Programming Logic and Design Comprehensive

Fourth Edition

Programming Logic and Design, Comprehensive, Fourth Edition introduces the beginning programmer to programming concepts early. Joyce Farrell maintains her successful pedagogy by combining text explanation with flowcharts and pseudocode examples to provide students with alternative means of expressing structured logic. Full-program exercises at the end of every chapter are included to assist in the illustration of concepts. Get your start in programming with the book that demonstrates proven success—*Programming Logic and Design, Comprehensive, Fourth Edition*!

About the Author

Joyce Farrell is also the author of *Java Programming, Microsoft Visual C# .NET*, and *Object-Oriented Programming Using C++*, all of which are published by Thomson Course Technology. She has been a full-time instructor of Computer Information Systems at Harper College in Palatine, IL, the University of Wisconsin–Stevens Point, and McHenry County College in Crystal Lake, IL.

Key Features

- NEW! Each chapter includes a "Find the Bugs" section in which programming examples are presented with errors for the student to find and correct.
- NEW! "Detective Work" sections have been added that present programming-related topics for the student to research.
- NEW! "Up For Discussion" sections present personal and ethical issues that programmers must consider.
- Can be bundled with Visual Logic software, allowing students to easily create flowcharts and diagrams while working through the text.
- Translates easily to modern languages, such as C#, C++, Java, and Visual Basic.

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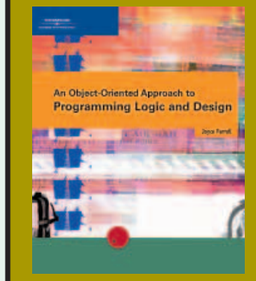

An Object-Oriented Approach to Programming Logic and Design

By Joyce Farrell

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By Joyce Farrell

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Programming Logic and Design, Comprehensive Fourth Edition Farrell

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Programming Logic and Design Comprehensive

Fourth Edition

Joyce Farrell

PROGRAMMING LOGIC AND DESIGN

COMPREHENSIVE

FOURTH EDITION

Joyce Farrell

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by Joyce Farrell

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PREFACE

Programming Logic and Design, Comprehensive, Fourth Edition provides the beginning programmer with a guide to developing structured program logic. This textbook assumes no programming language experience. The writing is nontechnical and emphasizes good programming practices. The examples are business examples; they do not assume mathematical background beyond high school business math. Additionally, the examples illustrate one or two major points; they do not contain so many features that students become lost following irrelevant and extraneous details.

The examples in *Programming Logic and Design* have been created to provide students with a sound background in logic, no matter what programming languages they eventually use to write programs. This book can be used in a standalone logic course that students take as a prerequisite to a programming course, or as a companion book to an introductory programming text using any programming language.

Organization and Coverage

Programming Logic and Design, Comprehensive, Fourth Edition introduces students to programming concepts and enforces good style and logical thinking. General programming concepts are introduced in Chapter 1. Chapter 2 discusses the key concepts of structure, including what structure is, how to recognize it, and, most importantly, the advantages to writing structured programs. Chapter 3 extends the information on structured programming to the area of modules. By Chapter 4 students can develop complete, structured business programs. Chapters 5 and 6 explore the intricacies of decision making and looping. Students learn to develop sophisticated programs that use control breaks and arrays in Chapters 7 and 8.

Chapters 9, 10, and 11 allow students to make more sophisticated applications, expanding on the concepts learned in the first eight chapters. Chapter 9 provides instruction on advanced array manipulation. In Chapter 10, students explore the intricacies of interactive menu programs, including validating input. Chapter 11 covers file merging, matching, and updating.

In Chapter 12, students learn how methods are implemented in modern programming languages, exploring the concepts of parameter passing, returning values, and hiding information. In Chapter 13, students learn the concepts and vocabulary necessary to understand object-oriented programming. Chapter 14 deals more specifically with issues in interactive, event-driven GUI programs.

Chapters 15 and 16 cover additional topics that all professional programmers should learn. Chapter 15 explores the UML, a powerful system design tool, and Chapter 16 provides a thorough tutorial in database creation and use—the basis for many modern programming applications.

Three appendices allow students to gain extra experience with structuring large unstructured programs, using the binary numbering system, and working with large decision tables.

Programming Logic and Design combines text explanation with flowcharts and pseudocode examples to provide students with alternative means of expressing structured logic. Numerous detailed, full-program exercises at the end of each chapter illustrate the concepts explained within the chapter, and reinforce understanding and retention of the material presented.

Programming Logic and Design distinguishes itself from other programming logic books in the following ways:

- It is written and designed to be non-language specific. The logic used in this book can be applied to any programming language.
- The examples are everyday business examples; no special knowledge of mathematics, accounting, or other disciplines is assumed.
- The concept of structure is covered earlier than in many other texts. Students are exposed to structure naturally, so they will automatically create properly designed programs.
- Text explanation is interspersed with both flowcharts and pseudocode so students can become comfortable with both logic development tools and understand their interrelationship.
- Complex programs are built through the use of complete business examples. Students see how an application is built from start to finish instead of studying only segments of programs.

Features of the Text

This edition of the text includes several new features to help students become better programmers and understand the big picture in program development. Because examining programs critically and closely is a crucial programming skill, each chapter includes a "Find the Bugs" section in which programming examples are presented that contain syntax errors and logical errors for the student to find and correct. Each chapter contains a new "Detective Work" section that presents programming-related topics for the student to research. Each chapter also contains a new section called "Up For Discussion," in which questions present personal and ethical issues that programmers must consider. These questions can be used for written assignments or as a starting point for classroom discussions.

To improve students' comprehension of arrays as they are used in most modern programming languages, arrays are now covered as zero-based arrays. Learning about arrays in this way will help students make the transition to using arrays effectively in languages such as C++, Java, and C#.

Each chapter lists key terms and their definitions; the list appears in the order the terms are encountered in the chapter. Along with the chapter summary, the list of key terms provides a snapshot overview of a chapter's main ideas. A glossary at the end of the book lists all the key terms in alphabetical order, along with working definitions.

Multiple-choice review questions appear at the end of every chapter to allow students to test their comprehension of the major ideas and techniques presented. Additionally, multiple end-of-chapter flowcharting and pseudocoding exercises are included so students have more opportunities to practice concepts as they learn them.

Programming Logic and Design is a superior textbook because it includes the following features:

- Microsoft® Office Visio® Professional 2003, 60-day version: This text includes Visio 2003, a diagramming program that helps users create flowcharts and diagrams easily while working through the text, enabling them to visualize concepts and learn more effectively.

New!

- Visual Logic™, version 2.0: Visual Logic™ is a simple but powerful tool for teaching programming logic and design without traditional high-level programming language syntax. Visual Logic uses flowcharts to explain essential programming concepts, including variables, input, assignment, output, conditions, loops, procedures, graphics, arrays, and files. It also has the ability to interpret and execute flowcharts, providing students with immediate and accurate feedback about their solutions. By executing student solutions, Visual Logic combines the power of a high-level language with the ease and simplicity of flowcharts.

  You have the option to bundle this software with your text! Please contact your Course Technology sales representative for more information.

- Interior design: A highly visual, full-color interior presents material in a way that is engaging and appealing to the reader.

- Objectives: Each chapter begins with a list of objectives so the student knows the topics that will be presented in the chapter. In addition to providing a quick reference to topics covered, this feature provides a useful study aid.

- Flowcharts: This book has plenty of figures and illustrations, including flowcharts, which provide the reader with a visual learning experience, rather than one that involves simply studying text. You can see an example of a flowchart in the sample page shown in this Preface.

- Pseudocode: This book also includes numerous examples of pseudocode, which illustrate correct usage of the programming logic and design concepts being taught. You can see an example of pseudocode in the sample page shown in this Preface.

- Tips: These notes provide additional information—for example, another location in the book that expands on a topic, or a common error to watch out for. You can see an example of a tip in the sample page shown in this Preface.

- Chapter summaries: Following each chapter is a summary that recaps the programming concepts and techniques covered in the chapter. This feature provides a concise means for students to review and check their understanding of the main points in each chapter.

- Key terms: Chapters end with a collection of all the key terms found throughout the chapter, as shown in the following sample. Definitions are included in sentence format and in the order in which they appear in the chapter.

SAMPLE LIST OF END-OF-CHAPTER KEY TERMS

KEY TERMS

The **mainline logic** of a program is the overall logic of the main program from beginning to end.

A **housekeeping** module includes steps you must perform at the beginning of a program, to get ready for the rest of the program.

The **main loop** of a program contains the steps that are repeated for every record.

- Review questions: Review questions at the end of each chapter reinforce the main ideas introduced in the chapter, as shown in the following sample. Successfully answering these questions demonstrates mastery of the concepts and information presented.

SAMPLE REVIEW QUESTIONS

REVIEW QUESTIONS

1. **Input records usually contain _____.**
   a. less data than an application needs
   b. more data than an application needs
   c. exactly the amount of data an application needs
   d. none of the data an application needs

2. **A program in which one operation follows another from the beginning until the end is a _____ program.**
   a. modular
   b. functional
   c. procedural
   d. object-oriented

- Exercises: Each chapter concludes with meaningful programming exercises that provide students with additional practice of the skills and concepts they have learned. These exercises increase in difficulty and are designed to allow students to explore logical programming concepts. Each exercise can be completed using flowcharts, pseudocode, or both. In addition, instructors can choose to assign the exercises as programming problems to be coded and executed in a programming language.

New!

- Each chapter contains at least one debugging exercise. Reading others' programs and desk-checking them is an important programming skill. The debugging exercises provide pseudocode with syntax errors and logical errors that the student can correct.

New!

- Each chapter contains "Detective Work" questions that provide research opportunities for students to learn more about an issue or programming topic. Each chapter also includes "Up For Discussion" questions, which allow students to express an opinion about controversial or ethical programming issues.

The following figure shows an example of our highly visual design, including an example of the numbered lists, tips, flowcharts, and pseudocode seen throughout the text.

SAMPLE PAGE SHOWING KEY ELEMENTS FOUND IN THE TEXT

follows another from the beginning until the end. You write the entire set of instructions for a procedural program, and when the program executes, instructions take place one at a time, following your program's logic. The overall logic, or **mainline logic**, of almost every procedural computer program can follow a general structure that consists of three distinct parts:

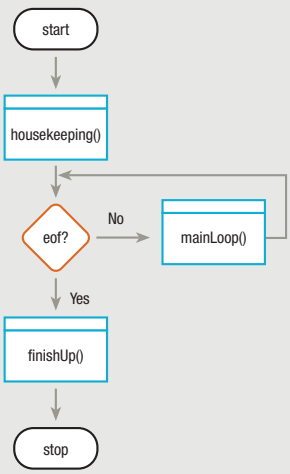
1. Performing housekeeping, or initialization tasks. **Housekeeping** includes steps you must perform at the beginning of a program to get ready for the rest of the program.
2. Performing the main loop repeatedly within the program. The **main loop** contains the instructions that are executed for every record until you reach the end of the input of records, or `eof`.
3. Performing the end-of-job routine. The **end-of-job routine** holds the steps you take at the end of the program to finish the application.

TIP Not all programs are procedural; some are object-oriented. A distinguishing feature of many but not all object-oriented programs is that they are event-driven; often the user determines the timing of events in the main loop of a program by using an input device such as a mouse. As you advance in your knowledge of programming, you will learn more about object-oriented techniques.

You can write any procedural program as one long series of programming language statements, but most programmers prefer to break their programs into at least three parts. The main program can call the three major modules, as shown in the flowchart and pseudocode in Figure 4-6. The module or subroutine names, of course, are entirely up to the programmer.

TIP Reducing a large program into more manageable modules is sometimes called functional decomposition.

FIGURE 4-6: FLOWCHART AND PSEUDOCODE OF MAINLINE LOGIC




```
start
   perform housekeeping()
   while not eof
      perform mainLoop()
   endwhile
   perform finishUp()
stop
```

Teaching Tools

The following supplemental materials are available when this book is used in a classroom setting. All of the teaching tools available with this book are provided to the instructor on a single CD-ROM.

Electronic Instructor's Manual. The Instructor's Manual that accompanies this textbook provides additional instructional material to assist in class preparation, including items such as Sample Syllabi, Chapter Outlines, Technical Notes, Lecture Notes, Quick Quizzes, Teaching Tips, Discussion Topics, and Key Terms.

ExamView®. This textbook is accompanied by ExamView, a powerful testing software package that allows instructors to create and administer printed, computer (LAN-based), and Internet exams. ExamView includes hundreds of questions that correspond to the topics covered in this text, enabling students to generate detailed study guides that include page references for further review. The computer-based and Internet testing components allow students to take exams at their computers, and save the instructor time by grading each exam automatically.

PowerPoint Presentations. This book comes with Microsoft PowerPoint slides for each chapter. These are included as a teaching aid for classroom presentation, to make available to students on your network for chapter review, or to be printed for classroom distribution. Instructors can add their own slides for additional topics they introduce to the class.

Solutions. Suggested solutions to Review Questions and Exercises are provided on the Teaching Tools CD-ROM and may also be found on the Course Technology Web site at *www.course.com*. The solutions are password protected.

Distance Learning. Course Technology offers online WebCT and Blackboard (versions 5.0 and 6.0) courses for this text to provide the most complete and dynamic learning experience possible. When you add online content to one of your courses, you're adding a lot: automated tests, topic reviews, quick quizzes, and additional case projects with solutions. For more information on how to bring distance learning to your course, contact your local Course Technology sales representative.

Acknowledgments

I would like to thank all of the people who helped to make this book a reality, especially Dan Seiter, Development Editor, whose hard work and attention to detail have made this a quality textbook. Dan suggested improvements that I had never considered in the first three editions, and this is a better book for his efforts. Thanks, Dan, for knowing what changes I meant to make even if I forgot to make them. Thanks also to Tricia Boyle, Senior Product Manager; Will Pitkin, Managing Editor; Jennifer Goguen McGrail, Production Editor; and John Bosco, Technical Editor. I am grateful to be able to work with so many fine people who are dedicated to producing quality instructional materials.

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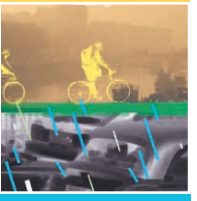
Thanks, too, to my husband, Geoff, who acts as friend and advisor in the book-writing process. This book is, as were its previous editions, dedicated to him and to my daughters, Andrea and Audrey.

–Joyce Farrell



1 AN OVERVIEW OF COMPUTERS AND LOGIC

After studying Chapter 1, you should be able to:

- Understand computer components and operations
- Describe the steps involved in the programming process
- Describe the data hierarchy
- Understand how to use flowchart symbols and pseudocode statements
- Use and name variables
- Use a sentinel, or dummy value, to end a program
- Use a connector symbol
- Assign values to variables
- Recognize the proper format of assignment statements
- Describe data types
- Understand the evolution of programming techniques

UNDERSTANDING COMPUTER COMPONENTS AND OPERATIONS

Hardware and software are the two major components of any computer system. **Hardware** is the equipment, or the devices, associated with a computer. For a computer to be useful, however, it needs more than equipment; a computer needs to be given instructions. The instructions that tell the computer what to do are called **software**, or programs, and are written by programmers. This book focuses on the process of writing these instructions.

TIP

Software can be classified as application software or system software. Application software comprises all the programs you apply to a task—word-processing programs, spreadsheets, payroll and inventory programs, and even games. System software comprises the programs that you use to manage your computer—operating systems, such as Windows, Linux, or UNIX. This book focuses on the logic used to write application software programs, although many of the concepts apply to both types of software.

Together, computer hardware and software accomplish four major operations:

1. Input
2. Processing
3. Output
4. Storage

Hardware devices that perform **input** include keyboards and mice. Through these devices, **data**, or facts, enter the computer system. **Processing** data items may involve organizing them, checking them for accuracy, or performing mathematical operations on them. The piece of hardware that performs these sorts of tasks is the **central processing unit**, or **CPU**. After data items have been processed, the resulting information is sent to a printer, monitor, or some other **output** device so people can view, interpret, and use the results. Often, you also want to store the output information on storage hardware, such as magnetic disks, tapes, compact discs, or flash media. Computer software consists of all the instructions that control how and when the data items are input, how they are processed, and the form in which they are output or stored.

TIP

Data includes all the text, numbers, and other information that are processed by a computer. However, many computer professionals reserve the term "information" for data that has been processed. For example, your name, Social Security number, and hourly pay rate are data items, but your paycheck holds information.

Computer hardware by itself is useless without a programmer's instructions, or software, just as your stereo equipment doesn't do much until you provide music on a CD or tape. You can buy prewritten software that is stored on a disk or that you download from the Internet, or you can write your own software instructions. You can enter instructions into a computer system through any of the hardware devices you use for data; most often, you type your instructions using a keyboard and store them on a device such as a disk or CD.

You write computer instructions in a computer **programming language**, such as Visual Basic, C#, C++, Java, or COBOL. Just as some people speak English and others speak Japanese, programmers also write programs in different

languages. Some programmers work exclusively in one language, whereas others know several and use the one that seems most appropriate for the task at hand.

No matter which programming language a computer programmer uses, the language has rules governing its word usage and punctuation. These rules are called the language's **syntax**. If you ask, "How the get to store do I?" in English, most people can figure out what you probably mean, even though you have not used proper English syntax. However, computers are not nearly as smart as most people; with a computer, you might as well have asked, "Xpu mxv ot dodnm cadf B?" Unless the syntax is perfect, the computer cannot interpret the programming language instruction at all.

