visual effects, playing audio and video, and responding to mouse and keyboard events.

The Swing and Applet material that appeared in the previous edition is still available on the book's companion Web site, as the following online chapters:

- The previous Chapter 12 *A First Look At GUI Applications* is now available online as Chapter 23.
- The previous Chapter 13 *Advanced GUI Applications* is now available online as Chapter 24.
- The previous Chapter 14 *Applets and More* is now available online as Chapter 25.

In addition to the new JavaFX chapters, the online Database chapter, which is now Chapter 22, has been updated to use JavaFX instead of Swing for its GUI applications. We have also added several new, motivational programming problems throughout the book.

Organization of the Text

The text teaches Java step by step. Each chapter covers a major set of topics and builds knowledge as students progress through the book. Although the chapters can be easily taught in their existing sequence, there is some flexibility. Figure P-1 shows chapter dependencies. Each box represents a chapter or a group of chapters. An arrow points from a chapter to the chapter that must be previously covered.

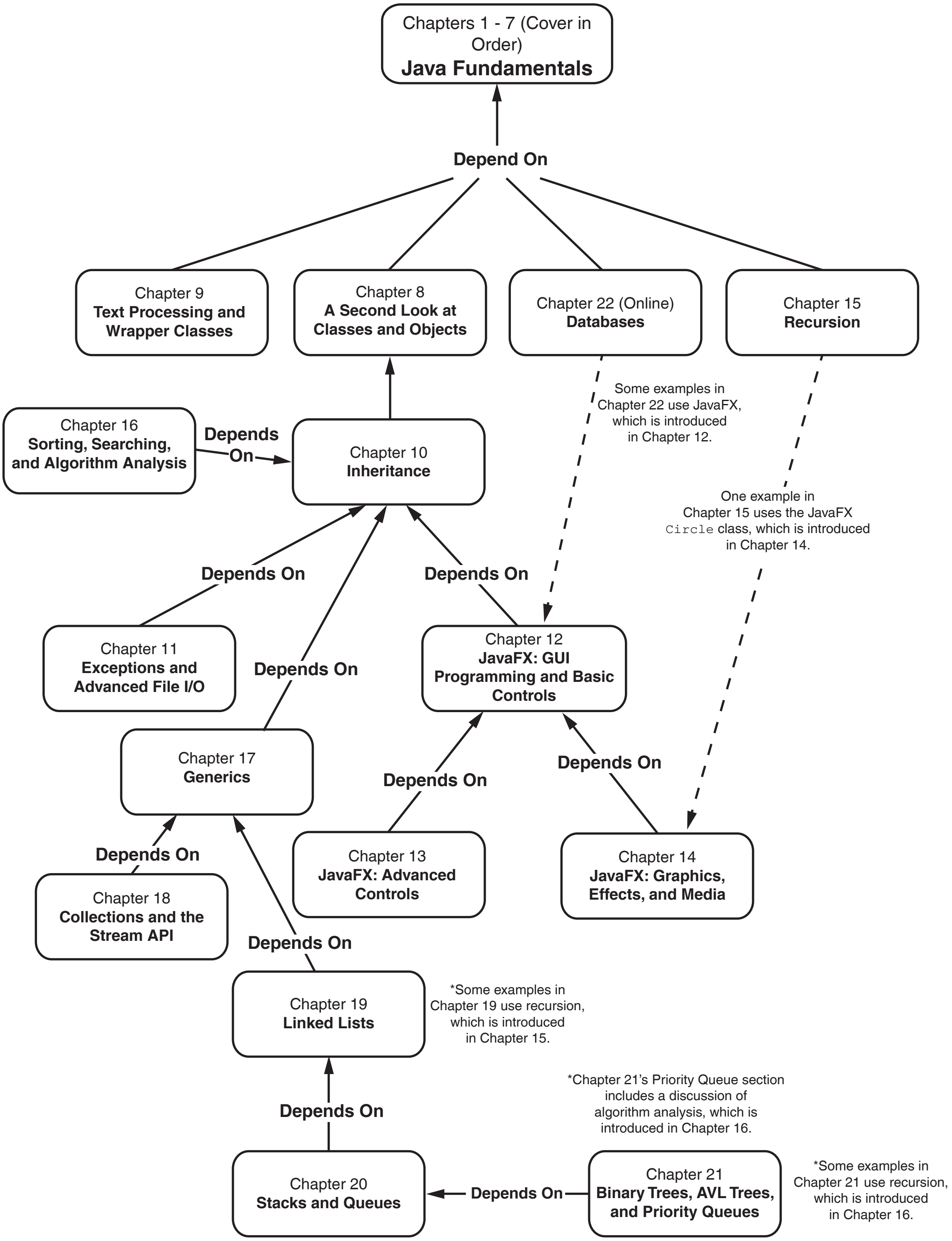
Brief Overview of Each Chapter

Chapter 1: Introduction to Computers and Java. This chapter provides an introduction to the field of computer science, and covers the fundamentals of hardware, software, and programming languages. The elements of a program, such as key words, variables, operators, and punctuation are discussed by examining a simple program. An overview of entering source code, compiling, and executing a program is presented. A brief history of Java is also given.

Chapter 2: Java Fundamentals. This chapter gets students started in Java by introducing data types, identifiers, variable declarations, constants, comments, program output, and simple arithmetic operations. The conventions of programming style are also introduced. Students learn to read console input with the Scanner class and with dialog boxes using `JOptionPane`.

Chapter 3: Decision Structures. In this chapter students explore relational operators and relational expressions, and are shown how to control the flow of a program with the `if`,

Figure P-1 Chapter dependencies


Chapters 1 - 7 (Cover in Order)
Java Fundamentals
Depend On
Chapter 9
Text Processing and Wrapper Classes
Chapter 8
A Second Look at Classes and Objects
Chapter 22 (Online)
Databases
Chapter 15
Recursion
Chapter 16
Sorting, Searching, and Algorithm Analysis
Depends On
Chapter 10
Inheritance
Some examples in Chapter 22 use JavaFX, which is introduced in Chapter 12.
One example in Chapter 15 uses the JavaFX Circle class, which is introduced in Chapter 14.
Depends On
Depends On
Chapter 11
Exceptions and Advanced File I/O
Depends On
Chapter 12
JavaFX: GUI Programming and Basic Controls
Chapter 17
Generics
Depends On
Depends On
Chapter 13
JavaFX: Advanced Controls
Chapter 14
JavaFX: Graphics, Effects, and Media
Depends On
Chapter 18
Collections and the Stream API
Depends On
Chapter 19
Linked Lists
*Some examples in Chapter 19 use recursion, which is introduced in Chapter 15.
Depends On
*Chapter 21's Priority Queue section includes a discussion of algorithm analysis, which is introduced in Chapter 16.
Chapter 20
Stacks and Queues
Depends On
Chapter 21
Binary Trees, AVL Trees, and Priority Queues
*Some examples in Chapter 21 use recursion, which is introduced in Chapter 16.

if-else, and if-else-if statements. Nested if statements, logical operators, the conditional operator, and the switch statement are also covered. The chapter discusses how to compare String objects with the equals, compareTo, equalsIgnoreCase, and compareToIgnoreCase methods. Formatting numeric output with the System.out.printf method and the String.format method is discussed.

Chapter 4: Loops and Files. This chapter covers Java's repetition control structures. The while loop, do-while loop, and for loop are taught, along with common uses for these devices. Counters, accumulators, running totals, sentinels, and other application-related topics are discussed. Simple file operations for reading and writing text files are included.

Chapter 5: Methods. In this chapter students learn how to write void methods, value-returning methods, and methods that do and do not accept arguments. The concept of functional decomposition is discussed.

Chapter 6: A First Look at Classes. This chapter introduces students to designing classes for the purpose of instantiating objects. Students learn about class fields and methods, and UML diagrams are introduced as a design tool. Then constructors and overloading are discussed. A BankAccount class is presented as a case study, and a section on object-oriented design is included. This section leads the students through the process of identifying classes and their responsibilities within a problem domain. There is also a section that briefly explains packages and the import statement.

Chapter 7: Arrays and the ArrayList Class. In this chapter students learn to create and work with single and multi-dimensional arrays. Numerous array-processing techniques are demonstrated, such as summing the elements in an array, finding the highest and lowest values, and sequentially searching an array are also discussed. Other topics, including ragged arrays and variable-length arguments (varargs) are also discussed. The ArrayList class is introduced and Java's generic types are briefly discussed and demonstrated.

Chapter 8: A Second Look at Classes and Objects. This chapter shows students how to write classes with added capabilities. Static methods and fields, interaction between objects, passing objects as arguments, and returning objects from methods are discussed. Aggregation and the "has a" relationship is covered, as well as enumerated types. A section on object-oriented design shows how to use CRC cards to determine the collaborations among classes.

Chapter 9: Text Processing and More about Wrapper Classes. This chapter discusses the numeric and Character wrapper classes. Methods for converting numbers to strings, testing the case of characters, and converting the case of characters are covered. Autoboxing and unboxing are also discussed. More String class methods are covered, including using the split method to tokenize strings. The chapter also covers the StringBuilder class.

Chapter 10: Inheritance. The study of classes continues in this chapter with the subjects of inheritance and polymorphism. The topics covered include superclasses, subclasses, how constructors work in inheritance, method overriding, polymorphism and dynamic binding, protected and package access, class hierarchies, abstract classes, abstract methods, anonymous inner classes, interfaces, and lambda expressions.

Chapter 11: Exceptions and Advanced File I/O. In this chapter students learn to develop enhanced error trapping techniques using exceptions. Handling exceptions is covered, as well as developing and throwing custom exceptions. The chapter discusses advanced techniques for working with sequential access, random access, text, and binary files.

Chapter 12: JavaFX: GUI Programming and Basic Controls. This chapter presents the basics of developing graphical user interface (GUI) applications with JavaFX. Fundamental controls, layout containers, and the basic concepts of event-driven programming are covered.

Chapter 13: JavaFX: Advanced Controls. This chapter discusses CSS styling and advanced user interface controls, such as RadioButtons, CheckBoxes, ListViews, ComboBoxes, Sliders, and TextAreas. Menu systems and FileChoosers are also covered.

Chapter 14: JavaFX: Graphics, Effects, and Media. This chapter discusses 2D shapes, animation, visual effects, playing audio and video, and responding to mouse and keyboard events.

Chapter 15: Recursion. This chapter presents recursion as a problem-solving technique. Numerous examples of recursive methods are demonstrated.

Chapter 16: Sorting, Searching, and Algorithm Analysis. In this chapter students learn the basics of sorting arrays and searching for data stored in them. The chapter covers the bubble sort, selection sort, insertion sort, Quicksort, sequential search, and binary search algorithms. A section on algorithm analysis is also provided, which covers basic steps, complexity, and Big O notation.

Chapter 17: Generics. This chapter shows students how to write generic classes and methods. Topics include erasure, passing instances of a generic class as arguments to a method, constraining type parameters, generics and inheritance, and generics and interfaces. Restrictions on the use of generic types are also discussed.

Chapter 18: Collections and the Stream API. This chapter introduces students to the Java Collections Framework (JCF). Lists, sets, maps, and the Collections class are discussed. The chapter concludes with a discussion of the classes and interfaces in the java.util.stream package.

Chapter 19: Linked Lists. This chapter introduces concepts and techniques for writing a linked list class. Basic linked list operations, such as adding, inserting, removing, and traversing, are covered. Doubly-linked lists, circularly-linked lists, and using recursion with linked lists are discussed.

Chapter 20: Stacks and Queues. In this chapter students learn about the operations of stacks and queues, and how to write array-based and linked list-based stack and queue classes.

Chapter 21: Binary Trees, AVL Trees, and Priority Queues. This chapter covers various aspects of binary trees and binary tree operations. The specific binary tree implementations covered are binary search trees, AVL trees, and priority queues.

Chapter 22 (Online): Databases. This chapter is available on the book's companion Web site (at www.pearson.com/gaddis). It introduces the students to database programming. The basic concepts of database management systems and SQL are first introduced. Then the students learn to use JDBC to write database applications in Java. Relational data is covered, and numerous example programs are presented throughout the chapter.

Chapters 23 – 25 (Online): Legacy Swing GUI Chapters. The previous edition's chapters on Swing GUI and Applet programming are now available on the book's companion website (at www.pearson.com/gaddis) as Chapters 23 through 25.

Features of the Text

Concept Statements. Each major section of the text starts with a concept statement that concisely summarizes the focus of the section.

Example Programs. The text has an abundant number of complete and partial example programs, each designed to highlight the current topic. In most cases the programs are practical, real-world examples.

Program Output. Each example program is followed by a sample of its output, which shows students how the program functions.

Checkpoints. Checkpoints, highlighted by the checkmark icon, appear at intervals throughout each chapter. They are designed to check students' knowledge soon after learning a new topic. Answers for all Checkpoint questions can be downloaded from the book's companion Web site at www.pearson.com/gaddis.

> **NOTE:** Notes appear at several places throughout the text. They are short explanationsof interesting or often misunderstood points relevant to the topic at hand.

> **TIP:** Tips advise the student on the best techniques for approaching different programming problems and appear regularly throughout the text.

> **WARNING!** Warnings caution students about certain Java features, programming techniques, or practices that can lead to malfunctioning programs or lost data.

In the Spotlight. Many of the chapters provide an *In the Spotlight* section that presents a programming problem, along with detailed, step-by-step analysis showing the student how to solve it.

VideoNote

VideoNotes. A series of online videos, developed specifically for this book, are available for viewing at www.pearson.com/gaddis. Icons appear throughout the text, alerting the student to videos about specific topics.

Case Studies. Case studies that simulate real-world business applications are introduced throughout the text and are available for download from the Gaddis resource page at www.pearson.com/gaddis.

Common Errors to Avoid. Most chapters provide a list of common errors and explanations of how to avoid them.

Review Questions and Exercises. Each chapter presents a thorough and diverse set of review questions and exercises. They include Multiple Choice and True/False, Find the Error, Algorithm Workbench, and Short Answer.

Programming Challenges. Each chapter offers a pool of programming challenges designed to solidify students' knowledge of topics at hand. In most cases the assignments present real-world problems to be solved.

Supplements

Student Online Resources

Many student resources are available for this book from the publisher. The following items are available on the Gaddis Series resource page at www.pearson.com/gaddis:

- The source code for each example program in the book
- Access to the book's companion VideoNotes
- Appendixes A–M (listed in the Contents)
- A collection of seven valuable Case Studies (listed in the Contents)
- Links to download the Java™ Edition Development Kit
- Links to download numerous programming environments, including jGRASP™, Eclipse™, TextPad™, NetBeans™, JCreator, and DrJava

Instructor Resources

The following supplements are available to qualified instructors:

- Answers to all of the Review Questions
- Solutions for the Programming Challenges
- PowerPoint presentation slides for each chapter

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CHAPTER 1

Introduction to Computers and Java

TOPICS

1.1 Introduction
1.2 Why Program?
1.3 Computer Systems: Hardware and Software
1.4 Programming Languages
1.5 What Is a Program Made Of?
1.6 The Programming Process
1.7 Object-Oriented Programming

1.1 Introduction

This book teaches programming using Java. Java is a powerful language that runs on practically every type of computer. It can be used to create large applications, small programs, mobile applications, and code that powers a Web site. Before plunging right into learning Java, however, this chapter will review the fundamentals of computer hardware and software, and then take a broad look at computer programming in general.

1.2 Why Program?

CONCEPT: Computers can do many different jobs because they are programmable.