Every computer operates on circuitry that consists of millions of on/off switches. Each programming language uses a piece of software to translate the specific programming language into the computer's on/off circuitry language, or **machine language**. The language translation software is called a **compiler** or **interpreter**, and it tells you if you have used a programming language incorrectly. Therefore, syntax errors are relatively easy to locate and correct—the compiler or interpreter you use highlights every syntax error. If you write a computer program using a language such as C++ but spell one of its words incorrectly or reverse the proper order of two words, the translator lets you know that it found a mistake by displaying an error message as soon as you try to translate the program.

TIP

Although there are differences in how compilers and interpreters work, their basic function is the same—to translate your programming statements into code the computer can use. When you use a compiler, an entire program is translated before it can execute; when you use an interpreter, each instruction is translated just prior to execution. Usually, you do not choose which type of translation to use—it depends on the programming language. However, there are some languages for which both compilers and interpreters are available.

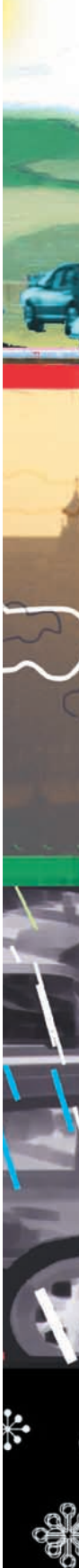
A program without syntax errors can be executed on a computer, but it might not produce correct results. For a program to work properly, you must give the instructions to the computer in a specific sequence, you must not leave any instructions out, and you must not add extraneous instructions. By doing this, you are developing the **logic** of the computer program. Suppose you instruct someone to make a cake as follows:

```
Stir
Add two eggs
Add a gallon of gasoline
Bake at 350 degrees for 45 minutes
Add three cups of flour
```

Even though you have used the English language syntax correctly, the instructions are out of sequence, some instructions are missing, and some instructions belong to procedures other than baking a cake. If you follow these instructions, you are not going to end up with an edible cake, and you may end up with a disaster. Logical errors are much more difficult to locate than syntax errors; it is easier for you to determine whether "eggs" is spelled incorrectly in a recipe than it is for you to tell if there are too many eggs or if they are added too soon.

TIP

Programmers often call logical errors semantic errors. For example, if you misspell a programming language word, you commit a syntax error, but if you use an otherwise correct word that does not make any sense in the current context, you commit a **semantic error**.



Just as baking directions can be given correctly in French, German, or Spanish, the same logic of a program can be expressed in any number of programming languages. This book is almost exclusively concerned with the logic development process. Because this book is not concerned with any specific language, the programming examples could have been written in Japanese, C++, or Java. The logic is the same in any language. For convenience, the book uses English!

Once instructions have been input to the computer and translated into machine language, a program can be **run**, or **executed**. You can write a program that takes a number (an input step), doubles it (processing), and tells you the answer (output) in a programming language such as Java or C++, but if you were to write it using English-like statements, it would look like this:

```
Get inputNumber.
Compute calculatedAnswer as inputNumber times 2.
Print calculatedAnswer.
```

TIP You will learn about the odd elimination of the space between words like "input" and "Number" and "calculated" and "Answer" in the next few pages.

The instruction to `Get inputNumber` is an example of an input operation. When the computer interprets this instruction, it knows to look to an input device to obtain a number. Computers often have several input devices, perhaps a keyboard, a mouse, a CD drive, and two or more disk drives. When you learn a specific programming language, you learn how to tell the computer which of those input devices to access for input. Logically, however, it doesn't really matter which hardware device is used, as long as the computer knows to look for a number. The logic of the input operation—that the computer must obtain a number for input, and that the computer must obtain it before multiplying it by two—remains the same regardless of any specific input hardware device. The same is true in your daily life. If you follow the instruction "Get eggs from store," it does not really matter if you are following a handwritten instruction from a list or a voice-mail instruction left on your cell phone—the process of getting the eggs, and the result of doing so, are the same.

TIP Many computer professionals categorize disk drives and CD drives as storage devices rather than input devices. Such devices actually can be used for input, storage, and output.

Processing is the step that occurs when the arithmetic is performed to double the `inputNumber`; the statement `Compute calculatedAnswer as inputNumber times 2` represents processing. Mathematical operations are not the only kind of processing, but they are very typical. After you write a program, the program can be used on computers of different brand names, sizes, and speeds. Whether you use an IBM, Macintosh, Linux, or UNIX operating system, and whether you use a personal computer that sits on your desk or a mainframe that costs hundreds of thousands of dollars and resides in a special building in a university, multiplying by 2 is the same process. The hardware is not important; the processing will be the same.

In the number-doubling program, the `Print calculatedAnswer` statement represents output. Within a particular program, this statement could cause the output to appear on the monitor (which might be a flat panel screen or a cathode-ray tube), or the output could go to a printer (which could be laser or ink-jet), or the output could be written to a disk or CD. The logic of the process called "Print" is the same no matter what hardware device you use.

Besides input, processing, and output, the fourth operation in any computer system is storage. When computers produce output, it is for human consumption. For example, output might be displayed on a monitor or sent to a printer. Storage, on the other hand, is meant for future computer use (for example, when data items are saved on a disk).

Computer storage comes in two broad categories. All computers have **internal storage**, often referred to as **memory**, **main memory**, **primary memory**, or **random access memory (RAM)**. This storage is located inside the system unit of the machine. (For example, if you own a microcomputer, the system unit is the large case that holds your CD or other disk drives. On a laptop computer, the system unit is located beneath the keyboard.) Internal storage is the type of storage most often discussed in this book.

Computers also use **external storage**, which is **persistent** (relatively permanent) storage on a device such as a floppy disk, hard disk, flash media, or magnetic tape. In other words, external storage is outside the main memory, not necessarily outside the computer. Both programs and data sometimes are stored on each of these kinds of media.

To use computer programs, you must first load them into memory. You might type a program into memory from the keyboard, or you might use a program that has already been written and stored on a disk. Either way, a copy of the instructions must be placed in memory before the program can be run.

A computer system needs both internal memory and external storage. Internal memory is needed to run the programs, but internal memory is **volatile**—that is, its contents are lost every time the computer loses power. Therefore, if you are going to use a program more than once, you must store it, or **save** it, on some nonvolatile medium. Otherwise, the program in main memory is lost forever when the computer is turned off. External storage (usually disks or tape) provides a nonvolatile (or persistent) medium.

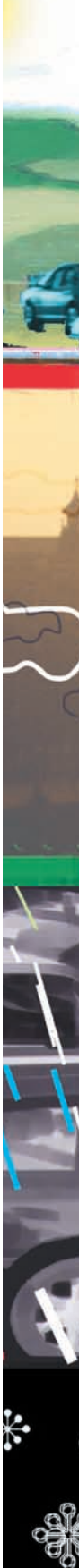
TIP

Even though a hard disk drive is located inside your computer, the hard disk is not main, internal memory. Internal memory is temporary and volatile; a hard drive is permanent, nonvolatile storage. After one or two "tragedies" of losing several pages of a typed computer program due to a power failure or other hardware problem, most programmers learn to periodically save the programs they are in the process of writing, using a nonvolatile medium such as a disk.

Once you have a copy of a program in main memory, you want to execute, or run, the program. To do so, you must also place any data that the program requires into memory. For example, after you place the following program into memory and start to run it, you need to provide an actual `inputNumber`—for example, 8—that you also place in main memory.

```
Get inputNumber.
Compute calculatedAnswer as inputNumber times 2.
Print calculatedAnswer.
```

The `inputNumber` is placed in memory at a specific memory location that the program will call `inputNumber`. Then, and only then, can the `calculatedAnswer`, in this case 16, be calculated and printed.



TIP

Computer memory consists of millions of numbered locations where data can be stored. The memory location of `inputNumber` has a specific numeric address, for example, 48604. Your program associates `inputNumber` with that address. Every time you refer to `inputNumber` within a program, the computer retrieves the value at the associated memory location. When you write programs, you seldom need to be concerned with the value of the memory address; instead, you simply use the easy-to-remember name you created.

Computer programmers often refer to memory addresses using hexadecimal notation, or base 16. Using this system, they might use a value like 42FF01A to refer to a memory address. Despite the use of letters, such an address is still a number. When you use the hexadecimal numbering system, the letters A through F stand for the values 10 through 15.

UNDERSTANDING THE PROGRAMMING PROCESS

A programmer's job involves writing instructions (such as the three instructions in the doubling program in the preceding section), but a professional programmer usually does not just sit down at a computer keyboard and start typing. The programmer's job can be broken down into six programming steps:

1. Understanding the problem
2. Planning the logic
3. Coding the program
4. Using software to translate the program into machine language
5. Testing the program
6. Putting the program into production

UNDERSTANDING THE PROBLEM

Professional computer programmers write programs to satisfy the needs of others. Examples could include a Human Resources Department that needs a printed list of all employees, a Billing Department that wants a list of clients who are 30 or more days overdue on their payments, and an office manager who wants to be notified when specific supplies reach the reorder point. Because programmers are providing a service to these users, programmers must first understand what it is the users want.

Suppose the director of human resources says to a programmer, "Our department needs a list of all employees who have been here over five years, because we want to invite them to a special thank-you dinner." On the surface, this seems like a simple enough request. An experienced programmer, however, will know that he or she may not yet understand the whole problem. Does the director want a list of full-time employees only, or a list of full- and part-time employees together? Does she want people who have worked for the company on a month-to-month contractual basis over the past five years, or only regular, permanent employees? Do the listed employees need to have worked for the organization for five years as of today, as of the date of the dinner, or as of some other cutoff date? What about an employee who worked three years, took a two-year leave of absence, and has been back for three years? Does he or she qualify? The programmer cannot make any of these decisions; the user is the one who must address these questions.

More decisions still might be required. For example, what does the user want the report of five-year employees to look like? Should it contain both first and last names? Social Security numbers? Phone numbers? Addresses? Is all this data available? Several pieces of documentation are often provided to help the programmer understand the problem. This documentation includes print layout charts and file specifications, which you will learn about in Chapter 3.

Really understanding the problem may be one of the most difficult aspects of programming. On any job, the description of what the user needs may be vague—worse yet, the user may not even really know what he or she wants, and users who think they know what they want frequently change their minds after seeing sample output. A good programmer is often part counselor, part detective!

PLANNING THE LOGIC

The heart of the programming process lies in planning the program's logic. During this phase of the programming process, the programmer plans the steps of the program, deciding what steps to include and how to order them. You can plan the solution to a problem in many ways. The two most common planning tools are flowcharts and pseudocode. Both tools involve writing the steps of the program in English, much as you would plan a trip on paper before getting into the car, or plan a party theme before going shopping for food and favors.

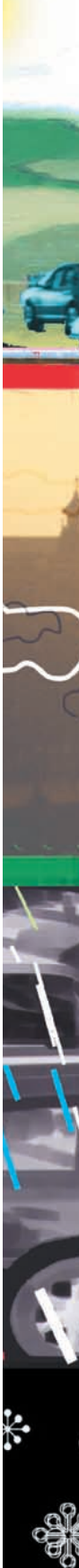
TIP You may hear programmers refer to planning a program as "developing an algorithm." An **algorithm** is the sequence of steps necessary to solve any problem. You will learn more about flowcharts and pseudocode later in this chapter.

The programmer doesn't worry about the syntax of any particular language at this point, just about figuring out what sequence of events will lead from the available input to the desired output. Planning the logic includes thinking carefully about all the possible data values a program might encounter and how you want the program to handle each scenario. The process of walking through a program's logic on paper before you actually write the program is called **desk-checking**. You will learn more about planning the logic later; in fact, this book focuses on this crucial step almost exclusively.

CODING THE PROGRAM

Once the programmer has developed the logic of a program, only then can he or she write the program in one of more than 400 programming languages. Programmers choose a particular language because some languages have built-in capabilities that make them more efficient than others at handling certain types of operations. Despite their differences, programming languages are quite alike—each can handle input operations, arithmetic processing, output operations, and other standard functions. The logic developed to solve a programming problem can be executed using any number of languages. It is only after a language is chosen that the programmer must worry about each command being spelled correctly and all of the punctuation getting into the right spots—in other words, using the correct *syntax*.

Some very experienced programmers can successfully combine the logic planning and the actual instruction writing, or **coding**, of the program in one step. This may work for planning and writing a very simple program, just as you can plan and write a postcard to a friend using one step. A good term paper or a Hollywood screenplay, however, needs planning before writing, and so do most programs.



Which step is harder, planning the logic or coding the program? Right now, it may seem to you that writing in a programming language is a very difficult task, considering all the spelling and grammar rules you must learn. However, the planning step is actually more difficult. Which is more difficult: thinking up the twists and turns to the plot of a best-selling mystery novel, or writing a translation of an already written novel from English to Spanish? And who do you think gets paid more, the writer who creates the plot or the translator? (Try asking friends to name any famous translator!)

USING SOFTWARE TO TRANSLATE THE PROGRAM INTO MACHINE LANGUAGE

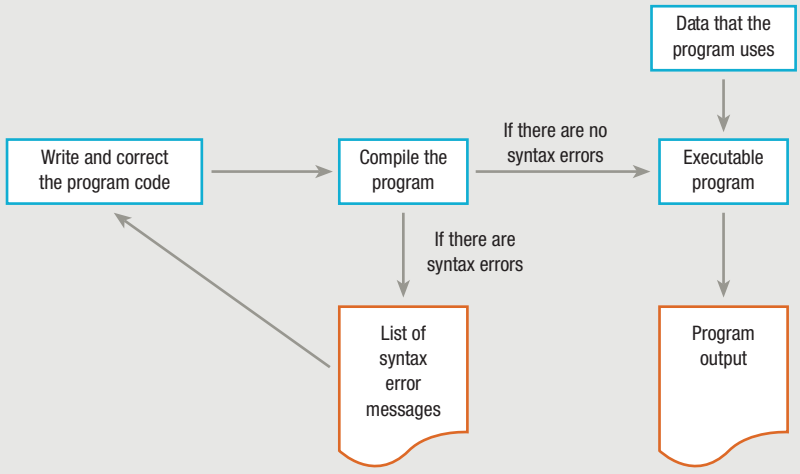
Even though there are many programming languages, each computer knows only one language, its machine language, which consists of many 1s and 0s. Computers understand machine language because computers themselves are made up of thousands of tiny electrical switches, each of which can be set in either the on or off state, which is represented by a 1 or 0, respectively.

Languages like Java or Visual Basic are available for programmers to use because someone has written a translator program (a compiler or interpreter) that changes the English-like **high-level programming language** in which the programmer writes into the **low-level machine language** that the computer understands. If you write a programming language statement incorrectly (for example, by misspelling a word, using a word that doesn't exist in the language, or using "illegal" grammar), the translator program doesn't know what to do and issues an error message identifying a **syntax error**, or misuse of a language's grammar rules. You receive the same response when you speak nonsense to a human-language translator. Imagine trying to look up a list of words in a Spanish-English dictionary if some of the listed words are misspelled—you can't complete the task until the words are spelled correctly. Although making errors is never desirable, syntax errors are not a major concern to programmers, because the compiler or interpreter catches every syntax error, and the computer will not execute a program that contains them.

A computer program must be free of syntax errors before you can execute it. Typically, a programmer develops a program's logic, writes the code, and then compiles the program, receiving a list of syntax errors. The programmer then corrects the syntax errors, and compiles the program again. Correcting the first set of errors frequently reveals a new set of errors that originally were not apparent to the compiler. For example, if you could use an English compiler and submit the sentence `The grl go to school`, the compiler at first would point out only one syntax error to you. The second word, `grl`, is illegal because it is not part of the English language. Only after you corrected the word `girl` would the compiler find another syntax error on the third word, `go`, because it is the wrong verb form for the subject `girl`. This doesn't mean `go` is necessarily the wrong word. Maybe `girl` is wrong; perhaps the subject should be `girls`, in which case `go` is right. Compilers don't always know exactly what you mean, nor do they know what the proper correction should be, but they do know when something is wrong with your syntax.

When writing a program, a programmer might need to recompile the code several times. An executable program is created only when the code is free of syntax errors. When you run an executable program, it typically also might require input data. Figure 1-1 shows a diagram of this entire process.

FIGURE 1-1: CREATING AN EXECUTABLE PROGRAM



TESTING THE PROGRAM

A program that is free of syntax errors is not necessarily free of **logical errors**. For example, the sentence `The girl goes to school`, although syntactically perfect, is not logically correct if the girl is a baby or a dropout.

Once a program is free from syntax errors, the programmer can test it—that is, execute it with some sample data to see whether the results are logically correct. Recall the number-doubling program:

```
Get inputNumber.
Compute calculatedAnswer as inputNumber times 2.
Print calculatedAnswer.
```

If you provide the value 2 as input to the program and the answer 4 prints, you have executed one successful test run of the program.

However, if the answer 40 prints, maybe it's because the program contains a logical error. Maybe the second line of code was mistyped with an extra zero, so that the program reads:

```
Get inputNumber.
Compute calculatedAnswer as inputNumber times 20.
Print calculatedAnswer.
```

The error of placing 20 instead of 2 in the multiplication statement caused a logical error. Notice that nothing is syntactically wrong with this second program—it is just as reasonable to multiply a number by 20 as by 2—but if the programmer intends only to double the `inputNumber`, then a logical error has occurred.