Every profession has tools that make the job easier to do. Carpenters use hammers, saws, and measuring tapes. Mechanics use wrenches, screwdrivers, and ratchets. Electronics technicians use probes, scopes, and meters. Some tools are unique and can be categorized as belonging to a single profession. For example, surgeons have certain tools that are designed specifically for surgical operations. Those tools probably aren't used by anyone other than surgeons. There are some tools, however, that are used in several professions. Screwdrivers, for instance, are used by mechanics, carpenters, and many others.

The computer is a tool used by so many professions that it cannot be easily categorized. It can perform so many different jobs that it is perhaps the most versatile tool ever made. To the accountant, computers balance books, analyze profits and losses, and prepare tax reports. To the factory worker, computers control manufacturing machines and track production. To the mechanic, computers analyze the various systems in an automobile and pinpoint hard-to-find problems. The computer can do such a wide variety of tasks because it can be *programmed*. It is a machine specifically designed to follow instructions. Because of the computer's programmability, it doesn't belong to any single profession. Computers are designed to do whatever job their programs, or *software*, tell them to do.

Computer programmers do a very important job. They create software that transforms computers into the specialized tools of many trades. Without programmers, the users of computers would have no software, and without software, computers would not be able to do anything.

Computer programming is both an art and a science. It is an art because every aspect of a program should be carefully designed. Here are a few of the things that must be designed for any real-world computer program:

- The logical flow of the instructions
- The mathematical procedures
- The layout of the programming statements
- The appearance of the screens
- The way information is presented to the user
- The program's "user friendliness"
- Manuals, help systems, and/or other forms of written documentation

There is also a science to programming. Because programs rarely work right the first time they are written, a lot of analyzing, experimenting, correcting, and redesigning is required. This demands patience and persistence of the programmer. Writing software demands discipline as well. Programmers must learn special languages such as Java because computers do not understand English or other human languages. Programming languages have strict rules that must be carefully followed.

Both the artistic and scientific nature of programming makes writing computer software like designing a car: Both cars and programs should be functional, efficient, powerful, easy to use, and pleasing to look at.

1.3 Computer Systems: Hardware and Software

CONCEPT: All computer systems consist of similar hardware devices and software components.

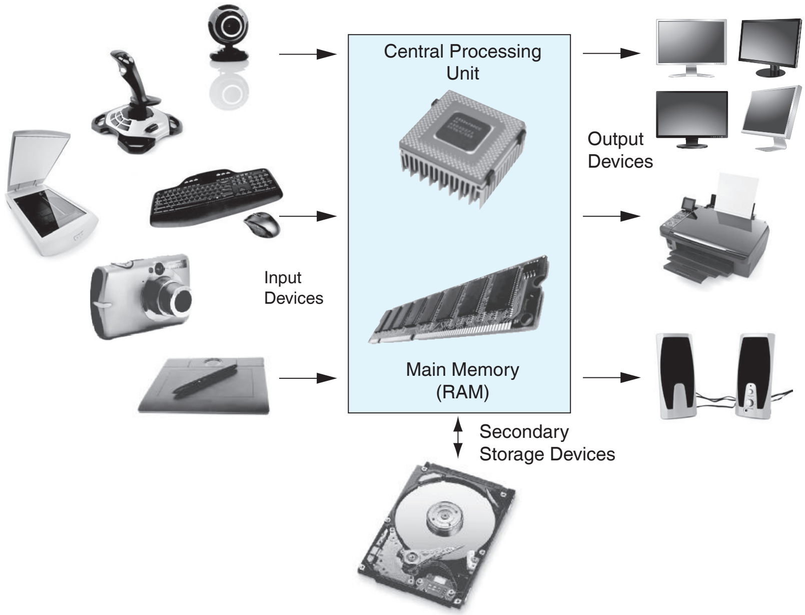
Hardware

Hardware refers to the physical components that a computer is made of. A computer, as we generally think of it, is not an individual device, but a system of devices. Like the instruments in a symphony orchestra, each device plays its own part. A typical computer system consists of the following major components:

- The central processing unit (CPU)
- Main memory
- Secondary storage devices
- Input devices
- Output devices

The organization of a computer system is shown in Figure 1-1.

Figure 1-1 The organization of a computer system 1-1a (TL) iko/Shutterstock, 1-1b (TL) Nikita Rogul/Shutterstock, 1-1c (TLC) Feng Yu/Shutterstock , 1-1d (TLC) Chiyacat/Shutterstock, 1-1e Elkostas/Shutterstock, 1-1f (TLB) tkemot/Shutterstock, 1-1g (BC) Vitaly Korovin/Shutterstock, 1-1h (TRB) Lusoimages/Shutterstock, 1-1i (TRC) jocic/Shutterstock, 1-1j (TR) Best Pictures here/Shutterstock, 1-1k (MC) Peter Guess/Shutterstock, 1-1l (TC) Aquila/Shutterstock

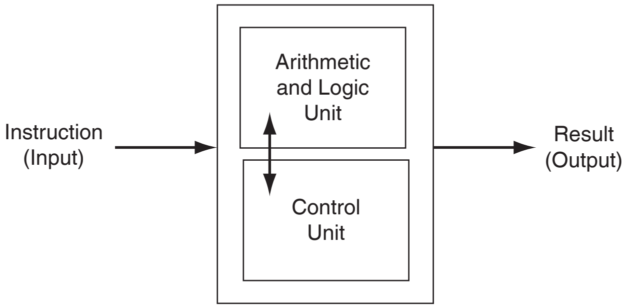


Let's take a closer look at each of these devices.

The CPU

At the heart of a computer is its *central processing unit*, or *CPU*. The CPU's job is to fetch instructions, follow the instructions, and produce some resulting data. Internally, the central processing unit consists of two parts: the *control unit* and the *arithmetic and logic unit (ALU)*. The control unit coordinates all of the computer's operations. It is responsible for determining where to get the next instruction and regulating the other major components of the computer with control signals. The arithmetic and logic unit, as its name suggests, is designed to perform mathematical operations. The organization of the CPU is shown in Figure 1-2.

Figure 1-2 The organization of the CPU



A program is a sequence of instructions stored in the computer's memory. When a computer is running a program, the CPU is engaged in a process known formally as the *fetch/decode/execute cycle*. The steps in the fetch/decode/execute cycle are as follows:

Fetch The CPU's control unit fetches, from main memory, the next instruction in the sequence of program instructions.

Decode The instruction is encoded in the form of a number. The control unit decodes the instruction and generates an electronic signal.

Execute The signal is routed to the appropriate component of the computer (such as the ALU, a disk drive, or some other device). The signal causes the component to perform an operation.

These steps are repeated as long as there are instructions to perform.

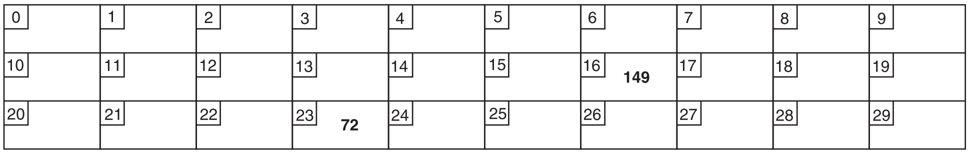
Main Memory

Commonly known as *random access memory*, or *RAM*, the computer's main memory is a device that holds information. Specifically, RAM holds the sequences of instructions in the programs that are running and the data those programs are using.

Memory is divided into sections that hold an equal amount of data. Each section is made of eight "switches" that may be either on or off. A switch in the on position usually represents the number 1, whereas a switch in the off position usually represents the number 0. The computer stores data by setting the switches in a memory location to a pattern that represents a character or a number. Each of these switches is known as a *bit*, which stands for *binary digit*. Each section of memory, which is a collection of eight bits, is known as a *byte*. Each byte is assigned a unique number known as an *address*. The addresses are ordered from lowest to highest. A byte is identified by its address in much the same way a post office box is identified by an address. Figure 1-3 shows a series of bytes with their addresses. In the illustration, sample data is stored in memory. The number 149 is stored in the byte at address 16, and the number 72 is stored in the byte at address 23.

RAM is usually a volatile type of memory, used only for temporary storage. When the computer is turned off, the contents of RAM are erased.

Figure 1-3 Memory bytes and their addresses



0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16 149	17	18	19
20	21	22	23 72	24	25	26	27	28	29

Secondary Storage

Secondary storage is a type of memory that can hold data for long periods of time—even when there is no power to the computer. Frequently used programs are stored in secondary memory and loaded into main memory as needed. Important data, such as word processing documents, payroll data, and inventory figures, is saved to secondary storage as well.

The most common type of secondary storage device is the *disk drive*. A traditional disk drive stores data by magnetically encoding it onto a spinning circular disk. *Solid state drives*, which store data in solid-state memory, are increasingly becoming popular. A solid-state drive has no moving parts, and operates faster than a traditional disk drive. Most computers have some sort of secondary storage device, either a traditional disk drive or a solid-state drive, mounted inside their case. External drives are also available, which connect to one of the computer's communication ports. External drives can be used to create backup copies of important data or to move data to another computer.

In addition to external drives, many types of devices have been created for copying data, and for moving it to other computers. *Universal Serial Bus drives,* or *USB drives* are small devices that plug into the computer's USB (Universal Serial Bus) port, and appear to the system as a disk drive. These drives do not actually contain a disk, however. They store data in a special type of memory known as *flash memory*. USB drives are inexpensive, reliable, and small enough to be carried in your pocket.

Optical devices such as the *CD* (compact disc) and the *DVD* (digital versatile disc) are also popular for data storage. Data is not recorded magnetically on an optical disc, but is encoded as a series of pits on the disc surface. CD and DVD drives use a laser to detect the pits and thus read the encoded data. Optical discs hold large amounts of data, and because recordable CD and DVD drives are now commonplace, they make a good medium for creating backup copies of data.

Input Devices

Input is any data the computer collects from the outside world. The device that collects the data and sends it to the computer is called an *input device*. Common input devices are the keyboard, mouse, scanner, and digital camera. Disk drives, optical drives, and USB drives can also be considered input devices because programs and data are retrieved from them and loaded into the computer's memory.

Output Devices

Output is any data the computer sends to the outside world. It might be a sales report, a list of names, or a graphic image. The data is sent to an output device, which formats and presents it. Common output devices are monitors and printers. Disk drives, USB drives, and CD recorders can also be considered output devices because the CPU sends data to them to be saved.

Software

As previously mentioned, software refers to the programs that run on a computer. There are two general categories of software: operating systems and application software. An operating system is a set of programs that manages the computer's hardware devices and controls their processes. Most all modern operating systems are multitasking, which means they are capable of running multiple programs at once. Through a technique called time sharing, a multitasking system divides the allocation of hardware resources and the attention of the CPU among all the executing programs. UNIX, Linux, Mac OS, and Windows are multitasking operating systems.

Application software refers to programs that make the computer useful to the user. These programs solve specific problems or perform general operations that satisfy the needs of the user. Word processing, spreadsheet, and database packages are all examples of application software.

Checkpoint

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1.1 Why is the computer used by so many different people, in so many different professions?

1.2 List the five major hardware components of a computer system.

1.3 Internally, the CPU consists of what two units?

1.4 Describe the steps in the fetch/decode/execute cycle.

1.5 What is a memory address? What is its purpose?

1.6 Explain why computers have both main memory and secondary storage.

1.7 What does the term *multitasking* mean?

1.4 Programming Languages

CONCEPT: A program is a set of instructions a computer follows in order to perform a task. A programming language is a special language used to write computer programs.

What Is a Program?

Computers are designed to follow instructions. A computer program is a set of instructions that enable the computer to solve a problem or perform a task. For example, suppose we want the computer to calculate someone's gross pay. The following is a list of things the computer should do to perform this task.

1. Display a message on the screen: "How many hours did you work?"
2. Allow the user to enter the number of hours worked.
3. Once the user enters a number, store it in memory.
4. Display a message on the screen: "How much do you get paid per hour?"
5. Allow the user to enter an hourly pay rate.
6. Once the user enters a number, store it in memory.
7. Once both the number of hours worked and the hourly pay rate are entered, multiply the two numbers and store the result in memory.
8. Display a message on the screen that shows the amount of money earned. The message must include the result of the calculation performed in Step 7.

Collectively, these instructions are called an *algorithm*. An algorithm is a set of well-defined steps for performing a task or solving a problem. Notice that these steps are sequentially ordered. Step 1 should be performed before Step 2, and so forth. It is important that these instructions be performed in their proper sequence.

Although you and I might easily understand the instructions in the pay-calculating algorithm, it is not ready to be executed on a computer. A computer's CPU can only process instructions that are written in *machine language*. If you were to look at a machine language program, you would see a stream of binary numbers (numbers consisting of only 1s and 0s). The binary numbers form machine language instructions, which the CPU interprets as commands. Here is an example of what a machine language instruction might look like:

```
1011010000000101
```

As you can imagine, the process of encoding an algorithm in machine language is very tedious and difficult. In addition, each different type of CPU has its own machine language. If you wrote a machine language program for computer A and then wanted to run it on computer B, which has a different type of CPU, you would have to rewrite the program in computer B's machine language.

Programming languages, which use words instead of numbers, were invented to ease the task of programming. A program can be written in a programming language, which is much easier to understand than machine language, and then translated into machine language. Programmers use software to perform this translation. Many programming languages have been created. Table 1-1 lists a few of the well-known ones.

Table 1-1 Programming languages

Language	Description
BASIC	Beginners All-purpose Symbolic Instruction Code is a general-purpose, procedural programming language. It was originally designed to be simple enough for beginners to learn.
FORTRAN	FORmula TRANslator is a procedural language designed for programming complex mathematical algorithms.
COBOL	Common Business-Oriented Language is a procedural language designed for business applications.
Pascal	Pascal is a structured, general-purpose, procedural language designed primarily for teaching programming.
C	C is a structured, general-purpose, procedural language developed at Bell Laboratories.
C+ +	Based on the C language, C+ + offers object-oriented features not found in C. C+ + was also invented at Bell Laboratories.
C#	Pronounced "C sharp." It is a language invented by Microsoft for developing applications based on the Microsoft .NET platform.
Java	Java is an object-oriented language invented at Sun Microsystems, and is now owned by Oracle. It may be used to develop stand-alone applications that operate on a single computer, or applications that run over the Internet from a Web server.
JavaScript	JavaScript is a programming language that can be used in a Web site to perform simple operations. Despite its name, JavaScript is not related to Java.
Perl	A general-purpose programming language used widely on Internet servers.
PHP	A programming language used primarily for developing Web server applications and dynamic Web pages.
Python	Python is an object-oriented programming language used in both business and academia. Many popular Web sites contain features developed in Python.
Ruby	Ruby is a simple but powerful object-oriented programming language. It can be used for a variety of purposes, from small utility programs to large Web applications.
Visual Basic	Visual Basic is a Microsoft programming language and software development environment that allows programmers to create Windows-based applications quickly.

A History of Java

In 1991 a team was formed at Sun Microsystems (a company that is now owned by Oracle) to speculate about the important technological trends that might emerge in the near future. The team, which was named the Green Team, concluded that computers would merge with consumer appliances. Their first project was to develop a handheld device named *7 (pronounced star seven) that could be used to control a variety of home entertainment devices. For the unit to work, it had to use a programming language that could be processed by all the devices it controlled. This presented a problem because different brands of consumer devices use different processors, each with its own machine language.

Because no such universal language existed, James Gosling, the team's lead engineer, created one. Programs written in this language, which was originally named Oak, were not translated into the machine language of a specific processor, but were translated into an intermediate language known as *byte code*. Another program would then translate the byte code into machine language that could be executed by the processor in a specific consumer device.

Unfortunately, the technology developed by the Green Team was ahead of its time. No customers could be found, mostly because the computer-controlled consumer appliance industry was just beginning. But rather than abandoning their hard work and moving on to other projects, the team saw another opportunity: the Internet. The Internet is a perfect environment for a universal programming language such as Oak. It consists of numerous different computer platforms connected together in a single network.