Programs should be tested with many sets of data. For example, if you write the program to double a number and enter 2 and get an output value of 4, that doesn't necessarily mean you have a correct program. Perhaps you have typed this program by mistake:

```
Get inputNumber.
Compute calculatedAnswer as inputNumber plus 2.
Print calculatedAnswer.
```

An input of 2 results in an answer of 4, but that doesn't mean your program doubles numbers—it actually only adds 2 to them. If you test your program with additional data and get the wrong answer—for example, if you use a 3 and get an answer of 5—you know there is a problem with your code.

Selecting test data is somewhat of an art in itself, and it should be done carefully. If the Human Resources Department wants a list of the names of five-year employees, it would be a mistake to test the program with a small sample file of only long-term employees. If no newer employees are part of the data being used for testing, you don't really know if the program would have eliminated them from the five-year list. Many companies don't know that their software has a problem until an unusual circumstance occurs—for example, the first time an employee has more than nine dependents, the first time a customer orders more than 999 items at a time, or when (in an example that was well-documented in the popular press) a new century begins.

PUTTING THE PROGRAM INTO PRODUCTION

Once the program is tested adequately, it is ready for the organization to use. Putting the program into production might mean simply running the program once, if it was written to satisfy a user's request for a special list. However, the process might take months if the program will be run on a regular basis, or if it is one of a large system of programs being developed. Perhaps data-entry people must be trained to prepare the input for the new program, users must be trained to understand the output, or existing data in the company must be changed to an entirely new format to accommodate this program. **Conversion**, the entire set of actions an organization must take to switch over to using a new program or set of programs, can sometimes take months or years to accomplish.

TIP

You might consider maintaining programs as a seventh step in the programming process. After programs are put into production, making required changes is called maintenance. Maintenance is necessary for many reasons: for example, new tax rates are legislated, the format of an input file is altered, or the end user requires additional information not included in the original output specifications. Frequently, your first programming job will require maintaining previously written programs. When you maintain the programs others have written, you will appreciate the effort the original programmer put into writing clear code, using reasonable variable names, and documenting his or her work.

You might consider retiring the program as the eighth and final step in the programming process. A program is retired when it is no longer needed by an organization—usually when a new program is in the process of being put into production.

UNDERSTANDING THE DATA HIERARCHY

Some very simple programs require very simple data. For example, the number-doubling program requires just one value as input. Most business programs, however, use much more data—inventory files list thousands of items, personnel and customer files list thousands of people. When data items are stored for use on computer systems, they are often stored in what is known as a **data hierarchy**, where the smallest usable unit of data is the character. **Characters** are letters, numbers, and special symbols, such as "A", "7", and "$". Anything you can type from the keyboard in one keystroke (including a space or a tab) is a character. Characters are made up of smaller elements called bits, but just as most human beings can use a pencil without caring whether atoms are flying around inside it, most computer users can store characters without caring about these bits.

TIP Computers also recognize characters you cannot enter from the keyboard, such as foreign alphabet characters like φ or Σ.

Characters are grouped together to form a field. A **field** is a single data item, such as `lastName`, `streetAddress`, or `annualSalary`. For most of us, an "S", an "m", an "i", a "t", and an "h" don't have much meaning individually, but if the combination of characters makes up your last name, "Smith", then as a group, the characters have useful meaning.

Related fields are often grouped together to form a record. **Records** are groups of fields that go together for some logical reason. A random name, address, and salary aren't very useful, but if they're your name, your address, and your salary, then that's your record. An inventory record might contain fields for item number, color, size, and price; a student record might contain ID number, grade point average, and major.

Related records, in turn, are grouped together to form a file. **Files** are groups of records that go together for some logical reason. The individual records of each student in your class might go together in a file called STUDENTS. Records of each person at your company might be in a file called PERSONNEL. Items you sell might be in an INVENTORY file.

Some files can have just a few records; others, such as the file of credit-card holders for a major department-store chain or policyholders of an insurance company, can contain thousands or even millions of records.

Finally, many organizations use database software to organize many files. A **database** holds a group of files, often called **tables**, that together serve the information needs of an organization. Database software establishes and maintains relationships between fields in these tables, so that users can write questions called **queries**. Queries pull related data items together in a format that allows businesspeople to make managerial decisions efficiently. Chapter 16 of the Comprehensive version of this text covers database creation.

In summary, you can picture the data hierarchy, as shown in Figure 1-2.

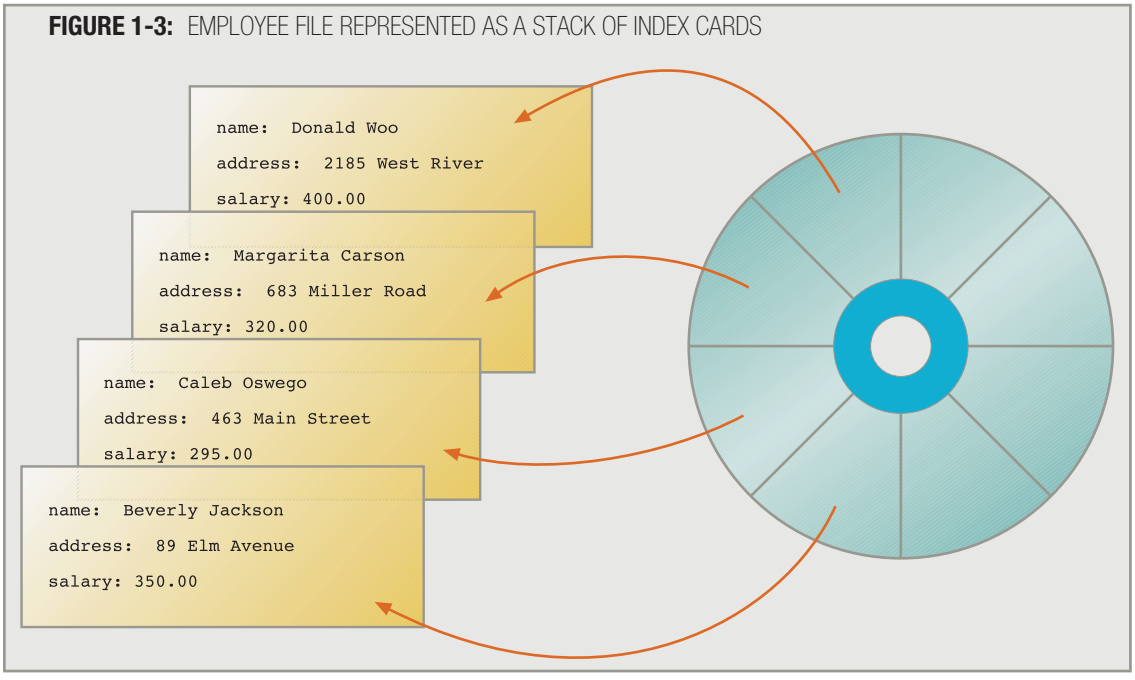
FIGURE 1-2: THE DATA HIERARCHY

```
Database
   File
      Record
         Field
            Character
```

A database contains many files. A file contains many records. Each record in a file has the same fields. Each record's fields contain different data items that consist of one or more stored characters in each field.

As an example, you can picture a file as a set of index cards, as shown in Figure 1-3. The stack of cards is the EMPLOYEE file, in which each card represents one employee record. On each card, each line holds one field—`name`, `address`, or `salary`. Almost all the program examples in this book use files that are organized in this way.

FIGURE 1-3: EMPLOYEE FILE REPRESENTED AS A STACK OF INDEX CARDS



USING FLOWCHART SYMBOLS AND PSEUDOCODE STATEMENTS

When programmers plan the logic for a solution to a programming problem, they often use one of two tools, **flowcharts** or **pseudocode** (pronounced "sue-doe-code"). A flowchart is a pictorial representation of the logical steps it takes to solve a problem. **Pseudocode** is an English-like representation of the same thing. *Pseudo* is a prefix that means "false," and to *code* a program means to put it in a programming language; therefore, *pseudocode* simply means "false code," or sentences that appear to have been written in a computer programming language but don't necessarily follow all the syntax rules of any specific language.

You have already seen examples of statements that represent pseudocode earlier in this chapter, and there is nothing mysterious about them. The following five statements constitute a pseudocode representation of a number-doubling problem:

```
start
  get inputNumber
  compute calculatedAnswer as inputNumber times 2
  print calculatedAnswer
stop
```

Using pseudocode involves writing down all the steps you will use in a program. Usually, programmers preface their pseudocode statements with a beginning statement like "start" and end them with a terminating statement like "stop". The statements between "start" and "stop" look like English and are indented slightly so that "start" and "stop" stand out. Most programmers do not bother with punctuation such as periods at the end of pseudocode statements, although it would not be wrong to use them if you prefer that style. Similarly, there is no need to capitalize the first word in a sentence, although you might choose to do so. This book follows the conventions of using lowercase letters for verbs that begin pseudocode statements and omitting periods at the end of statements.

Some professional programmers prefer writing pseudocode to drawing flowcharts, because using pseudocode is more similar to writing the final statements in the programming language. Others prefer drawing flowcharts to represent the logical flow, because flowcharts allow programmers to visualize more easily how the program statements will connect. Especially for beginning programmers, flowcharts are an excellent tool to help visualize how the statements in a program are interrelated.

Almost every program involves the steps of input, processing, and output. Therefore, most flowcharts need some graphical way to separate these three steps. When you create a flowchart, you draw geometric shapes around the individual statements and connect them with arrows.

When you draw a flowchart, you use a parallelogram to represent an **input symbol**, which indicates an input operation. You write an input statement, in English, inside the parallelogram, as shown in Figure 1-4.

FIGURE 1-4: INPUT SYMBOL

TIP

When you want to represent entering two or more values in a program, you can use one or multiple flowchart symbols or pseudocode statements—whichever seems more reasonable and clear to you. For example, the pseudocode to input a user's name and address might be written as:

```
get inputName
get inputAddress
```

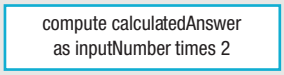
or as:

```
get inputName,inputAddress
```

The first version implies two separate input operations, whereas the second implies a single input operation retrieving two data items. If your application will accept user input from a keyboard, using two separate input statements might make sense, because the user will type one item at a time. If your application will accept data from a storage device, obtaining all the data at once is more common. Logically, either format represents the retrieval of two data items. The end result is the same in both cases—after the statements have executed, `inputName` and `inputAddress` will have received values from an input device.

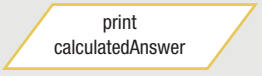
Arithmetic operation statements are examples of processing. In a flowchart, you use a rectangle as the **processing symbol** that contains a processing statement, as shown in Figure 1-5.

FIGURE 1-5: PROCESSING SYMBOL



To represent an output statement, you use the same symbol as for input statements—the **output symbol** is a parallelogram, as shown in Figure 1-6.

FIGURE 1-6: OUTPUT SYMBOL



TIP

As with input, output statements can be organized in whatever way seems most reasonable. A program that prints the length and width of a room might use the statement:

```
print length
print width
```

or:

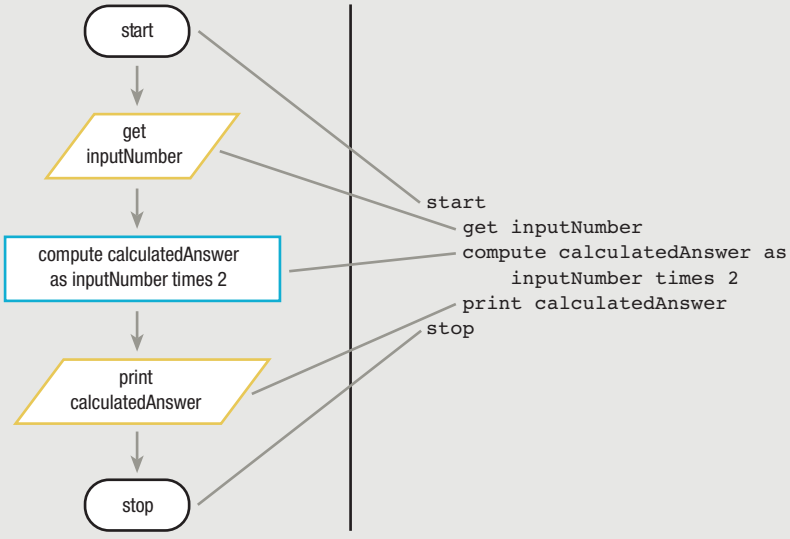
```
print length, width
```

In some programming languages, using two print statements places the output values on two separate lines on the monitor or printer, whereas using a single print statement places the values next to each other on the same line. This book follows the convention of using one print statement per line of output.

To show the correct sequence of these statements, you use arrows, or **flowlines**, to connect the steps. Whenever possible, most of a flowchart should read from top to bottom or from left to right on a page. That's the way we read English, so when flowcharts follow this convention, they are easier for us to understand.

To be complete, a flowchart should include two more elements: a **terminal symbol**, or start/stop symbol, at each end. Often, you place a word like "start" or "begin" in the first terminal symbol and a word like "end" or "stop" in the other. The standard terminal symbol is shaped like a racetrack; many programmers refer to this shape as a **lozenge**, because it resembles the shape of a medicated candy lozenge you might use to soothe a sore throat. Figure 1-7 shows a complete flowchart for the program that doubles a number, and the pseudocode for the same problem.

FIGURE 1-7: FLOWCHART AND PSEUDOCODE OF PROGRAM THAT DOUBLES A NUMBER



TIP Programmers seldom create both pseudocode and a flowchart for the same problem. You usually use one or the other.

The logic for the program represented by the flowchart and pseudocode in Figure 1-7 is correct no matter what programming language the programmer eventually uses to write the corresponding code. Just as the same statements could be translated into Italian or Chinese without losing their meaning, they also can be coded in C#, Java, or any other programming language.

After the flowchart or pseudocode has been developed, the programmer only needs to: (1) buy a computer, (2) buy a language compiler, (3) learn a programming language, (4) code the program, (5) attempt to compile it, (6) fix the syntax errors, (7) compile it again, (8) test it with several sets of data, and (9) put it into production.

"Whoa!" you are probably saying to yourself. "This is simply not worth it! All that work to create a flowchart or pseudocode, and *then* all those other steps? For five dollars, I can buy a pocket calculator that will double any number for me instantly!" You are absolutely right. If this were a real computer program, and all it did was double the value of a number, it simply would not be worth all the effort. Writing a computer program would be worth the effort only if you had many—let's say 10,000—numbers to double in a limited amount of time—let's say the next two minutes. Then, it would be worth your while to create a computer program.

Unfortunately, the number-doubling program represented in Figure 1-7 does not double 10,000 numbers; it doubles only one. You could execute the program 10,000 times, of course, but that would require you to sit at the computer telling it to run the program over and over again. You would be better off with a program that could process 10,000 numbers, one after the other.

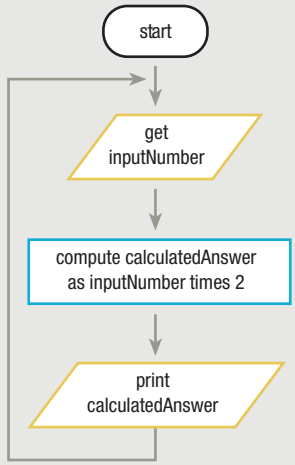
One solution is to write the program as shown in Figure 1-8 and execute the same steps 10,000 times. Of course, writing this program would be very time-consuming; you might as well buy the calculator.

FIGURE 1-8: INEFFICIENT PSEUDOCODE FOR PROGRAM THAT DOUBLES 10,000 NUMBERS

```
start
     get inputNumber
     compute calculatedAnswer as inputNumber times 2
     print calculatedAnswer
     get inputNumber
     compute calculatedAnswer as inputNumber times 2
     print calculatedAnswer
     get inputNumber
     compute calculatedAnswer as inputNumber times 2
     print calculatedAnswer
     . . . and so on
```

A better solution is to have the computer execute the same set of three instructions over and over again, as shown in Figure 1-9. With this approach, the computer gets a number, doubles it, prints the answer, and then starts over again with the first instruction. The same spot in memory, called `inputNumber`, is reused for the second number and for any subsequent numbers. The spot in memory named `calculatedAnswer` is reused each time to store the result of the multiplication operation. The logic illustrated in the flowchart shown in Figure 1-9 contains a major problem—the sequence of instructions never ends. You will learn to handle this problem later in this chapter.

FIGURE 1-9: FLOWCHART OF INFINITE NUMBER-DOUBLING PROGRAM



USING AND NAMING VARIABLES

Programmers commonly refer to the locations in memory called `inputNumber` and `calculatedAnswer` as variables. **Variables** are memory locations, whose contents can vary or differ over time. Sometimes, `inputNumber` can hold a 2 and `calculatedAnswer` will hold a 4; at other times, `inputNumber` can hold a 6 and `calculatedAnswer` will hold a 12. It is the ability of memory variables to change in value that makes computers and programming worthwhile. Because one memory location can be used over and over again with different values, you can write program instructions once and then use them for thousands of separate calculations. *One* set of payroll instructions at your company produces each individual's paycheck, and *one* set of instructions at your electric company produces each household's bill.

The number-doubling example requires two variables, `inputNumber` and `calculatedAnswer`. These can just as well be named `userEntry` and `programSolution`, or `inputValue` and `twiceTheValue`. As a programmer, you choose reasonable names for your variables. The language interpreter then associates the names you choose with specific memory addresses.