To demonstrate the effectiveness of its language, which was renamed Java, the team used it to develop a Web browser. The browser, named HotJava, was able to download and run small Java programs known as applets. This gave the browser the capability to display animation and interact with the user. HotJava was demonstrated at the 1995 SunWorld conference before a wowed audience. Later the announcement was made that Netscape would incorporate Java technology into its Navigator browser. Other Internet companies rapidly followed, increasing the acceptance and the influence of the Java language. Today, Java is very popular for developing not only applets for developing Web applications, mobile apps, and desktop applications.

1.5 What Is a Program Made Of?

CONCEPT: There are certain elements that are common to all programming languages.

Language Elements

All programming languages have some things in common. Table 1-2 lists the common elements you will find in almost every language.

Table 1-2 The common elements of a programming language

Language Element	Description
Key Words	These are words that have a special meaning in the programming language. They may be used for their intended purpose only. Key words are also known as reserved words.
Operators	Operators are symbols or words that perform operations on one or more operands. An operand is usually an item of data, such as a number.
Punctuation	Most programming languages require the use of punctuation characters. These characters serve specific purposes, such as marking the beginning or ending of a statement, or separating items in a list.
Programmer-Defined Names	Unlike key words, which are part of the programming language, these are words or names that are defined by the programmer. They are used to identify storage locations in memory and parts of the program that are created by the programmer. Programmer-defined names are often called identifiers.
Syntax	These are rules that must be followed when writing a program. Syntax dictates how key words and operators may be used, and where punctuation symbols must appear.

Let's look at an example Java program and identify an instance of each of these elements. Code Listing 1-1 shows the code listing with each line numbered.

NOTE: The line numbers are not part of the program. They are included to help point out specific parts of the program.

Code Listing 1-1 `Payroll.java`

```
 1  public class Payroll
 2  {
 3     public static void main(String[] args)
 4     {
 5        int hours = 40;
 6        double grossPay, payRate = 25.0;
 7
 8        grossPay = hours * payRate;
 9        System.out.println("Your gross pay is $" + grossPay);
10     }
11  }
```

Key Words (Reserved Words)

Two of Java's key words appear in line 1: `public` and `class`. In line 3, the words `public`, `static`, and `void` are all key words. The words `int` in line 5 and `double` in line 6 are also key words. These words, which are always written in lowercase, each have a special meaning in Java and can only be used for their intended purpose. As you will see, the programmer is allowed to make up his or her own names for certain things in a program. Key words, however, are reserved and cannot be used for anything other than their designated purpose. Part of learning a programming language is learning the commonly used key words, what they mean, and how to use them.

Table 1-3 shows a list of the Java key words[1].

Table 1-3 The Java key words

`abstract`	`const`	`final`	`int`	`public`	`throw`
`assert`	`continue`	`finally`	`interface`	`return`	`throws`
`boolean`	`default`	`float`	`long`	`short`	`transient`
`break`	`do`	`for`	`native`	`static`	`true`
`byte`	`double`	`goto`	`new`	`strictfp`	`try`
`case`	`else`	`if`	`null`	`super`	`void`
`catch`	`enum`	`implements`	`package`	`switch`	`volatile`
`char`	`extends`	`import`	`private`	`synchronized`	`while`
`class`	`false`	`instanceof`	`protected`	`this`	

Programmer-Defined Names

The words `hours`, `payRate`, and `grossPay` that appear in the program in lines 5, 6, 8, and 9 are programmer-defined names. They are not part of the Java language but are names made up by the programmer. In this particular program, these are the names of variables. As you will learn later in this chapter, variables are the names of memory locations that may hold data.

Operators

In line 8 the following line appears:

```
grossPay = hours * payRate;
```

The `=` and `*` symbols are both operators. They perform operations on items of data, known as operands. The `*` operator multiplies its two operands, which in this example are the variables `hours` and `payRate`. The `=` symbol is called the assignment operator. It takes the value of the expression that appears at its right and stores it in the variable whose name appears at its left. In this example, the `=` operator stores in the `grossPay` variable the result of the `hours` variable multiplied by the `payRate` variable. In other words, the statement says, "the `grossPay` variable is assigned the value of `hours` times `payRate`."

[1] Java 9 also introduces a set of *restricted words* that are treated as key words under certain circumstances. See Appendix C for the full list.

Punctuation

Notice that lines 5, 6, 8, and 9 end with a semicolon. A semicolon in Java is similar to a period in English: It marks the end of a complete sentence (or statement, as it is called in programming jargon). Semicolons do not appear at the end of every line in a Java program, however. There are rules that govern where semicolons are required and where they are not. Part of learning Java is learning where to place semicolons and other punctuation symbols.

Lines and Statements

Often, the contents of a program are thought of in terms of lines and statements. A *line* is just that—a single line as it appears in the body of a program. Code Listing 1-1 is shown with each of its lines numbered. Most of the lines contain something meaningful; however, line 7 is empty. Blank lines are only used to make a program more readable.

A statement is a complete instruction that causes the computer to perform some action. Here is the statement that appears in line 9 of Code Listing 1-1:

```
System.out.println("Your gross pay is $" + grossPay);
```

This statement causes the computer to display a message on the screen. Statements can be a combination of key words, operators, and programmer-defined names. Statements often occupy only one line in a program, but sometimes they are spread out over more than one line.

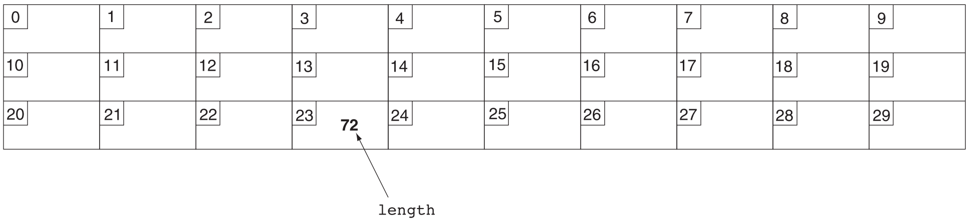
Variables

The most fundamental way that a Java program stores an item of data in memory is with a variable. A *variable* is a named storage location in the computer's memory. The data stored in a variable may change while the program is running (hence the name "variable"). Notice that in Code Listing 1-1 the programmer-defined names `hours`, `payRate`, and `grossPay` appear in several places. All three of these are the names of variables. The `hours` variable is used to store the number of hours the user has worked. The `payRate` variable stores the user's hourly pay rate. The `grossPay` variable holds the result of `hours` multiplied by `payRate`, which is the user's gross pay.

Variables are symbolic names made up by the programmer that represent locations in the computer's RAM. When data is stored in a variable, it is actually stored in RAM. Assume that a program has a variable named `length`. Figure 1-4 illustrates the way the variable name represents a memory location.

In Figure 1-4, the variable `length` is holding the value 72. The number 72 is actually stored in RAM at address 23, but the name `length` symbolically represents this storage location. If it helps, you can think of a variable as a box that holds data. In Figure 1-4, the number 72 is stored in the box named `length`. Only one item may be stored in the box at any given time. If the program stores another value in the box, it will take the place of the number 72.

Figure 1-4 A variable name represents a location in memory



The Compiler and the Java Virtual Machine

When a Java program is written, it must be typed into the computer and saved to a file. A *text editor*, which is similar to a word processing program, is used for this task. The Java programming statements written by the programmer are called *source code*, and the file they are saved in is called a *source file*. Java source files end with the *.java* extension.

After the programmer saves the source code to a file, he or she runs the Java compiler. A *compiler* is a program that translates source code into an executable form. During the translation process, the compiler uncovers any syntax errors that may be in the program. *Syntax errors* are mistakes that the programmer has made that violate the rules of the programming language. These errors must be corrected before the compiler can translate the source code. Once the program is free of syntax errors, the compiler creates another file that holds the translated instructions.