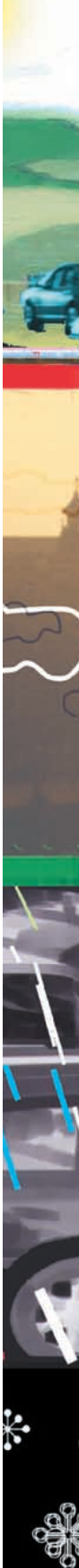
A variable name is also called an **identifier**. Every computer programming language has its own set of rules for naming identifiers. Most languages allow both letters and digits within variable names. Some languages allow hyphens in variable names—for example, `hourly-wage`. Others allow underscores, as in `hourly_wage`. Still others allow neither. Some languages allow dollar signs or other special characters in variable names (for example, `hourly$`); others allow foreign alphabet characters, such as π or Ω.

TIP

You also can refer to a variable name as a **mnemonic**. In everyday language, a mnemonic is a memory device, like the sentence "Every good boy does fine," which makes it easier to remember the notes that occupy the lines on the staff in sheet music. In programming, a variable name is a device that makes it easier to reference a memory address.

TIP

Different languages put different limits on the length of variable names, although in general, newer languages allow longer names. For example, in some very old versions of BASIC, a variable name could consist of only one or two letters and one or two digits. You could have some cryptic variable names like `hw` or `a3` or `re02`. Fortunately, most modern languages allow variable names to be much longer; in the newest versions of C++, C#, and Java, the length of identifiers is virtually unlimited. Variable names in these languages usually consist of lowercase letters, don't allow hyphens, but do allow underscores, so you can use a name like `price_of_item`. These languages are case sensitive, so `HOURLYWAGE`, `hourlywage`, and `hourlyWage` are considered three separate variable names, although the last example, in which the new word begins with an uppercase letter, is easiest to read. Most programmers who use the more modern languages employ the format in which multiple-word variable names are run together, and each new word within the variable name begins with an uppercase letter. This format is called **camel casing**, because such variable names, like `hourlyWage`, have a "hump" in the middle. The variable names in this text are shown using camel casing.



Even though every language has its own rules for naming variables, when designing the logic of a computer program, you should not concern yourself with the specific syntax of any particular computer language. The logic, after all, works with any language. The variable names used throughout this book follow only two rules:

1. *Variable names must be one word.* The name can contain letters, digits, hyphens, underscores, or any other characters you choose, with the exception of *spaces*. Therefore, `r` is a legal variable name, as is `rate`, as is `interestRate`. The variable name `interest rate` is not allowed because of the space. No programming language allows spaces within a variable name. If you see a name such as `interest rate` in a flowchart or pseudocode, you should assume that the programmer is discussing two variables, `interest` and `rate`, each of which individually would be a fine variable name.

TIP As a convention, this book begins variable names with a lowercase letter. You might find programming texts in languages such as Visual Basic and C++ in which the author has chosen to begin variable names with an uppercase letter. As long as you adopt a convention and use it consistently, your programs will be easier to read and understand.

TIP When you write a program using an editor that is packaged with a compiler, the compiler may display variable names in a different color from the rest of the program. This visual aid helps your variable names stand out from words that are part of the programming language.

2. *Variable names should have some appropriate meaning.* This is not a rule of any programming language. When computing an interest rate in a program, the computer does not care if you call the variable `g`, `u84`, or `fred`. As long as the correct numeric result is placed in the variable, its actual name doesn't really matter. However, it's much easier to follow the logic of a program with a statement in it like `compute finalBalance as equal to initialInvestment times interestRate` than one with a statement in it like `compute someBanana as equal to j89 times myFriendLinda`. You might think you will remember how you intended to use a cryptic variable name within a program, but several months or years later when a program requires changes, you, and other programmers working with you, will appreciate clear, descriptive variable names.

Notice that the flowchart in Figure 1-9 follows these two rules for variables: both variable names, `inputNumber` and `calculatedAnswer`, are one word, and they have appropriate meanings. Some programmers have fun with their variable names by naming them after friends or creating puns with them, but such behavior is unprofessional and marks those programmers as amateurs. Table 1-1 lists some possible variable names that might be used to hold an employee's last name and provides a rationale for the appropriateness of each one.

TIP Another general rule in all programming languages is that variable names may not begin with a digit, although usually they may contain digits. Thus, in most languages `budget2013` is a legal variable name, but `2013Budget` is not.

TABLE 1-1: VALID AND INVALID VARIABLE NAMES FOR AN EMPLOYEE'S LAST NAME

Suggested variable names for employee's last name	Comments
`employeeLastName`	Good
`employeeLast`	Good—most people would interpret `Last` as meaning `Last Name`
`empLast`	Good—`emp` is short for employee
`emlstnam`	Legal—but cryptic
`lastNameOfTheEmployeeInQuestion`	Legal—but awkward
`last name`	Not legal—embedded space
`employeelastname`	Legal—but hard to read without camel casing

ENDING A PROGRAM BY USING SENTINEL VALUES

Recall that the logic in the flowchart for doubling numbers, shown in Figure 1-9, has a major flaw—the program never ends. This programming situation is known as an **infinite loop**—a repeating flow of logic with no end. If, for example, the input numbers are being entered at the keyboard, the program will keep accepting numbers and printing doubles forever. Of course, the user could refuse to type in any more numbers. But the computer is very patient, and if you refuse to give it any more numbers, it will sit and wait forever. When you finally type in a number, the program will double it, print the result, and wait for another. The program cannot progress any further while it is waiting for input; meanwhile, the program is occupying computer memory and tying up operating system resources. Refusing to enter any more numbers is not a practical solution. Another way to end the program is simply to turn the computer off. But again, that's neither the best nor an elegant way to bring the program to an end.

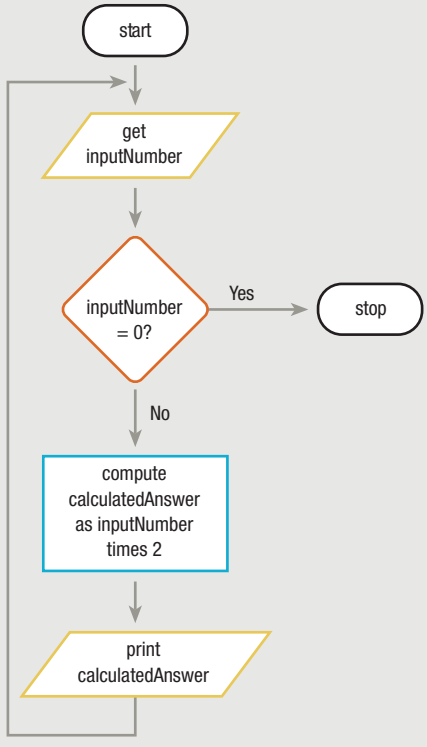
A superior way to end the program is to set a predetermined value for `inputNumber` that means "Stop the program!" For example, the programmer and the user could agree that the user will never need to know the double of 0 (zero), so the user could enter a 0 when he or she wants to stop. The program could then test any incoming value contained in `inputNumber` and, if it is a 0, stop the program. Testing a value is also called making a **decision**.

You represent a decision in a flowchart by drawing a **decision symbol**, which is shaped like a diamond. The diamond usually contains a question, the answer to which is one of two mutually exclusive options—often yes or no. All good computer questions have only two mutually exclusive answers, such as yes and no or true and false. For example, "What day of the year is your birthday?" is not a good computer question because there are 366 possible answers. But "Is your birthday June 24?" is a good computer question because, for everyone in the world, the answer is either yes or no.

TIP A yes-or-no decision is called a **binary decision**, because there are two possible outcomes.

The question to stop the doubling program should be "Is the `inputNumber` just entered equal to 0?" or "`inputNumber = 0`?" for short. The complete flowchart will now look like the one shown in Figure 1-10.

FIGURE 1-10: FLOWCHART FOR NUMBER-DOUBLING PROGRAM WITH SENTINEL VALUE OF 0

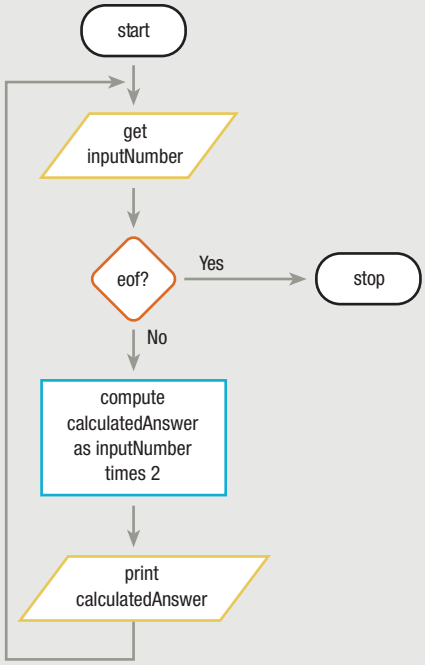


One drawback to using 0 to stop a program, of course, is that it won't work if the user does need to find the double of 0. In that case, some other data-entry value that the user never will need, such as 999 or –1, could be selected to signal that the program should end. A preselected value that stops the execution of a program is often called a **dummy value** because it does not represent real data, but just a signal to stop. Sometimes, such a value is called a **sentinel value** because it represents an entry or exit point, like a sentinel who guards a fortress.

Not all programs rely on user data entry from a keyboard; many read data from an input device, such as a disk or tape drive. When organizations store data on a disk or other storage device, they do not commonly use a dummy value to signal the end of the file. For one thing, an input record might have hundreds of fields, and if you store a dummy record in every file, you are wasting a large quantity of storage on "non-data." Additionally, it is often difficult to choose sentinel values for fields in a company's data files. Any `balanceDue`, even a zero or a negative number, can be a legitimate value, and any `customerName`, even "ZZ", could be someone's name. Fortunately, programming languages can

recognize the end of data in a file automatically, through a code that is stored at the end of the data. Many programming languages use the term **eof** (for "end of file") to talk about this marker that automatically acts as a sentinel. This book, therefore, uses **eof** to indicate the end of data, regardless of whether the code is a special disk marker or a dummy value such as 0 that comes from the keyboard. Therefore, the flowchart and pseudocode can look like the examples shown in Figure 1-11.

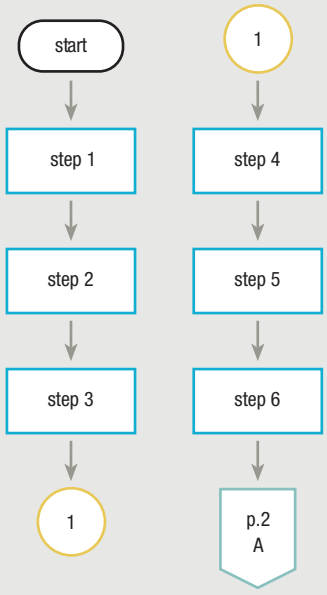
FIGURE 1-11: FLOWCHART USING **eof**



USING THE CONNECTOR

By using just the input, processing, output, decision, and terminal symbols, you can represent the flowcharting logic for many diverse applications. When drawing a flowchart segment, you might use another symbol, the **connector**. You can use a connector when limited page size forces you to continue a flowchart in an unconnected location or on another page. If a flowchart has six processing steps and a page provides room for only three, you might represent the logic as shown in Figure 1-12.

FIGURE 1-12: FLOWCHART USING THE CONNECTOR



By convention, programmers use a circle as an on-page connector symbol, and a symbol that looks like a square with a pointed bottom as an off-page connector symbol. The on-page connector at the bottom of the left column in Figure 1-12 tells someone reading the flowchart that there is more to the flowchart. The circle should contain a number or letter that can then be matched to another number or letter somewhere else, in this case on the right. If a large flowchart needed more connectors, new numbers or letters would be assigned in sequence (1, 2, 3... or A, B, C...) to each successive pair of connectors. The off-page connector at the bottom of the right column in Figure 1-12 tells a reader that there is more to the flowchart on another page.

When you are creating your own flowcharts, you should avoid using any connectors, if at all possible; flowcharts are more difficult to follow when their segments do not fit together on a page. Some programmers would even say that if a flowchart must connect to another page, it is a sign of poor design. Your instructor or future programming supervisor may require that long flowcharts be redrawn so you don't need to use the connector symbol. However, when continuing to a new location or page is unavoidable, the connector provides the means.

ASSIGNING VALUES TO VARIABLES

When you create a flowchart or pseudocode for a program that doubles numbers, you can include the statement `compute calculatedAnswer as inputNumber times 2`. This statement incorporates two actions. First, the computer calculates the arithmetic value of `inputNumber times 2`. Second, the computed value is

stored in the `calculatedAnswer` memory location. Most programming languages allow a shorthand expression for **assignment statements** such as `compute calculatedAnswer as inputNumber times 2`. The shorthand takes the form `calculatedAnswer = inputNumber * 2`. The equal sign is the **assignment operator**; it always requires the name of a memory location on its left side—the name of the location where the result will be stored.

TIP

When they write pseudocode or draw a flowchart, most programmers use the asterisk (*) to represent multiplication. When you write pseudocode, you can use an X or a dot for multiplication (as most mathematicians do), but you will be using an unconventional format. This book will always use an asterisk to represent multiplication.

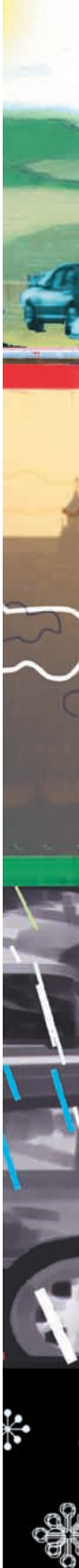
According to the rules of algebra, a statement like `calculatedAnswer = inputNumber * 2` should be exactly equivalent to the statement `inputNumber * 2 = calculatedAnswer`. That's because in algebra, the equal sign always represents equivalency. In most programming languages, however, the equal sign represents assignment, and `calculatedAnswer = inputNumber * 2` means "multiply `inputNumber` by 2 and store the result in the variable called `calculatedAnswer`." Whatever operation is performed to the right of the equal sign results in a value that is placed in the memory location to the left of the equal sign. Therefore, the incorrect statement `inputNumber * 2 = calculatedAnswer` means to attempt to take the value of `calculatedAnswer` and store it in a location called `inputNumber * 2`, but there can't be a location called `inputNumber * 2`. For one thing, you should recognize that the expression `inputNumber * 2` can't be a variable because it has spaces in it. For another, a location can't be multiplied. Its contents can be multiplied, but the location itself cannot be. The backward statement `inputNumber * 2 = calculatedAnswer` contains a syntax error, no matter what programming language you use; a program with such a statement will not execute.

TIP

When you create an assignment statement, it may help to imagine the word "let" in front of the statement. Thus, you can read the statement `calculatedAnswer = inputNumber * 2` as "Let `calculatedAnswer` equal `inputNumber` times two." The BASIC programming language allows you to use the word "let" in such statements. You might also imagine the word "gets" or "receives" in place of the assignment operator. In other words, `calculatedAnswer = inputNumber * 2` means both `calculatedAnswer gets inputNumber * 2` and `calculatedAnswer receives inputNumber * 2`.

Computer memory is made up of millions of distinct locations, each of which has an address. Fifty or sixty years ago, programmers had to deal with these addresses and had to remember, for instance, that they had stored a salary in location 6428 of their computer. Today, we are very fortunate that high-level computer languages allow us to pick a reasonable "English" name for a memory address and let the computer keep track of where it is. Just as it is easier for you to remember that the president lives in the White House than at 1600 Pennsylvania Avenue, Washington, D.C., it is also easier for you to remember that your salary is in a variable called `mySalary` than at memory location 6428104.

Similarly, it does not usually make sense to perform mathematical operations on names given to memory addresses, but it does make sense to perform mathematical operations on the *contents* of memory addresses. If you live in



`blueSplitLevelOnTheCorner`, adding 1 to that would be meaningless, but you certainly can add 1 person to the number of people already in that house. For our purposes, then, the statement `calculatedAnswer = inputNumber * 2` means exactly the same thing as the statement `calculate inputNumber * 2` (that is, double the contents in the memory location named `inputNumber`) `and store the result in the memory location named calculatedAnswer.`

TIP

Many programming languages allow you to create named constants. A named constant is a named memory location, similar to a variable, except its value never changes during the execution of a program. If you are working with a programming language that allows it, you might create a constant for a value such as `PI = 3.14` or `COUNTY_SALES_TAX_RATE = .06`. Many programmers follow the convention of using camel casing for variable identifiers but all capital letters for constant identifiers.

UNDERSTANDING DATA TYPES

Computers deal with two basic types of data—text and numeric. When you use a specific numeric value, such as 43, within a program, you write it using the digits and no quotation marks. A specific numeric value is often called a **numeric constant**, because it does not change—a 43 always has the value 43. When you use a specific text value, or string of characters, such as "Amanda", you enclose the **string constant**, or **character constant**, within quotation marks.

TIP

Some languages require single quotation marks surrounding character constants, whereas others require double quotation marks. Many languages, including C++, C#, and Java, reserve single quotes for a single character such as 'A', and double quotes for a character string such as "Amanda".

Similarly, most computer languages allow at least two distinct types of variables. A variable's **data type** describes the kind of values the variable can hold and the types of operations that can be performed with it. One type of variable can hold a number, and is often called a **numeric variable**. A numeric variable is one that can have mathematical operations performed on it; it can hold digits, and usually can hold a decimal point and a sign indicating positive or negative if you want. In the statement `calculatedAnswer = inputNumber * 2`, both `calculatedAnswer` and `inputNumber` are numeric variables; that is, their intended contents are numeric values, such as 6 and 3, 150 and 75, or –18 and –9.