Most programming language compilers translate source code directly into files that contain machine language instructions. These are called *executable files* because they may be executed directly by the computer's CPU. The Java compiler, however, translates a Java source file into a file that contains byte code instructions. Byte code instructions are not machine language, and therefore cannot be directly executed by the CPU. Instead, they are executed by the *Java Virtual Machine* (JVM). The JVM is a program that reads Java byte code instructions and executes them as they are read. For this reason, the JVM is often called an interpreter, and Java is often referred to as an interpreted language. Figure 1-5 illustrates the process of writing a Java program, compiling it to byte code, and running it.

Although Java byte code is not machine language for a CPU, it can be considered as machine language for the JVM. You can think of the JVM as a program that simulates a computer whose machine language is Java byte code.

Portability

The term *portable* means that a program may be written on one type of computer and then run on a wide variety of computers, with little or no modification necessary. Because Java byte code is the same on all computers, compiled Java programs are highly portable. In fact, a compiled Java program may be run on any computer that has a Java Virtual Machine. Figure 1-6 illustrates the concept of a compiled Java program running on Windows, Linux, Mac, and UNIX computers.

With most other programming languages, portability is achieved by the creation of a compiler for each type of computer that the language is to run on. For example, in order for the C+ + language to be supported by Windows, Linux, and Mac computers, a separate C+ + compiler must be created for each of those environments. Compilers are very complex programs, and more difficult to develop than interpreters. For this reason, a JVM has been developed for many types of computers.

Figure 1-5 Program development process

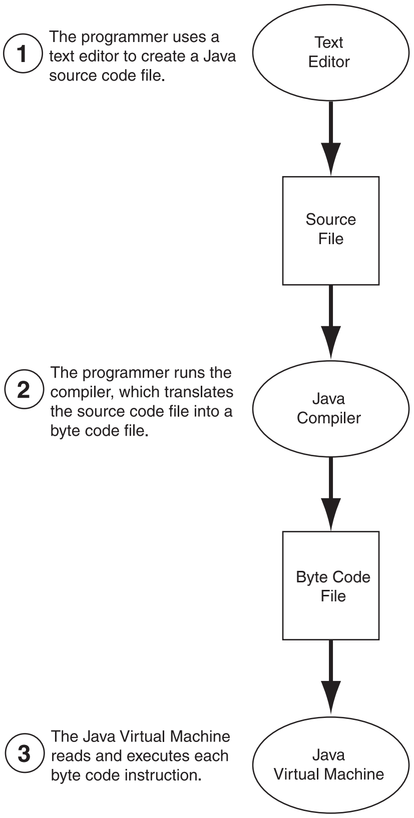
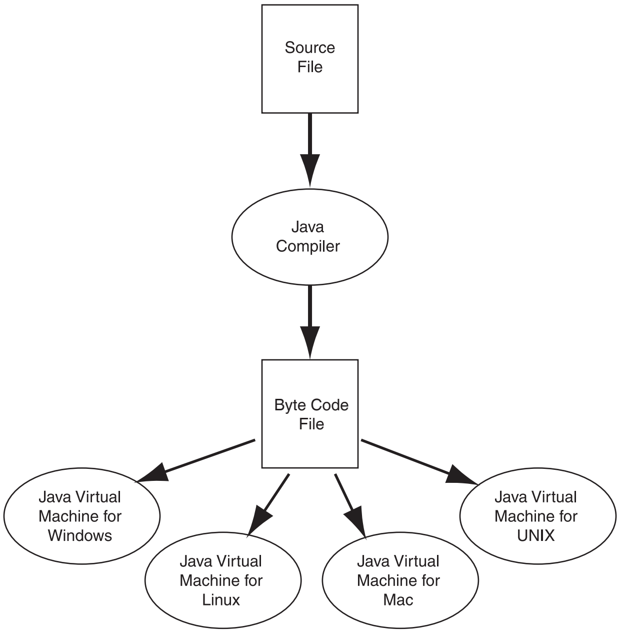

1
The programmer uses a text editor to create a Java source code file.
Text Editor
Source File
2
The programmer runs the compiler, which translates the source code file into a byte code file.
Java Compiler
Byte Code File
3
The Java Virtual Machine reads and executes each byte code instruction.
Java Virtual Machine

Figure 1-6 Java byte code may be run on any computer with a Java Virtual Machine


Source File
Java Compiler
Byte Code File
Java Virtual Machine for Windows
Java Virtual Machine for Linux
Java Virtual Machine for Mac
Java Virtual Machine for UNIX

Java Software Editions

The software that you use to create Java programs is referred to as the *JDK* (Java Development Kit) or the *SDK* (Software Development Kit). There are the following different editions of the JDK available from Oracle:

- *Java SE*—The Java Standard Edition provides all the essential software tools necessary for writing Java applications.
- *Java EE*—The Java Enterprise Edition provides tools for creating large business applications that employ servers and provide services over the Web.
- *Java ME*—The Java Micro Edition provides a small, highly optimized runtime environment for consumer products such as cell phones, pagers, and appliances.

These editions of Java may be downloaded from Oracle by going to:

http://java.oracle.com

NOTE: You can follow the instructions in Appendix D, which can be downloaded from the book's companion Web site, to install the JDK on your system. You can access the book's companion Web site by going to www.pearsonhighered.com/gaddis.

Compiling and Running a Java Program

Compiling a Java program is a simple process. Once you have installed the JDK, go to your operating system's command prompt.

TIP: In Windows click Start, go to All Programs, and then go to Accessories. Click Command Prompt on the Accessories menu. A command prompt window should open.

VideoNote
Compiling and Running a Java Program

At the operating system command prompt, make sure you are in the same directory or folder where the Java program that you want to compile is located. Then, use the `javac` command, in the following form:

```
javac  Filename
```

`Filename` is the name of a file that contains the Java source code. As mentioned earlier, this file has the *.java* extension. For example, if you want to compile the *Payroll.java* file, you would execute the following command:

```
javac Payroll.java
```

This command runs the compiler. If the file contains any syntax errors, you will see one or more error messages and the compiler will not translate the file to byte code. When this happens you must open the source file in a text editor and fix the error. Then you can run the compiler again. If the file has no syntax errors, the compiler will translate it to byte code. Byte code is stored in a file with the *.class* extension, so the byte code for the *Payroll.java* file will be stored in *Payroll.class*, which will be in the same directory or folder as the source file.

To run the Java program, you use the `java` command in the following form:

```
java  ClassFilename
```

`ClassFilename` is the name of the *.class* file that you wish to execute; however, you do not type the *.class* extension. For example, to run the program that is stored in the *Payroll.class* file, you would enter the following command:

```
java Payroll
```

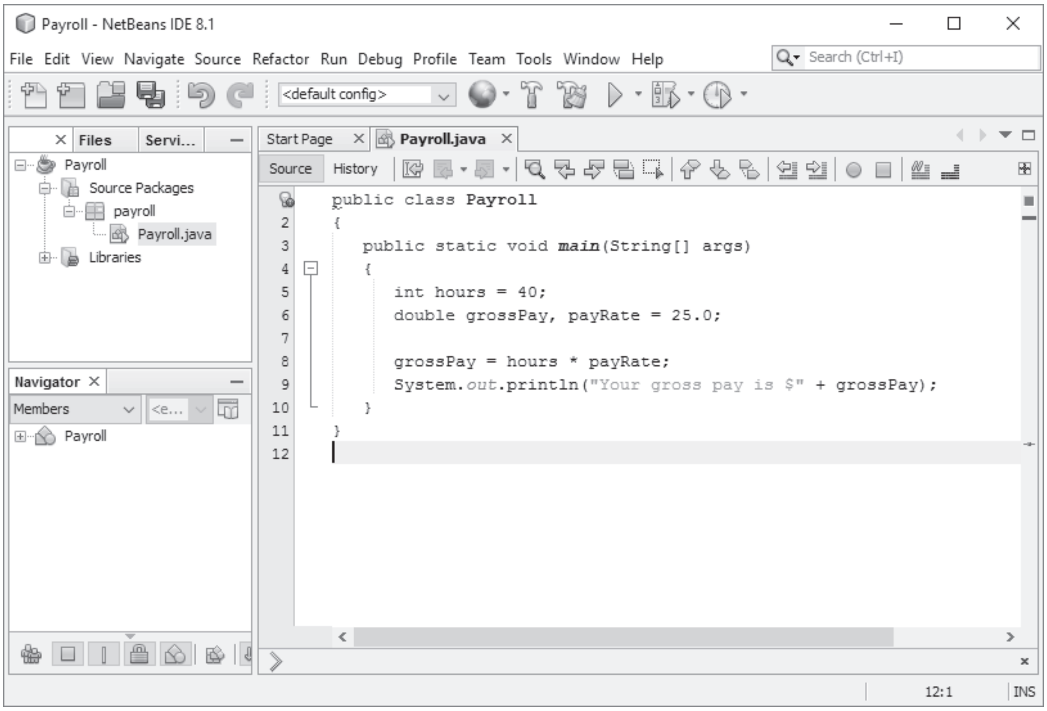
This command runs the Java interpreter (the JVM) and executes the program.