Most programming languages have a separate type of variable that can hold letters of the alphabet and other special characters such as punctuation marks. Depending on the language, these variables are called **character**, **text**, or **string variables**. If a working program contains the statement `lastName = "Lincoln"`, then `lastName` is a character or string variable.

Programmers must distinguish between numeric and character variables, because computers handle the two types of data differently. Therefore, means are provided within the syntax rules of computer programming languages to tell the

computer which type of data to expect. How this is done is different in every language; some languages have different rules for naming the variables, but with others you must include a simple statement (called a **declaration**) telling the computer which type of data to expect.

Some languages allow for several types of numeric data. Languages such as C++, C#, Visual Basic, and Java distinguish between **integer** (whole number) numeric variables and **floating-point** (fractional) numeric variables that contain a decimal point. Thus, in some languages, the values 4 and 4.3 would be stored in different types of numeric variables.

Some programming languages allow even more specific variable types, but the character versus numeric distinction is universal. For the programs you develop in this book, assume that each variable is one of the two broad types. If a variable called `taxRate` is supposed to hold a value of 2.5, assume that it is a numeric variable. If a variable called `inventoryItem` is supposed to hold a value of "monitor", assume that it is a character variable.

TIP

Values such as "monitor" and 2.5 are called constants or literal constants because they never change. A variable value *can* change. Thus, `inventoryItem` can hold "monitor" at one moment during the execution of a program, and later you can change its value to "modem".

TIP

Some languages allow you to invent your own data type. In Chapter 12 of the Comprehensive version of this book, you will learn that object-oriented programming languages allow you to create new data types called classes.

By convention, this book encloses character data like "monitor" within quotation marks to distinguish the characters from yet another variable name. Also by convention, numeric data values are not enclosed within quotation marks. According to these conventions, then, `taxRate = 2.5` and `inventoryItem = "monitor"` are both valid statements. The statement `inventoryItem = monitor` is a valid statement only if `monitor` is also a character variable. In other words, if `monitor = "color"`, and subsequently `inventoryItem = monitor`, then the end result is that the memory address named `inventoryItem` contains the string of characters "color".

Every computer handles text or character data differently from the way it handles numeric data. You may have experienced these differences if you have used application software such as spreadsheets or database programs. For example, in a spreadsheet, you cannot sum a column of words. Similarly, every programming language requires that you distinguish variables as to their correct type, and that you use each type of variable appropriately. Identifying your variables correctly as numeric or character is one of the first steps you have to take when writing programs in any programming language. Table 1-2 provides you with a few examples of legal and illegal variable assignment statements.

TIP

The process of naming program variables and assigning a type to them is called **making declarations**, or **declaring variables**. You will learn how to declare variables in Chapter 4.

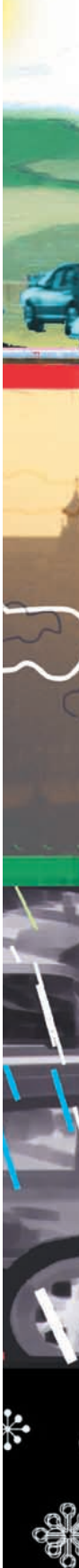


TABLE 1-2: SOME EXAMPLES OF LEGAL AND ILLEGAL ASSIGNMENTS

Assume `lastName` *and* `firstName` *are character variables.*

Assume `quizScore` *and* `homeworkScore` *are numeric variables.*

Examples of valid assignments	Examples of invalid assignments	Explanation of invalid examples
`lastName = "Parker"`	`lastName = Parker`	If `Parker` is the last name, it requires quotes. If `Parker` is a named string variable, this assignment would be allowed.
`firstName = "Laura"`	`"Parker" = lastName`	Value on left must be a variable name, not a constant
`lastName = firstName`	`lastName = quizScore`	The data types do not match
`quizScore = 86`	`homeworkScore = firstName`	The data types do not match
`homeworkScore = quizScore`	`homeworkScore = "92"`	The data types do not match
`homeworkScore = 92`	`quizScore = "zero"`	The data types do not match
`quizScore = homeworkScore + 25`	`firstName = 23`	The data types do not match
`homeworkScore = 3 * 10`	`100 = homeworkScore`	Value on left must be a variable name, not a constant

UNDERSTANDING THE EVOLUTION OF PROGRAMMING TECHNIQUES

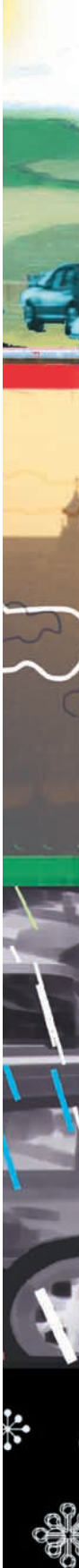
People have been writing computer programs since the 1940s. The oldest programming languages required programmers to work with memory addresses and to memorize awkward codes associated with machine languages. Newer programming languages look much more like natural language and are easier for programmers to use. Part of the reason it is easier to use newer programming languages is that they allow programmers to name variables instead of using awkward memory addresses. Another reason is that newer programming languages provide programmers with the means to create self-contained modules or program segments that can be pieced together in a variety of ways. The oldest computer programs were written in one piece, from start to finish; modern programs are rarely written that way—they are created by teams of programmers, each developing his or her own reusable and connectable program procedures. Writing several small modules is easier than writing one large program, and most large tasks are easier when you break the work into units and get other workers to help with some of the units.

You will learn to create program modules in Chapter 3.

Currently, there are two major techniques used to develop programs and their procedures. One technique, called **procedural programming**, focuses on the procedures that programmers create. That is, procedural programmers focus on the actions that are carried out—for example, getting input data for an employee and writing the calculations needed to produce a paycheck from the data. Procedural programmers would approach the job of producing a paycheck by breaking down the paycheck-producing process into manageable subtasks.

The other popular programming technique, called **object-oriented programming**, focuses on objects, or "things," and describes their features, or attributes, and their behaviors. For example, object-oriented programmers might design a payroll application by thinking about employees and paychecks, and describing their attributes (such as last name or check amount) and behaviors (such as the calculations that result in the check amount).

With either approach, procedural or object-oriented, you can produce a correct paycheck, and both techniques employ reusable program modules. The major difference lies in the focus the programmer takes during the earliest planning stages of a project. Object-oriented programming employs a large vocabulary; you can learn this terminology in Chapter 13 of the Comprehensive version of this book. For now, this book focuses on procedural programming techniques. The skills you gain in programming procedurally—declaring variables, accepting input, making decisions, producing output, and so on—will serve you well whether you eventually write programs in a procedural or object-oriented fashion, or in both.



CHAPTER SUMMARY

- Together, computer hardware (equipment) and software (instructions) accomplish four major operations: input, processing, output, and storage. You write computer instructions in a computer programming language that requires specific syntax; the instructions are translated into machine language by a compiler or interpreter. When both the syntax and logic of a program are correct, you can run, or execute, the program to produce the desired results.
- A programmer's job involves understanding the problem, planning the logic, coding the program, translating the program into machine language, testing the program, and putting the program into production.
- When data items are stored for use on computer systems, they are stored in a data hierarchy of character, field, record, file, and database.
- When programmers plan the logic for a solution to a programming problem, they often use flowcharts or pseudocode. When you draw a flowchart, you use parallelograms to represent input and output operations, and rectangles to represent processing.
- Variables are named memory locations, the contents of which can vary. As a programmer, you choose reasonable names for your variables. Every computer programming language has its own set of rules for naming variables; however, all variable names must be written as one word without embedded spaces, and should have appropriate meaning.
- Testing a value involves making a decision. You represent a decision in a flowchart by drawing a diamond-shaped decision symbol containing a question, the answer to which is either yes or no. You can stop a program's execution by using a decision to test for a sentinel value.
- A connector symbol is used to continue a flowchart that does not fit together on a page, or must continue on an additional page.
- Most programming languages use the equal sign to assign values to variables. Assignment always takes place from right to left.
- Programmers must distinguish between numeric and character variables, because computers handle the two types of data differently. A variable declaration tells the computer which type of data to expect. By convention, character data values are included within quotation marks.
- Procedural and object-oriented programmers approach program problems differently. Procedural programmers concentrate on the actions performed with data. Object-oriented programmers focus on objects and their behaviors and attributes.

KEY TERMS

Hardware is the equipment of a computer system.

Software consists of the programs that tell the computer what to do.

Input devices include keyboards and mice; through these devices, data items enter the computer system. Data can also enter a system from storage devices such as magnetic disks and CDs.

Data includes all the text, numbers, and other information that are processed by a computer.

Processing data items may involve organizing them, checking them for accuracy, or performing mathematical operations on them.

The **central processing unit**, or **CPU**, is the piece of hardware that processes data.

Information is sent to a printer, monitor, or some other **output** device so people can view, interpret, and work with the results.

Programming languages, such as Visual Basic, C#, C++, Java, or COBOL, are used to write programs.

The **syntax** of a language consists of its rules.

Machine language is a computer's on/off circuitry language.

A **compiler** or **interpreter** translates a high-level language into machine language and tells you if you have used a programming language incorrectly.

You develop the **logic** of the computer program when you give instructions to the computer in a specific sequence, without leaving any instructions out or adding extraneous instructions.

A **semantic error** occurs when a correct word is used in an incorrect context.

The **running**, or **executing**, of a program occurs when the computer actually uses the written and compiled program.

Internal storage is called **memory**, **main memory**, **primary memory**, or **random access memory (RAM)**.

External storage is **persistent** (relatively permanent) storage outside the main memory of the machine, on a device such as a floppy disk, hard disk, or magnetic tape.

Internal memory is **volatile**—that is, its contents are lost every time the computer loses power.

You **save** a program on some nonvolatile medium.

An **algorithm** is the sequence of steps necessary to solve any problem.

Desk-checking is the process of walking through a program solution on paper.

Coding a program means writing the statements in a programming language.

High-level programming languages are English-like.

Machine language is the **low-level** language made up of 1s and 0s that the computer understands.

A **syntax error** is an error in language or grammar.

Logical errors occur when incorrect instructions are performed, or when instructions are performed in the wrong order.

Conversion is the entire set of actions an organization must take to switch over to using a new program or set of programs.

The **data hierarchy** represents the relationship of databases, files, records, fields, and characters.

Characters are letters, numbers, and special symbols such as "A", "7", and "$".

A **field** is a single data item, such as `lastName`, `streetAddress`, or `annualSalary`.

Records are groups of fields that go together for some logical reason.

Files are groups of records that go together for some logical reason.

A **database** holds a group of files, often called **tables**, that together serve the information needs of an organization.

Queries are questions that pull related data items together from a database in a format that enhances efficient management decision making.

A **flowchart** is a pictorial representation of the logical steps it takes to solve a problem.

Pseudocode is an English-like representation of the logical steps it takes to solve a problem.

Input symbols, which indicate input operations, are represented as parallelograms in flowcharts.

Processing symbols are represented as rectangles in flowcharts.

Output symbols, which indicate output operations, are represented as parallelograms in flowcharts.

Flowlines, or arrows, connect the steps in a flowchart.

A **terminal symbol**, or start/stop symbol, is used at each end of a flowchart. Its shape is a **lozenge**.

Variables are memory locations, whose contents can vary or differ over time.

A variable name is also called an **identifier**.

A **mnemonic** is a memory device; variable identifiers act as mnemonics for hard-to-remember memory addresses.

Camel casing is the format for naming variables in which multiple-word variable names are run together, and each new word within the variable name begins with an uppercase letter.

An **infinite loop** is a repeating flow of logic without an ending.

Testing a value is also called making a **decision**.

You represent a decision in a flowchart by drawing a **decision symbol**, which is shaped like a diamond.

A yes-or-no decision is called a **binary decision**, because there are two possible outcomes.

A **dummy value** is a preselected value that stops the execution of a program. Such a value is sometimes called a **sentinel value** because it represents an entry or exit point, like a sentinel who guards a fortress.

Many programming languages use the term **eof** (for "end of file") to talk about an end-of-data file marker.

A **connector** is a flowchart symbol used when limited page size forces you to continue the flowchart elsewhere on the same page or on the following page.

An **assignment statement** stores the result of any calculation performed on its right side to the named location on its left side.

The equal sign is the **assignment operator**; it always requires the name of a memory location on its left side.

A **numeric constant** is a specific numeric value.

A **string constant**, or **character constant**, is enclosed within quotation marks.

A variable's **data type** describes the kind of values the variable can hold and the types of operations that can be performed with it.

Numeric variables hold numeric values.

Character, **text**, or **string variables** hold character values. If a working program contains the statement `lastName = "Lincoln"`, then `lastName` is a character or string variable.

A **declaration** is a statement that names a variable and tells the computer which type of data to expect.

Integer values are whole-number, numeric variables.

Floating-point values are fractional, numeric variables that contain a decimal point.

The process of naming program variables and assigning a type to them is called **making declarations**, or **declaring variables**.

The technique known as **procedural programming** focuses on the procedures that programmers create.

The technique known as **object-oriented programming** focuses on objects, or "things," and describes their features, or attributes, and their behaviors.

REVIEW QUESTIONS

1. **The two major components of any computer system are its _____.**
   a. input and output
   b. data and programs
   c. hardware and software
   d. memory and disk drives

2. **The major computer operations include _____.**
   a. hardware and software
   b. input, processing, output, and storage
   c. sequence and looping
   d. spreadsheets, word processing, and data communications

3. **Another term meaning "computer instructions" is _____.**
   a. hardware
   b. software
   c. queries
   d. data

4. **Visual Basic, C++, and Java are all examples of computer _____.**
   a. operating systems
   b. hardware
   c. machine languages
   d. programming languages

5. A programming language's rules are its _____.

a. syntax
b. logic
c. format
d. options

6. The most important task of a compiler or interpreter is to _____.

a. create the rules for a programming language
b. translate English statements into a language such as Java
c. translate programming language statements into machine language
d. execute machine language programs to perform useful tasks

7. Which of the following is a typical input instruction?

a. `get accountNumber`
b. `calculate balanceDue`
c. `print customerIdentificationNumber`
d. `total = janPurchase + febPurchase`

8. Which of the following is a typical processing instruction?

a. `print answer`
b. `get userName`
c. `pctCorrect = rightAnswers / allAnswers`
d. `print calculatedPercentage`

9. Which of the following is not associated with internal storage?

a. main memory
b. hard disk
c. primary memory
d. volatile

10. Which of the following pairs of steps in the programming process is in the correct order?

a. code the program, plan the logic
b. test the program, translate it into machine language
c. put the program into production, understand the problem
d. code the program, translate it into machine language

11. The two most commonly used tools for planning a program's logic are _____.

a. flowcharts and pseudocode
b. ASCII and EBCDIC
c. Java and Visual Basic
d. word processors and spreadsheets

12. The most important thing a programmer must do before planning the logic to a program is _____.

a. decide which programming language to use
b. code the problem
c. train the users of the program
d. understand the problem

13. Writing a program in a language such as C++ or Java is known as _____ the program.

a. translating
b. coding
c. interpreting
d. compiling

14. A compiler would find all of the following programming errors except _____.

a. the misspelled word "prrint" in a language that includes the word "print"
b. the use of an "X" for multiplication in a language that requires an asterisk
c. a `newBalanceDue` calculated by adding a `customerPayment` to an `oldBalanceDue` instead of subtracting it
d. an arithmetic statement written as `regularSales + discountedSales = totalSales`

15. Which of the following is true regarding the data hierarchy?

a. files contain records
b. characters contain fields
c. fields contain files
d. fields contain records

16. The parallelogram is the flowchart symbol representing _____.

a. input
b. output
c. both a and b
d. none of the above

17. Which of the following is not a legal variable name in any programming language?

a. `semester grade`
b. `fall2005_grade`
c. `GradeInCIS100`
d. `MY_GRADE`

18. In flowcharts, the decision symbol is a _____.

a. parallelogram
b. rectangle
c. lozenge
d. diamond

19. The term "eof" represents _____.

a. a standard input device
b. a generic sentinel value
c. a condition in which no more memory is available for storage
d. the logical flow in a program

20. The two broadest types of data are _____.

a. internal and external
b. volatile and constant
c. character and numeric
d. permanent and temporary

FIND THE BUGS

Since the early days of computer programming, program errors have been called "bugs." The term is often said to have originated from an actual moth that was discovered trapped in the circuitry of a computer at Harvard University in 1945. Actually, the term "bug" was in use prior to 1945 to mean trouble with any electrical apparatus; even during Thomas Edison's life, it meant an "industrial defect." However, the process of finding and correcting program errors has come to be known as debugging.