Integrated Development Environments

VideoNote
Using an IDE

In addition to the command prompt programs, there are also several Java integrated development environments (IDEs). These environments consist of a text editor, compiler, debugger, and other utilities integrated into a package with a single set of menus. A program is compiled and executed with a single click of a button, or by selecting a single item from a menu. Figure 1-7 shows a screen from the NetBeans IDE.

Figure 1-7 An integrated development environment (IDE) (Oracle Corporate Counsel)



```
public class Payroll
{
   public static void main(String[] args)
   {
      int hours = 40;
      double grossPay, payRate = 25.0;

      grossPay = hours * payRate;
      System.out.println("Your gross pay is $" + grossPay);
   }
}
```

Checkpoint

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1.8 Describe the difference between a key word and a programmer-defined symbol.

1.9 Describe the difference between operators and punctuation symbols.

1.10 Describe the difference between a program line and a statement.

1.11 Why are variables called “variable”?

1.12 What happens to a variable’s current contents when a new value is stored there?

1.13 What is a compiler?

1.14 What is a syntax error?

1.15 What is byte code?

1.16 What is the JVM?

1.6 The Programming Process

CONCEPT: The programming process consists of several steps, which include design, creation, testing, and debugging activities.

Now that you have been introduced to what a program is, it's time to consider the process of creating a program. Quite often when inexperienced students are given programming assignments, they have trouble getting started because they don't know what to do first. If you find yourself in this dilemma, the following steps may help.

1. Clearly define what the program is to do.
2. Visualize the program running on the computer.
3. Use design tools to create a model of the program.
4. Check the model for logical errors.
5. Enter the code and compile it.
6. Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary.
7. Run the program with test data for input.
8. Correct any runtime errors found while running the program. Repeat Steps 5 through 8 as many times as necessary.
9. Validate the results of the program.

These steps emphasize the importance of planning. Just as there are good ways and bad ways to paint a house, there are good ways and bad ways to create a program. A good program always begins with planning. With the pay-calculating algorithm that was presented earlier in this chapter serving as our example, let's look at each of the steps in more detail.

1. Clearly define what the program is to do

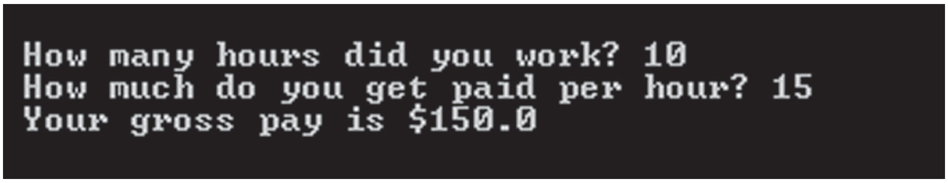
This step commonly requires you to identify the purpose of the program, the data that is to be input, the processing that is to take place, and the desired output. Let's examine each of these requirements for the pay-calculating algorithm.

Purpose	To calculate the user's gross pay.
Input	Number of hours worked, hourly pay rate.
Process	Multiply number of hours worked by hourly pay rate. The result is the user's gross pay.
Output	Display a message indicating the user's gross pay.

2. Visualize the program running on the computer

Before you create a program on the computer, you should first create it in your mind. Try to imagine what the computer screen will look like while the program is running. If it helps, draw pictures of the screen, with sample input and output, at various points in the program. For instance, Figure 1-8 shows the screen we might want produced by a program that implements the pay-calculating algorithm.

Figure 1-8 Screen produced by the pay-calculating algorithm



```
How many hours did you work? 10
How much do you get paid per hour? 15
Your gross pay is $150.0
```

In this step, you must put yourself in the shoes of the user. What messages should the program display? What questions should it ask? By addressing these concerns, you can determine most of the program's output.

3. Use design tools to create a model of the program

While planning a program, the programmer uses one or more design tools to create a model of the program. For example, *pseudocode* is a cross between human language and a programming language and is especially helpful when designing an algorithm. Although the computer can't understand pseudocode, programmers often find it helpful to write an algorithm in a language that's "almost" a programming language, but still very similar to natural language. For example, here is pseudocode that describes the pay-calculating algorithm:

```
Get payroll data.
Calculate gross pay.
Display gross pay.
```

Although this pseudocode gives a broad view of the program, it doesn't reveal all the program's details. A more detailed version of the pseudocode follows:

```
Display "How many hours did you work?"
Input hours.
Display "How much do you get paid per hour?"
Input rate.
Store the value of hours times rate in the pay variable.
Display the value in the pay variable.
```

Notice that the pseudocode uses statements that look more like commands than the English statements that describe the algorithm in Section 1.4. The pseudocode even names variables and describes mathematical operations.

4. Check the model for logical errors

Logical errors are mistakes that cause the program to produce erroneous results. Once a model of the program is assembled, it should be checked for these errors. For example, if pseudocode is used, the programmer should trace through it, checking the logic of each step. If an error is found, the model can be corrected before the next step is attempted.

5. Enter the code and compile it

Once a model of the program has been created, checked, and corrected, the programmer is ready to write source code on the computer. The programmer saves the source code to a file and begins the process of compiling it. During this step the compiler will find any syntax errors that may exist in the program.

6. Correct any errors found during compilation. Repeat Steps 5 and 6 as many times as necessary

If the compiler reports any errors, they must be corrected. Steps 5 and 6 must be repeated until the program is free of compile-time errors.

7. Run the program with test data for input

Once an executable file is generated, the program is ready to be tested for runtime errors. A runtime error is an error that occurs while the program is running. These are usually logical errors, such as mathematical mistakes.

Testing for runtime errors requires that the program be executed with sample data or sample input. The sample data should be such that the correct output can be predicted. If the program does not produce the correct output, a logical error is present in the program.

8. Correct any runtime errors found while running the program. Repeat Steps 5 through 8 as many times as necessary

When runtime errors are found in a program, they must be corrected. You must identify the step where the error occurred and determine the cause. If an error is a result of incorrect logic (such as an improperly stated math formula), you must correct the statement or statements involved in the logic. If an error is due to an incomplete understanding of the program requirements, then you must restate the program purpose and modify the program model and source code. The program must then be saved, recompiled, and retested. This means Steps 5 though 8 must be repeated until the program reliably produces satisfactory results.

9. Validate the results of the program

When you believe you have corrected all the runtime errors, enter test data and determine whether the program solves the original problem.

Software Engineering

The field of software engineering encompasses the whole process of crafting computer software. It includes designing, writing, testing, debugging, documenting, modifying, and maintaining complex software development projects. Like traditional engineers, software engineers use a number of tools in their craft. Here are a few examples:

- Program specifications
- Diagrams of screen output
- Diagrams representing the program components and the flow of data
- Pseudocode
- Examples of expected input and desired output
- Special software designed for testing programs

Most commercial software applications are large and complex. Usually a team of programmers, not a single individual, develops them. It is important that the program requirements be thoroughly analyzed and divided into subtasks that are handled by individual teams, or individuals within a team.