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. This pseudocode segment is intended to describe computing your average score of two classroom tests.

```
input midtermGrade
input finalGrade
average = (inputGrade + final) / 3
print average
```

2. This pseudocode segment is intended to describe computing the number of miles per gallon you get with your automobile.

```
input milesTraveled
input gallonsOfGasUsed
gallonsOfGasUsed / milesTravelled = milesPerGallon
print milesPerGal
```

3. This pseudocode segment is intended to describe computing the cost per day and the cost per week for a vacation.

```
input totalDollarsSpent
input daysOnTrip
costPerDay = totalMoneySpent * daysOnTrip
weeks = daysOnTrip / 7
costPerWeek = daysOnTrip / numberOfWeeks
print costPerDay, week
```

EXERCISES

1. Match the definition with the appropriate term.

1. Computer system equipment	a. compiler
2. Another word for programs	b. syntax
3. Language rules	c. logic
4. Order of instructions	d. hardware
5. Language translator	e. software

2. In your own words, describe the steps to writing a computer program.

3. Consider a student file that contains the following data:

LAST NAME	FIRST NAME	MAJOR	GRADE POINT AVERAGE
Andrews	David	Psychology	3.4
Broederdorf	Melissa	Computer Science	4.0
Brogan	Lindsey	Biology	3.8
Carson	Joshua	Computer Science	2.8
Eisfelder	Katie	Mathematics	3.5
Faris	Natalie	Biology	2.8
Fredricks	Zachary	Psychology	2.0
Gonzales	Eduardo	Biology	3.1

Would this set of data be suitable and sufficient to use to test each of the following programs? Explain why or why not.

a. a program that prints a list of Psychology majors
b. a program that prints a list of Art majors
c. a program that prints a list of students on academic probation—those with a grade point average under 2.0
d. a program that prints a list of students on the dean's list
e. a program that prints a list of students from Wisconsin
f. a program that prints a list of female students

4. Suggest a good set of test data to use for a program that gives an employee a $50 bonus check if the employee has produced more than 1,000 items in a week.

5. Suggest a good set of test data for a program that computes gross paychecks (that is, before any taxes or other deductions) based on hours worked and rate of pay. The program computes gross as hours times rate, unless hours are over 40. If so, the program computes gross as regular rate of pay for 40 hours, plus one and a half times the rate of pay for the hours over 40.

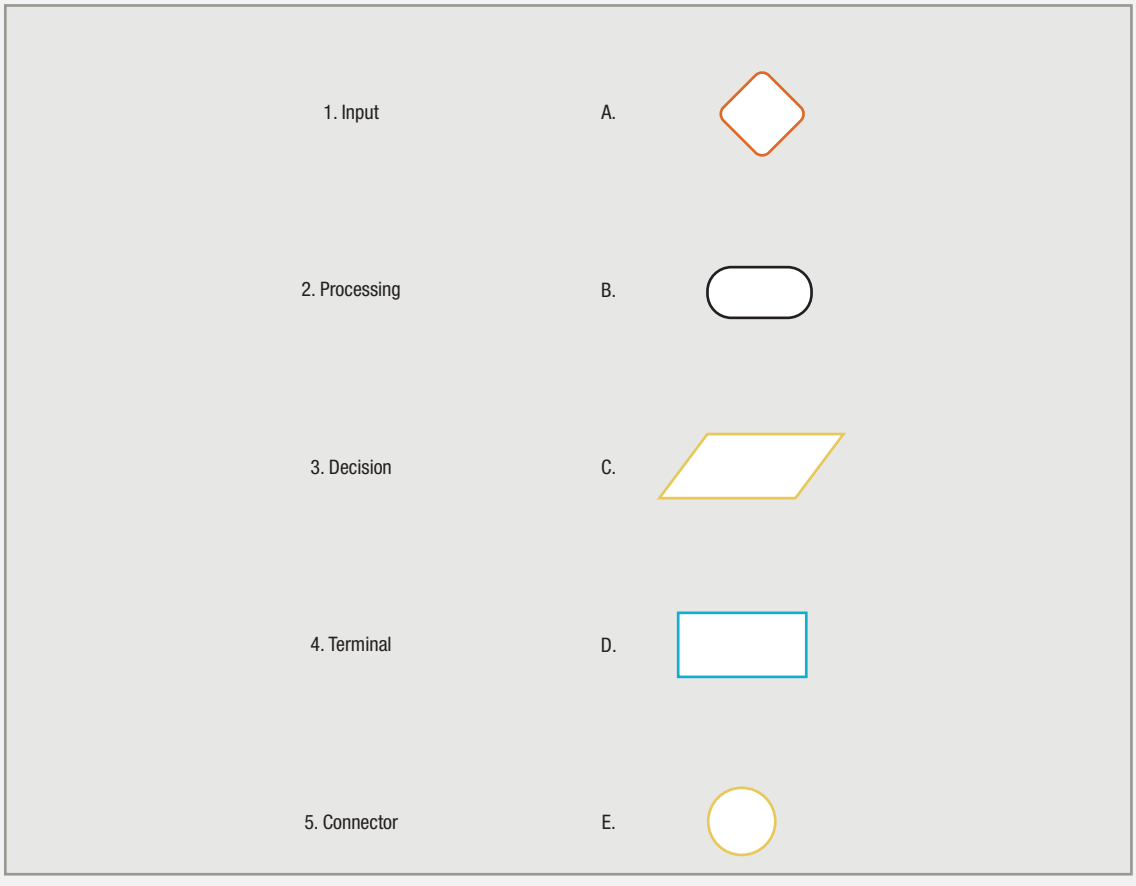
6. Suggest a good set of test data for a program that is intended to output a student's grade point average based on letter grades (A, B, C, D, or F) in five courses.

7. Suggest a good set of test data for a program for an automobile insurance company that wants to increase its premiums by $50 per month for every ticket a driver receives in a three-year period.

8. **Assume that a grocery store keeps a file for inventory, where each grocery item has its own record. Two fields within each record are the name of the manufacturer and the weight of the item. Name at least six more fields that might be stored for each record. Provide an example of the data for one record. For example, for one product the manufacturer is DelMonte, and the weight is 12 ounces.**

9. **Assume that a library keeps a file with data about its collection, one record for each item the library lends out. Name at least eight fields that might be stored for each record. Provide an example of the data for one record.**

10. **Match the term with the appropriate shape.**



11. **Which of the following names seem like good variable names to you? If a name doesn't seem like a good variable name, explain why not.**

    a. `c`
    b. `cost`
    c. `costAmount`
    d. `cost amount`

e. `cstofdngbsns`
f. `costOfDoingBusinessThisFiscalYear`
g. `cost2004`

12. If `myAge` and `yourRate` are numeric variables, and `departmentCode` is a character variable, which of the following statements are valid assignments? If a statement is not valid, explain why not.

a. `myAge = 23`
b. `myAge = yourRate`
c. `myAge = departmentCode`
d. `myAge = "departmentCode"`
e. `42 = myAge`
f. `yourRate = 3.5`
g. `yourRate = myAge`
h. `yourRate = departmentCode`
i. `6.91 = yourRate`
j. `departmentCode = Personnel`
k. `departmentCode = "Personnel"`
l. `departmentCode = 413`
m. `departmentCode = "413"`
n. `departmentCode = myAge`
o. `departmentCode = yourRate`
p. `413 = departmentCode`
q. `"413" = departmentCode`

13. Complete the following tasks:

a. Draw a flowchart to represent the logic of a program that allows the user to enter a value. The program multiplies the value by 10 and prints the result.
b. Write pseudocode for the same problem.

14. Complete the following tasks:

a. Draw a flowchart to represent the logic of a program that allows the user to enter a value that represents the radius of a circle. The program calculates the diameter (by multiplying the radius by 2), and then calculates the circumference (by multiplying the diameter by 3.14). The program prints both the diameter and the circumference.
b. Write pseudocode for the same problem.

15. Complete the following tasks:

a. Draw a flowchart to represent the logic of a program that allows the user to enter two values. The program prints the sum of the two values.
b. Write pseudocode for the same problem.

16. Complete the following tasks:

a. Draw a flowchart to represent the logic of a program that allows the user to enter three values. The first value represents hourly pay rate, the second represents the number of hours worked this pay period, and the third represents the percentage of gross salary that is withheld. The program multiplies the hourly pay rate by the number of hours worked, giving the gross pay; then, it multiplies the gross pay by the withholding percentage, giving the withholding amount. Finally, it subtracts the withholding amount from the gross pay, giving the net pay after taxes. The program prints the net pay.

b. Write pseudocode for the same problem.

DETECTIVE WORK

1. **Even Shakespeare referred to a "bug" as a negative occurrence. Name the work in which he wrote, "Warwick was a bug that fear'd us all."**
2. **What are the distinguishing features of the programming language called Short Code? When was it invented?**
3. **What is the difference between a compiler and an interpreter? Under what conditions would you prefer to use one over the other?**

UP FOR DISCUSSION

1. **Which is the better tool for learning programming—flowcharts or pseudocode? Cite any educational research you can find.**
2. **What is the image of the computer programmer in popular culture? Is the image different in books than in TV shows and movies? Would you like that image for yourself?**

2 UNDERSTANDING STRUCTURE

After studying Chapter 2, you should be able to:

- Describe the features of unstructured spaghetti code
- Describe the three basic structures—sequence, selection, and loop
- Use a priming read
- Appreciate the need for structure
- Recognize structure
- Describe three special structures—case, do-while, and do-until

UNDERSTANDING UNSTRUCTURED SPAGHETTI CODE

Professional computer programs usually get far more complicated than the number-doubling program from Chapter 1, shown in Figure 2-1.

FIGURE 2-1: NUMBER-DOUBLING PROGRAM

```
get inputNumber
calculatedAnswer = inputNumber * 2
print calculatedAnswer
```

Imagine the number of instructions in the computer program that NASA uses to calculate the launch angle of a space shuttle, or in the program the IRS uses to audit your income tax return. Even the program that produces a paycheck for you on your job contains many, many instructions. Designing the logic for such a program can be a time-consuming task. When you add several thousand instructions to a program, including several hundred decisions, it is easy to create a complicated mess. The popular name for logically snarled program statements is **spaghetti code**. The reason for the name should be obvious—the code is as confusing to read as following one noodle through a plate of spaghetti.

For example, suppose you are in charge of admissions at a college, and you've decided you will admit prospective students based on the following criteria:

- You will admit students who score 90 or better on the admissions test your college gives, as long as they are in the upper 75 percent of their high-school graduating class. (These are smart students who score well on the admissions test. Maybe they didn't do so well in high school because it was a tough school, or maybe they have matured.)
- You will admit students who score at least 80 on the admissions test if they are in the upper 50 percent of their high-school graduating class. (These students score fairly well on the test, and do fairly well in school.)
- You will admit students who score as low as 70 on your test if they are in the top 25 percent of their class. (Maybe these students don't take tests well, but obviously they are achievers.)

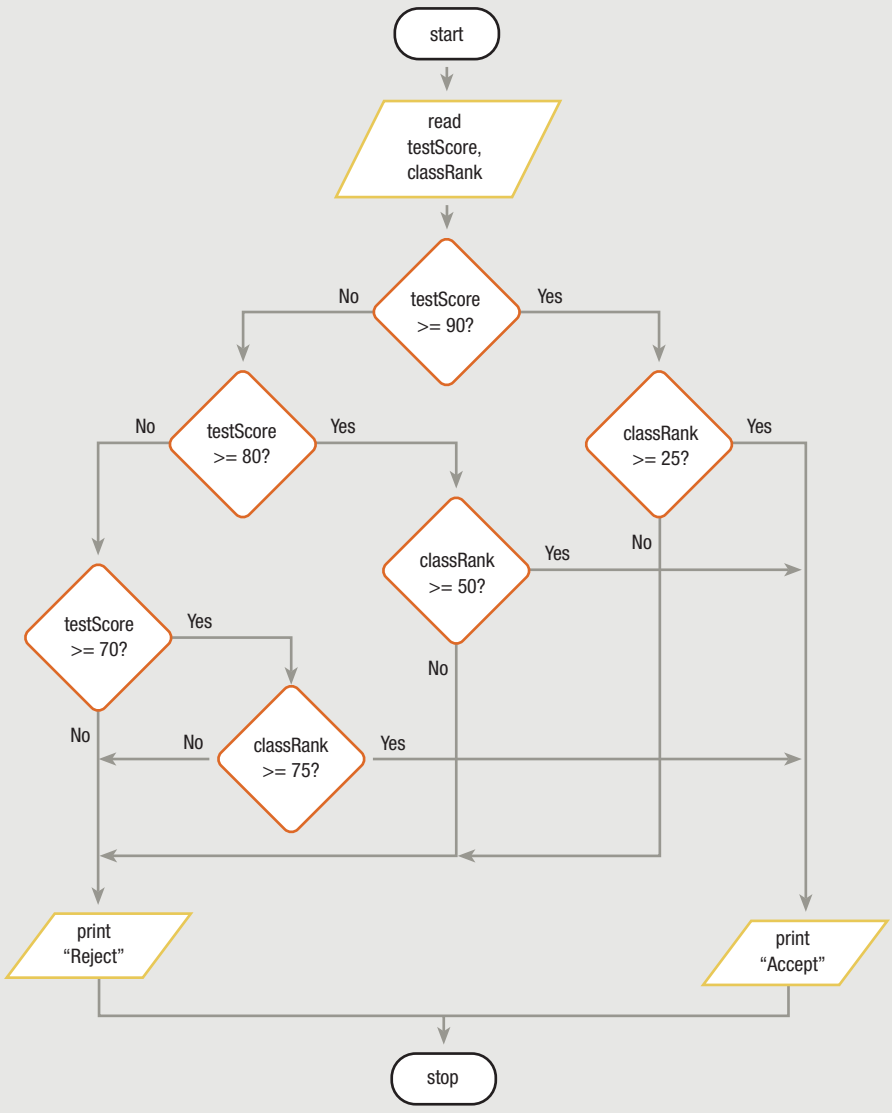
Table 2-1 summarizes the admission requirements.

TABLE 2-1: ADMISSION REQUIREMENTS

Test score	High-school rank
90–100	Upper 75 percent (from 25th to 100th percentile)
80–89	Upper half (from 50th to 100th percentile)
70–79	Upper 25 percent (from 75th to 100th percentile)

The flowchart for this program could look like the one in Figure 2-2. This kind of flowchart is an example of spaghetti code. Many computer programs (especially older computer programs) bear a striking resemblance to the flowchart in Figure 2-2. Such programs might "work"—that is, they might produce correct results—but they are very difficult to read and maintain, and their logic is difficult to follow.

FIGURE 2-2: SPAGHETTI CODE EXAMPLE

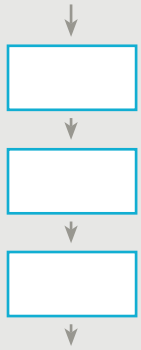


UNDERSTANDING THE THREE BASIC STRUCTURES

In the mid-1960s, mathematicians proved that any program, no matter how complicated, can be constructed using one or more of only three structures. A **structure** is a basic unit of programming logic; each structure is a sequence, selection, or loop. With these three structures alone, you can diagram any task, from doubling a number to performing brain surgery. You can diagram each structure with a specific configuration of flowchart symbols.

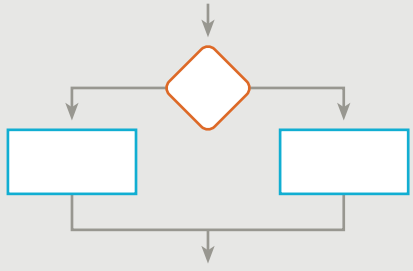
The first of these structures is a sequence, as shown in Figure 2-3. With a **sequence structure**, you perform an action or task, and then you perform the next action, in order. A sequence can contain any number of tasks, but there is no chance to branch off and skip any of the tasks. Once you start a series of actions in a sequence, you must continue step-by-step until the sequence ends.

FIGURE 2-3: SEQUENCE STRUCTURE



The second structure is called a **selection structure** or **decision structure**, as shown in Figure 2-4. With this structure, you ask a question, and, depending on the answer, you take one of two courses of action. Then, no matter which path you follow, you continue with the next task.

FIGURE 2-4: SELECTION STRUCTURE



Some people call the selection structure an **if-then-else** because it fits the following statement:

```
if someCondition is true then
   do oneProcess
else
   do theOtherProcess
```

For example, while cooking you may decide the following:

```
if we have brownSugar then
   use brownSugar
else
   use whiteSugar
```

Similarly, a payroll program might include a statement such as:

```
if hoursWorked is more than 40 then
   calculate regularPay and overtimePay
else
   calculate regularPay
```

The previous examples can also be called **dual-alternative ifs**, because they contain two alternatives—the action taken when the tested condition is true and the action taken when it is false. Note that it is perfectly correct for one branch of the selection to be a "do nothing" branch. For example:

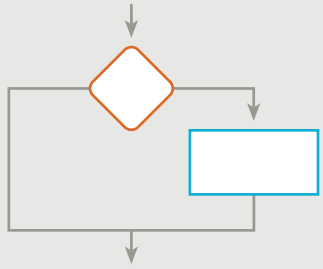
```
if it is raining then
   take anUmbrella
```

or

```
if employee belongs to dentalPlan then
   deduct $40 from employeeGrossPay
```

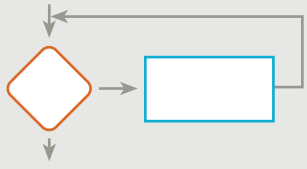
The previous examples are **single-alternative ifs**, and a diagram of their structure is shown in Figure 2-5. In these cases, you don't take any special action if it is not raining or if the employee does not belong to the dental plan. The case where nothing is done is often called the **null case**.

FIGURE 2-5: SINGLE-ALTERNATIVE DECISION STRUCTURE



The third structure, shown in Figure 2-6, is a loop. In a **loop structure**, you continue to repeat actions based on the answer to a question. In the most common type of loop, you first ask a question; if the answer requires an action, you perform the action and ask the original question again. If the answer requires that the action be taken again, you take the action and then ask the original question again. This continues until the answer to the question is such that the action is no longer required; then you exit the structure. You may hear programmers refer to looping as **repetition** or **iteration**.

FIGURE 2-6: LOOP STRUCTURE



Some programmers call this structure a **while...do**, or more simply, a **while** loop, because it fits the following statement:

```
while testCondition continues to be true
   do someProcess
```

You encounter examples of looping every day, as in:

```
while you continue to beHungry
   take anotherBiteOfFood
```

or

```
while unreadPages remain in the readingAssignment
   read another unreadPage
```

In a business program, you might write:

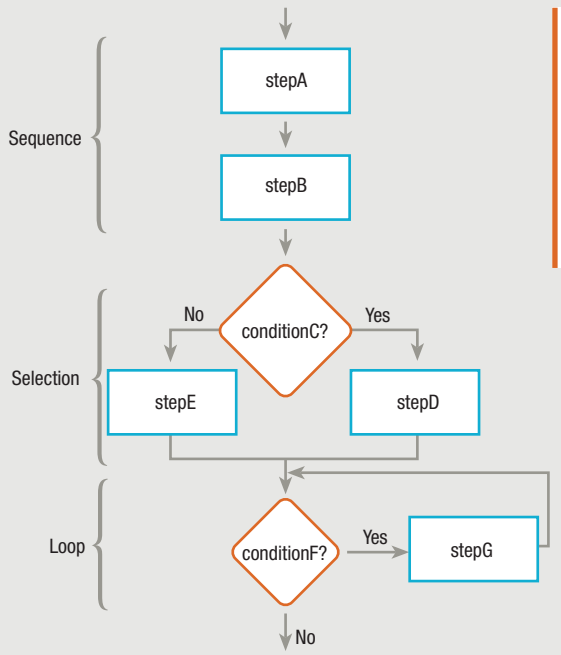
```
while quantityInInventory remains low
   continue to orderItems
```

or

```
while there are more retailPrices to be discounted
   compute a discount
```

All logic problems can be solved using only these three structures—sequence, selection, and loop. The three structures, of course, can be combined in an infinite number of ways. For example, you can have a sequence of tasks followed by a selection, or a loop followed by a sequence. Attaching structures end-to-end is called **stacking** structures. For example, Figure 2-7 shows a structured flowchart achieved by stacking structures, and shows pseudocode that might follow that flowchart logic.

FIGURE 2-7: STRUCTURED FLOWCHART AND PSEUDOCODE




```
do stepA
do stepB
if conditionC is true then
     do stepD
else
     do stepE
endif
while conditionF is true
     do stepG
endwhile
```

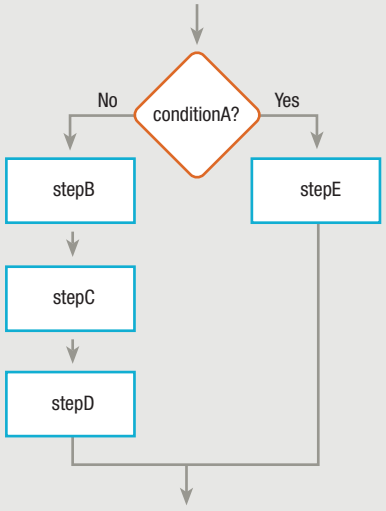
The pseudocode in Figure 2-7 shows two end-structure statements—`endif` and `endwhile`. You can use an `endif` statement to clearly show where the actions that depend on a decision end. The instruction that follows `if` occurs when its tested condition is true, the instruction that follows `else` occurs when the tested condition is false, and the instruction that follows `endif` occurs in either case—it is not dependent on the `if` statement at all. In other words, statements beyond the `endif` statement are "outside" the decision structure. Similarly, you use an `endwhile`

statement to show where a loop structure ends. In Figure 2-7, while `conditionF` continues to be true, `stepG` continues to execute. If any statements followed the `endwhile` statement, they would be outside of, and not a part of, the loop.

TIP Whether you are drawing a flowchart or writing pseudocode, you can use either of the following pairs to represent decision outcomes: yes and no or true and false. This book follows the convention of using yes and no in flowchart diagrams and true and false in pseudocode.

Besides stacking structures, you can replace any individual tasks or steps in a structured flowchart diagram or pseudocode segment with additional structures. In other words, any sequence, selection, or loop can contain other sequences, selections, or loops. For example, you can have a sequence of three tasks on one side of a selection, as shown in Figure 2-8. Placing a structure within another structure is called **nesting** the structures.

FIGURE 2-8: FLOWCHART AND PSEUDOCODE SHOWING A SEQUENCE NESTED WITHIN A SELECTION

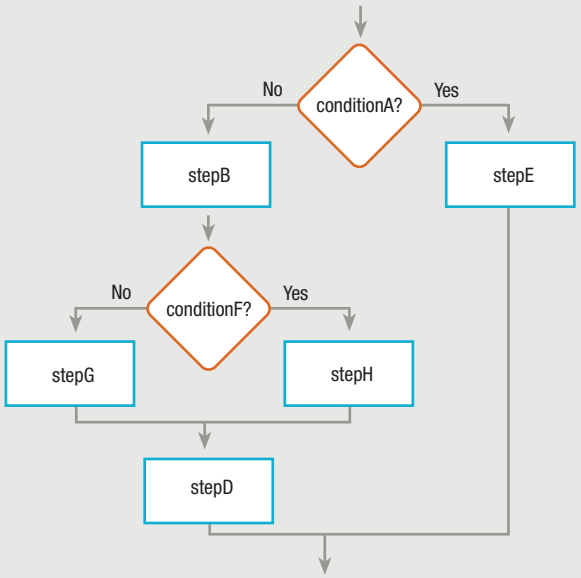



```
if conditionA is true then
     do stepE
else
     do stepB
     do stepC
     do stepD
endif
```

When you write the pseudocode for the logic shown in Figure 2-8, the convention is to indent all statements that depend on one branch of the decision, as shown in the pseudocode. The indentation and the `endif` statement both show that all three statements (`do stepB`, `do stepC`, and `do stepD`) must execute if `conditionA` is not true. The three statements constitute a **block**, or a group of statements that execute as a single unit.

In place of one of the steps in the sequence in Figure 2-8, you can insert a selection. In Figure 2-9, the process named `stepC` has been replaced with a selection structure that begins with a test of the condition named `conditionF`.

FIGURE 2-9: SELECTION IN A SEQUENCE WITHIN A SELECTION



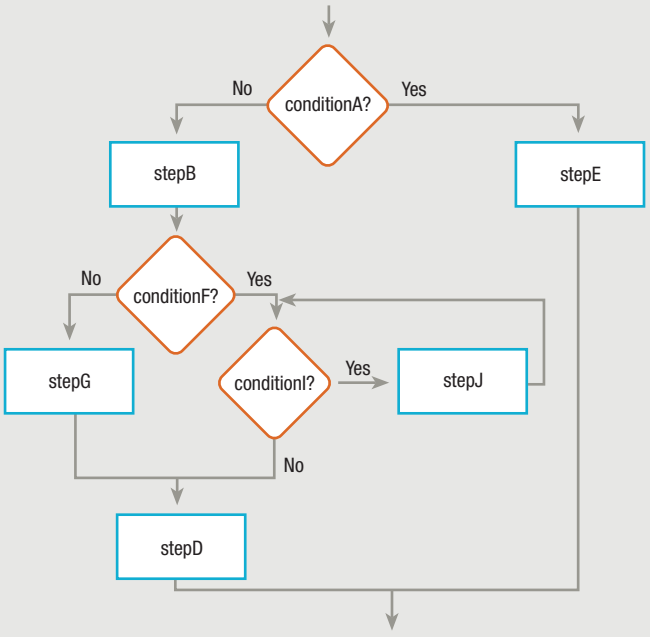

```
if conditionA is true then
     do stepE
else
     do stepB
     if conditionF is true then
          do stepH
     else
          do stepG
     endif
     do stepD
endif
```

In the pseudocode shown in Figure 2-9, notice that `do stepB`, `if conditionF is true then`, `else`, `endif`, and `do stepD` all align vertically with each other. This shows that they are all "on the same level." If you look at the same problem flowcharted in Figure 2-9, you see that you could draw a vertical line through the symbols containing `stepB`, `conditionF`, and `stepD`. The flowchart and the pseudocode represent exactly the same logic. The `stepH` and `stepG` processes, on the other hand, are one level "down"; they are dependent on the answer to the `conditionF` question. Therefore, the `do stepH` and `do stepG` statements are indented one additional level in the pseudocode.

Also notice that the pseudocode in Figure 2-9 has two `endif` statements. Each is aligned to correspond to an `if`. An `endif` always partners with the most recent `if` that does not already have an `endif` partner, and an `endif` should always align vertically with its `if` partner.

In place of `do stepH` on one side of the new selection in Figure 2-9, you can insert a loop. This loop, based on `conditionI`, appears inside the selection that is within the sequence that constitutes the "No" side of the original `conditionA` selection. In the pseudocode in Figure 2-10, notice that the `while` aligns with the `endwhile`, and that the entire `while` structure is indented within the true ("Yes") half of the `if` structure that begins with the decision based on `conditionF`. The indentation used in the pseudocode reflects the logic you can see laid out graphically in the flowchart.

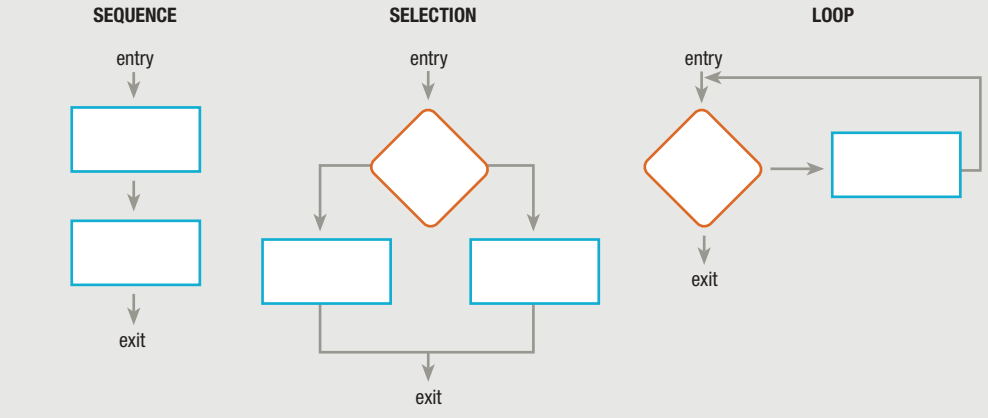
FIGURE 2-10: FLOWCHART AND PSEUDOCODE FOR LOOP WITHIN SELECTION WITHIN SEQUENCE WITHIN SELECTION




```
if conditionA is true then
     do stepE
else
     do stepB
     if conditionF is true then
          while conditionI is true
               do stepJ
          endwhile
     else
          do stepG
     endif
     do stepD
endif
```

The combinations are endless, but each of a structured program's segments is a sequence, a selection, or a loop. The three structures are shown together in Figure 2-11. Notice that each structure has one entry and one exit point. One structure can attach to another only at one of these points.

FIGURE 2-11: THE THREE STRUCTURES



TIP

Try to imagine physically picking up any of the three structures using the "handles" marked entry and exit. These are the spots at which you could connect a structure to any of the others. Similarly, any complete structure, from its entry point to its exit point, can be inserted within the process symbol of any other structure.

In summary, a structured program has the following characteristics:

- A structured program includes only combinations of the three basic structures—sequence, selection, and loop. Any structured program might contain one, two, or all three types of structures.
- Structures can be stacked or connected to one another only at their entry or exit points.
- Any structure can be nested within another structure.

TIP

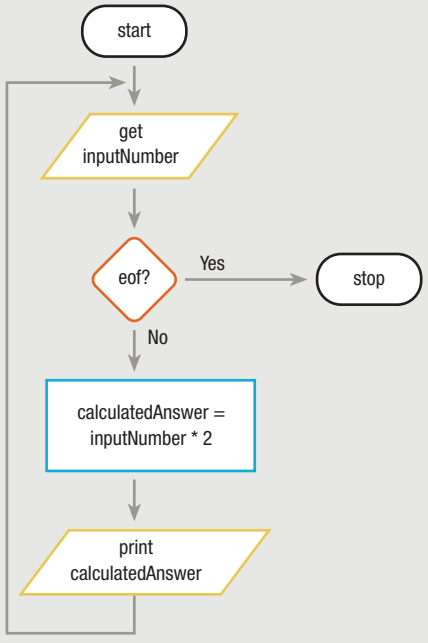
A structured program is never required to contain examples of all three structures; a structured program might contain only one or two of them. For example, many simple programs contain only a sequence of several tasks that execute from start to finish without any needed selections or loops. As another example, a program might display a series of numbers, looping to do so, but never making any decisions about the numbers.

USING THE PRIMING READ

For a program to be structured and work the way you want it to, sometimes you need to add extra steps. The priming read is one kind of added step. A **priming read** or **priming input** is the statement that reads the first input data record. If a program will read 100 data records, you read the first data record in a statement that is separate from the other 99. You must do this to keep the program structured.

At the end of Chapter 1, you read about a program like the one in Figure 2-12. The program gets a number and checks for the end-of-file condition. If it is not the end of file, then the number is doubled, the answer is printed, and the next number is input.

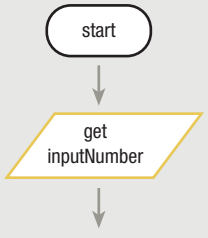
FIGURE 2-12: UNSTRUCTURED FLOWCHART OF A NUMBER-DOUBLING PROGRAM



Is the program represented by Figure 2-12 structured? At first, it might be hard to tell. The three allowed structures were illustrated in Figure 2-11.

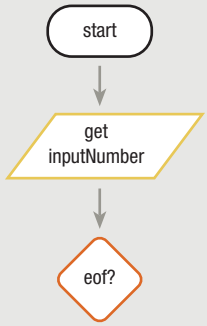
The flowchart in Figure 2-12 does not look exactly like any of the three shapes shown in Figure 2-11. However, because you may stack and nest structures while retaining overall structure, it might be difficult to determine whether a flowchart as a whole is structured. It's easiest to analyze the flowchart in Figure 2-12 one step at a time. The beginning of the flowchart looks like Figure 2-13.

FIGURE 2-13: BEGINNING OF A NUMBER-DOUBLING FLOWCHART



Is this portion of the flowchart structured? Yes, it's a sequence. (Even a single task can be a sequence—it's just a brief sequence.) Adding the next piece of the flowchart looks like Figure 2-14.

FIGURE 2-14: NUMBER-DOUBLING FLOWCHART



The sequence is finished; either a selection or a loop is starting. You might not know which one, but you do know the sequence is not continuing, because sequences can't contain questions. With a sequence, each task or step must follow without any opportunity to branch off. Therefore, which type of structure starts with the question in Figure 2-14? Is it a selection or a loop?

With a selection structure, the logic goes in one of two directions after the question, and then the flow comes back together; the question is not asked a second time. However, in a loop, if the answer to the question results in the loop being entered and the loop statements executing, then the logic returns to the question that started the loop; when the body of a loop executes, the question that controls the loop is always asked again.

In the number-doubling problem in the original Figure 2-12, if it is not `eof` (that is, if the end-of-file condition is not met), then some math is done, an answer is printed, a new number is obtained, and the `eof` question is asked again. In other words, while the answer to the `eof` question continues to be *no*, eventually the logic will return to the `eof` question. (Another way to phrase this is that while it continues to be true that `eof` has not yet been reached, the logic keeps returning to the same question.) Therefore, the number-doubling problem contains a structure beginning with the `eof` question that is more like the beginning of a loop than it is like a selection.

The number-doubling problem *does* contain a loop, but it's not a structured loop. In a structured loop, the rules are:

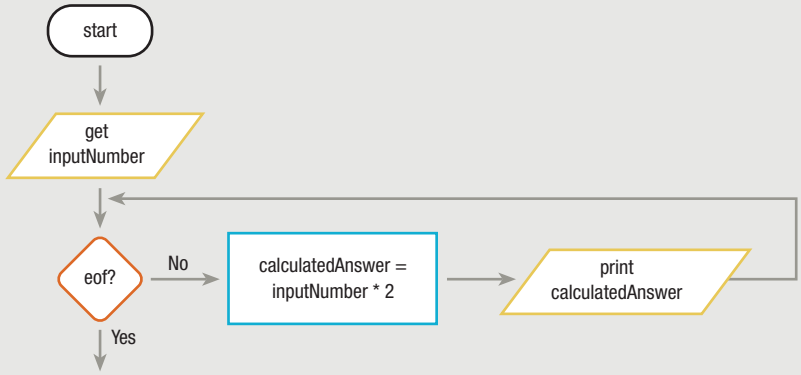
1. You ask a question.
2. If the answer indicates you should take some action or perform a procedure, then you do so.
3. If you perform the procedure, then you must go right back to repeat the question.

The flowchart in Figure 2-12 asks a question; if the answer is *no* (that is, while it is true that the `eof` condition has not been met), then the program performs two tasks: it does the arithmetic and it prints the results. Doing two things is acceptable because two tasks with no possible branching constitute a sequence, and it is fine to nest a structure within another structure. However, when the sequence ends, the logic doesn't flow right back to the question. Instead, it goes

above the question to get another number. For the loop in Figure 2-12 to be a structured loop, the logic must return to the `eof` question when the embedded sequence ends.