Checkpoint

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1.17 What four items should you identify when defining what a program is to do?

1.18 What does it mean to “visualize a program running”? What is the value of such an activity?

1.19 What is pseudocode?

1.20 Describe what a compiler does with a program’s source code.

1.21 What is a runtime error?

1.22 Is a syntax error (such as misspelling a key word) found by the compiler or when the program is running?

1.23 What is the purpose of testing a program with sample data or input?

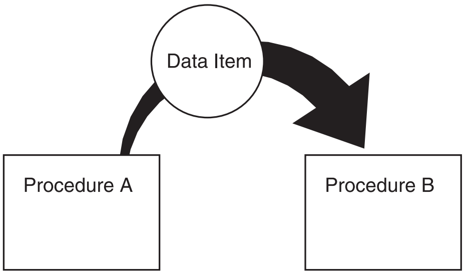
1.7 Object-Oriented Programming

CONCEPT: Java is an object-oriented programming (OOP) language. OOP is a method of software development that has its own practices, concepts, and vocabulary.

There are primarily two methods of programming in use today: procedural and object-oriented. The earliest programming languages were procedural, meaning a program was made of one or more procedures. A *procedure* is a set of programming statements that, together, perform a specific task. The statements might gather input from the user, manipulate data stored in the computer’s memory, and perform calculations or any other operation necessary to complete the procedure’s task.

Procedures typically operate on data items that are separate from the procedures. In a procedural program, the data items are commonly passed from one procedure to another, as shown in Figure 1-9.

Figure 1-9 Data is passed among procedures



As you might imagine, the focus of procedural programming is on the creation of procedures that operate on the program's data. The separation of data and the code that operates on the data often leads to problems, however. For example, the data is stored in a particular format, which consists of variables and more complex structures that are created from variables. The procedures that operate on the data must be designed with that format in mind. But, what happens if the format of the data is altered? Quite often, a program's specifications change, resulting in a redesigned data format. When the structure of the data changes, the code that operates on the data must also be changed to accept the new format. This results in added work for programmers and a greater opportunity for bugs to appear in the code.

This has helped influence the shift from procedural programming to object-oriented programming (OOP). Whereas procedural programming is centered on creating procedures, object-oriented programming is centered on creating objects. An object is a software entity that contains data and procedures. The data contained in an object is known as the object's *attributes*. The procedures, or behaviors, that an object performs are known as the object's *methods*. The object is, conceptually, a self-contained unit consisting of data (attributes) and procedures (methods). This is illustrated in Figure 1-10.

OOP addresses the problem of code/data separation through encapsulation and data hiding. *Encapsulation* refers to the combining of data and code into a single object. *Data hiding* refers to an object's ability to hide its data from code that is outside the object. Only the object's methods may then directly access and make changes to the object's data. An object typically hides its data, but allows outside code to access the methods that operate on the data. As shown in Figure 1-11, the object's methods provide programming statements outside the object with indirect access to the object's data.

When an object's internal data is hidden from outside code and access to that data is restricted to the object's methods, the data is protected from accidental corruption. In addition, the programming code outside the object does not need to know about the format or internal structure of the object's data. The code only needs to interact with the object's methods.

Figure 1-10 An object contains data and procedures

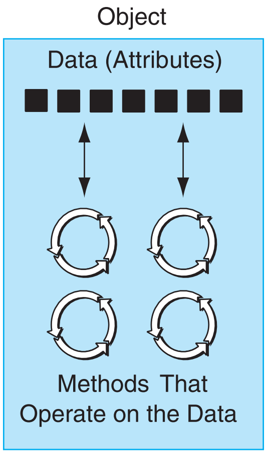
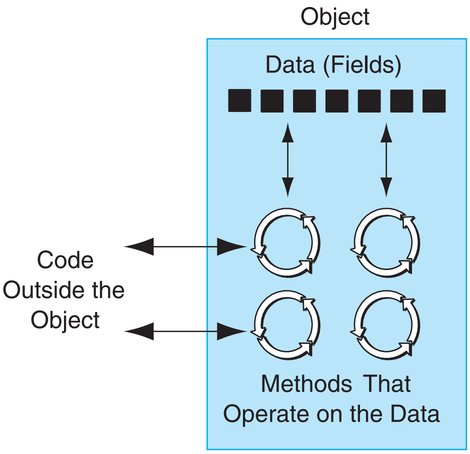


Figure 1-11 Code outside the object interacts with the object's methods



When a programmer changes the structure of an object's internal data, he or she also modifies the object's methods so they may properly operate on the data. The way in which outside code interacts with the methods, however, does not change.

These are just a few of the benefits of object-oriented programming. Because Java is fully object-oriented, you will learn much more about OOP practices, concepts, and terms as you progress through this book.

Checkpoint

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1.24 In procedural programming, what two parts of a program are typically separated?

1.25 What are an object's attributes?

1.26 What are an object's methods?

1.27 What is encapsulation?

1.28 What is data hiding?

Review Questions and Exercises

Multiple Choice

1. This part of the computer fetches instructions, carries out the operations commanded by the instructions, and produces some outcome or resultant information.
   a. memory
   b. CPU
   c. secondary storage
   d. input device
2. A byte is made up of eight
   a. CPUs
   b. addresses
   c. variables
   d. bits
3. Each byte is assigned a unique
   a. address
   b. CPU
   c. bit
   d. variable
4. This type of memory can hold data for long periods of time—even when there is no power to the computer.
   a. RAM
   b. primary storage
   c. secondary storage
   d. CPU storage

5. If you were to look at a machine language program, you would see _______.
   a. Java source code
   b. a stream of binary numbers
   c. English words
   d. circuits
6. These are words that have a special meaning in the programming language.
   a. punctuation
   b. programmer-defined names
   c. key words
   d. operators
7. These are symbols or words that perform operations on one or more operands.
   a. punctuation
   b. programmer-defined names
   c. key words
   d. operators
8. These characters serve specific purposes, such as marking the beginning or ending of a statement, or separating items in a list.
   a. punctuation
   b. programmer-defined names
   c. key words
   d. operators
9. These are words or names that are used to identify storage locations in memory and parts of the program that are created by the programmer.
   a. punctuation
   b. programmer-defined names
   c. key words
   d. operators
10. These are the rules that must be followed when writing a program.
    a. syntax
    b. punctuation
    c. key words
    d. operators
11. This is a named storage location in the computer's memory.
    a. class
    b. key word
    c. variable
    d. operator
12. The Java compiler generates _______.
    a. machine code
    b. byte code
    c. source code
    d. HTML
13. JVM stands for _______.
    a. Java Variable Machine
    b. Java Variable Method
    c. Java Virtual Method
    d. Java Virtual Machine

Find the Error

1. The following pseudocode algorithm has an error. The program is supposed to ask the user for the length and width of a rectangular room, and then display the room's area. The program must multiply the width by the length to determine the area. Find the error.

```
area = width × length
Display "What is the room's width?"
Input width
Display "What is the room's length?"
Input length
Display area
```

Algorithm Workbench

Write pseudocode algorithms for the programs described as follows:

1. **Available Credit**

   A program that calculates a customer's available credit should ask the user for the following:

   - The customer's maximum amount of credit
   - The amount of credit used by the customer

   Once these items have been entered, the program should calculate and display the customer's available credit. You can calculate available credit by subtracting the amount of credit used from the maximum amount of credit.

2. **Sales Tax**

   A program that calculates the total of a retail sale should ask the user for the following:

   - The retail price of the item being purchased
   - The sales tax rate

   Once these items have been entered, the program should calculate and display the following:

   - The sales tax for the purchase
   - The total of the sale

3. **Account Balance**

   A program that calculates the current balance in a savings account must ask the user for the following:

   The starting balance
   The total dollar amount of deposits made
   The total dollar amount of withdrawals made
   The monthly interest rate

   Once the program calculates the current balance, it should be displayed on the screen.