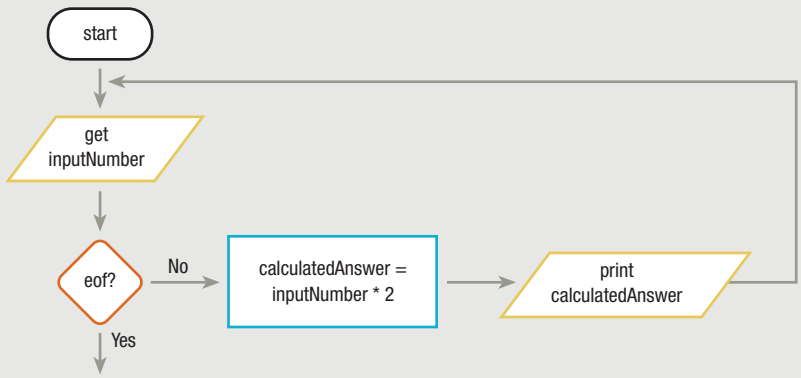
The flowchart in Figure 2-15 shows the flow of logic returning to the `eof` immediately after the sequence. Figure 2-15 shows a structured flowchart, but the flowchart has one major flaw—it doesn't do the job of continuously doubling different numbers.

FIGURE 2-15: STRUCTURED, BUT NONFUNCTIONAL, FLOWCHART OF NUMBER-DOUBLING PROBLEM



Follow the flowchart in Figure 2-15 through a typical program run. Suppose when the program starts, the user enters a 9 for the value of `inputNumber`. That's not `eof`, so the number doubles, and 18 prints out as the `calculatedAnswer`. Then the question `eof?` is asked again. It can't be `eof` because a new value representing the sentinel (ending) value can't be entered. The logic never returns to the `get inputNumber` task, so the value of `inputNumber` never changes. Therefore, 9 doubles again and the answer 18 prints again. It's still not `eof`, so the same steps are repeated. This goes on *forever*, with the answer 18 printing repeatedly. The program logic shown in Figure 2-15 is structured, but it doesn't work as intended; the program in Figure 2-16 works, but it isn't structured!

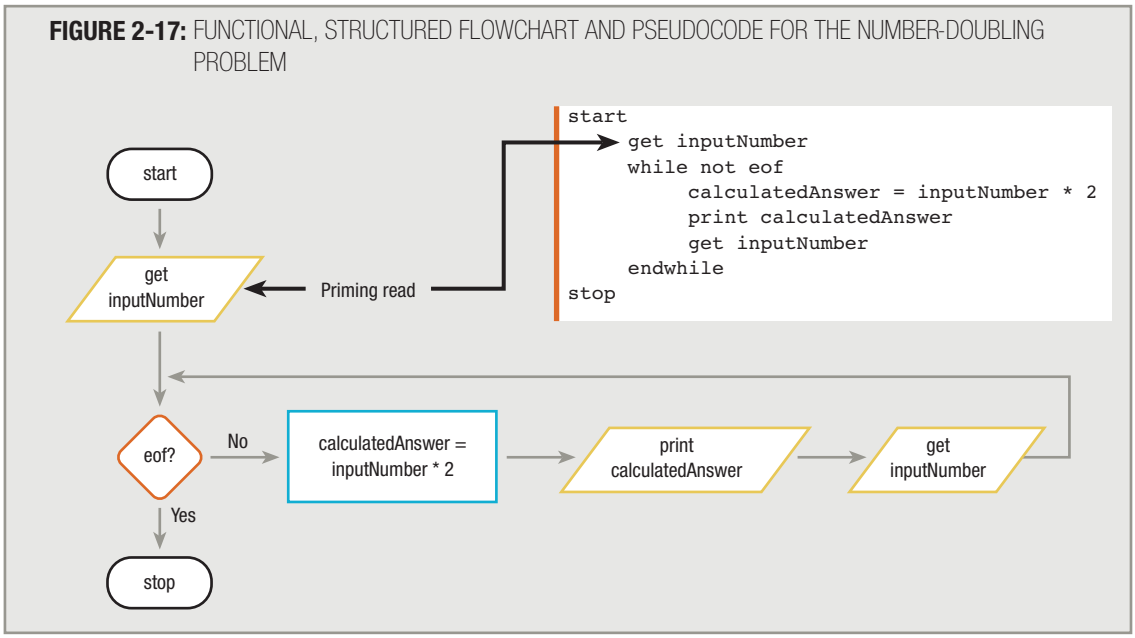
FIGURE 2-16: FUNCTIONAL BUT NONSTRUCTURED FLOWCHART



TIP The loop in Figure 2-16 is not structured because in a structured loop, after the tasks execute within the loop, the flow of logic must return directly to the loop-controlling question. In Figure 2-16, the logic does not return to the loop-controlling question; instead, it goes "too high" outside the loop to repeat the `get inputNumber` task.

How can the number-doubling problem be both structured and work as intended? Often, for a program to be structured, you must add something extra. In this case, it's an extra `get inputNumber` step. Consider the solution in Figure 2-17; it's structured *and* it does what it's supposed to do. The program logic illustrated in Figure 2-17 contains a sequence and a loop. The loop contains another sequence.

FIGURE 2-17: FUNCTIONAL, STRUCTURED FLOWCHART AND PSEUDOCODE FOR THE NUMBER-DOUBLING PROBLEM



The additional `get inputNumber` step is typical in structured programs. The first of the two input steps is the priming input, or priming read. The term *priming* comes from the fact that the read is first, or *primary* (what gets the process going, as in "priming the pump"). The purpose of the priming read step is to control the upcoming loop that begins with the `eof` question. The last element within the structured loop gets the next, and all subsequent, input values. This is also typical in structured loops—the last step executed within the loop alters the condition tested in the question that begins the loop, which in this case is the `eof` question.

As an additional way to determine whether a flowchart segment is structured, you can try to write pseudocode for it. Examine the unstructured flowchart in Figure 2-12 again. To write pseudocode for it, you would begin with the following:

```
start
     get inputNumber
```

When you encounter the `eof` question in the flowchart, you know that either a selection or loop structure should begin. Because you return to a location higher in the flowchart when the answer to the `eof` question is *no* (that is, while the `not eof` condition continues to be *true*), you know that a loop is beginning. So you continue to write the pseudocode as follows:

```
start
     get inputNumber
     while not eof
          calculatedAnswer = inputNumber * 2
          print calculatedAnswer
```

Continuing, the step after `print calculatedAnswer` is `get inputNumber`. This ends the `while` loop that began with the `eof` question. So the pseudocode becomes:

```
start
     get inputNumber
     while not eof
          calculatedAnswer = inputNumber * 2
          print calculatedAnswer
          get inputNumber
     endwhile
stop
```

This pseudocode is identical to the pseudocode in Figure 2-17 and now matches the flowchart in the same figure. It does not match the flowchart in Figure 2-12, because that flowchart contains only one `get inputNumber` step. Creating the pseudocode correctly using the `while` statement requires you to repeat the `get inputNumber` statement. The structured pseudocode makes use of a priming read and forces the logic to become structured—a sequence followed by a loop that contains a sequence of three statements.

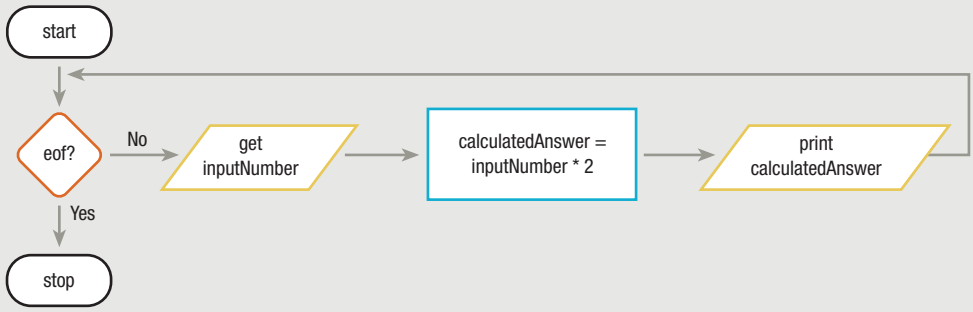
TIP

Years ago, programmers could avoid using structure by inserting a "go to" statement into their pseudocode. A "go to" statement would say something like "after print answer, go to the first get number box", and would be the equivalent of drawing an arrow starting after "print answer" and pointing directly to the first "get number" box in the flowchart. Because "go to" statements cause spaghetti code, they are not allowed in structured programming. Some programmers call structured programming "goto-less" programming.

Figure 2-18 shows another way you might attempt to draw the logic for the number-doubling program. At first glance, the figure might seem to show an acceptable solution to the problem—it is structured, containing a single loop with a sequence of three steps within it, and it appears to eliminate the need for the priming input statement. When the program starts, the `eof` question is asked. The answer is *no*, so the program gets an input number, doubles it, and prints it. Then, if it is still not `eof`, the program gets another number, doubles it, and prints it. The program continues until `eof` is encountered when getting input. The last time the `get inputNumber` statement executes, it encounters `eof`, but the program does not stop—instead, it calculates and

prints one last time. This last output is extraneous—the `eof` value should not be doubled and printed. As a general rule, an `eof` question should always come immediately after an input statement. Therefore, the best solution to the number-doubling problem remains the one shown in Figure 2-17—the solution containing the priming input statement.

FIGURE 2-18: STRUCTURED BUT INCORRECT SOLUTION TO THE NUMBER-DOUBLING PROBLEM



TIP

A few languages do not require the priming read. For example, programs written using the Visual Basic programming language can "look ahead" to determine whether the end of file will be reached on the next input record. However, most programming languages cannot predict the end of file until an actual read operation is performed, and they require a priming read to properly handle file data.

UNDERSTANDING THE REASONS FOR STRUCTURE

At this point, you may very well be saying, "I liked the original number-doubling program just fine. I could follow it. Also, the first program had one less step in it, so it was less work. Who cares if a program is structured?"

Until you have some programming experience, it is difficult to appreciate the reasons for using only the three structures—sequence, selection, and loop. However, staying with these three structures is better for the following reasons:

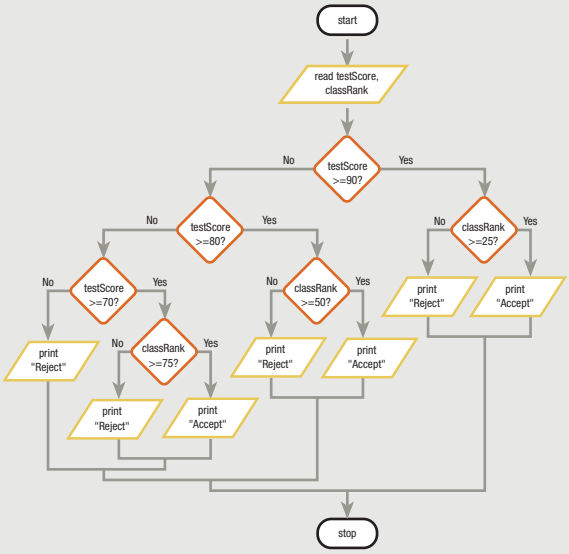
- *Clarity*—The number-doubling program is a small program. As programs get bigger, they get more confusing if they're not structured.
- *Professionalism*—All other programmers (and programming teachers you might encounter) expect your programs to be structured. It's the way things are done professionally.
- *Efficiency*—Most newer computer languages are structured languages with syntax that lets you deal efficiently with sequence, selection, and looping. Older languages, such as assembly languages, COBOL, and RPG, were developed before the principles of structured programming were discovered. However, even programs that use those older languages can be written in a structured form, and structured programming is expected on the job today. Newer languages such as C#, C++, and Java enforce structure by their syntax.

- *Maintenance*—You, as well as other programmers, will find it easier to modify and maintain structured programs as changes are required in the future.
- *Modularity*—Structured programs can be easily broken down into routines or modules that can be assigned to any number of programmers. The routines are then pieced back together like modular furniture at each routine's single entry or exit point. Additionally, often a module can be used in multiple programs, saving development time in the new project.

Most programs that you purchase are huge, consisting of thousands or millions of statements. If you've worked with a word-processing program or spreadsheet, think of the number of menu options and keystroke combinations available to the user. Such programs are not the work of one programmer. The modular nature of structured programs means that work can be divided among many programmers; then the modules can be connected, and a large program can be developed much more quickly. Money is often a motivating factor—the faster you write a program and make it available for use, the sooner it begins making money for the developer.

Consider the college admissions program from the beginning of this chapter. It has been rewritten in structured form in Figure 2-19 and is easier to follow now. Figure 2-19 also shows structured pseudocode for the same problem.

FIGURE 2-19: FLOWCHART AND PSEUDOCODE OF STRUCTURED COLLEGE ADMISSION PROGRAM




```
start
     read testScore, classRank
     if testScore >= 90 then
          if classRank >= 25 then
               print "Accept"
          else
               print "Reject"
          endif
     else
          if testScore >= 80 then
               if classRank >= 50 then
                    print "Accept"
               else
                    print "Reject"
               endif
          else
               if testScore >= 70 then
                    if classRank >= 75 then
                         print "Accept"
                    else
                         print "Reject"
                    endif
               else
                    print "Reject"
               endif
          endif
     endif
stop
```

```
start
    read testScore, classRank
    if testScore >= 90 then
            if classRank >= 25 then
                    print "Accept"
            else
                    print "Reject"
            endif
    else
            if testScore >= 80 then
                    if classRank >= 50 then
                            print "Accept"
                    else
                            print "Reject"
                    endif
            else
                    if testScore >= 70 then
                            if classRank >= 75 then
                                    print "Accept"
                            else
                                    print "Reject"
                            endif
                    else
                            print "Reject"
                    endif
            endif
    endif
stop
```

TIP Don't be alarmed if it is difficult for you to follow the many nested `if`s within the pseudocode in Figure 2-19. After you study the selection process in more detail, reading this type of pseudocode will become much easier for you.

In the lower portion of Figure 2-19, the pseudocode is repeated using colored backgrounds to help you identify the indentations that match, distinguishing the different levels of the nested structures.

TIP As you examine Figure 2-19, notice that the bottoms of the three `testScore` decision structures join at the bottom of the diagram. These three joinings correspond to the last three `endif` statements in the pseudocode.

RECOGNIZING STRUCTURE

Any set of instructions can be expressed in a structured format. If you can teach someone how to perform any ordinary activity, then you can express it in a structured way. For example, suppose you wanted to teach a child how to play Rock, Paper, Scissors. In this game, two players simultaneously show each other one hand, in one of three positions—clenched in a fist, representing a rock; opened flat, representing a piece of paper; or with two fingers extended in a V, representing scissors. The goal is to guess which hand position your opponent might show, so that you can show the one that beats it. The rules are that a flat hand beats a fist (because a piece of paper can cover a rock), a fist beats a hand with two extended fingers (because a rock can smash a pair of scissors), and a hand with two extended fingers beats a flat hand (because scissors can cut paper). Figure 2-20 shows the pseudocode for the game.

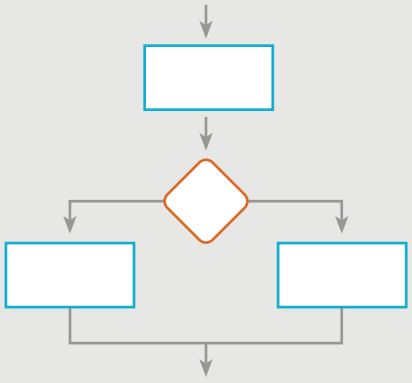
Figure 2-20 also shows a fairly complicated set of statements. Its purpose is not to teach you how to play a game (although you could learn how to play by following the logic), but rather to convince you that any task to which you can apply rules can be expressed logically using only combinations of sequence, selection, and looping. In this example, a game continues while a friend agrees to play, and within that loop, several decisions must be made in order to determine the winner.

FIGURE 2-20: PSEUDOCODE FOR THE ROCK, PAPER, SCISSORS GAME

```
start
    ask friend to play a game of Rock, Paper, Scissors
    while answer is yes
        extend yourHand and myHand
        if yourHand = "Paper" then
            if myHand = "Rock" then
                winner = yourHand
            else
                if myHand = "Scissors" then
                    winner = myHand
                else
                    winner = tie
                endif
            endif
        else
            if yourHand = "Scissors" then
                if myHand = "Rock" then
                    winner = myHand
                else
                    if myHand = "Paper" then
                        winner = yourHand
                    else
                        winner = tie
                    endif
                endif
            else
                if myHand = "Rock" then
                    winner = tie
                else
                    if myHand = "Paper" then
                        winner = myHand
                    else
                        winner = yourHand
                    endif
                endif
            endif
        endif
        ask friend to play a game of Rock, Paper, Scissors
    endwhile
stop
```

When you are just learning about structured program design, it is difficult to detect whether a flowchart of a program's logic is structured. For example, is the flowchart segment in Figure 2-21 structured?

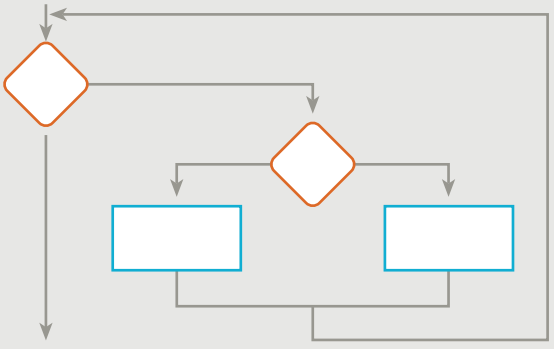
FIGURE 2-21: EXAMPLE 1



Yes, it is. It has a sequence and a selection structure.

Is the flowchart segment in Figure 2-22 structured?

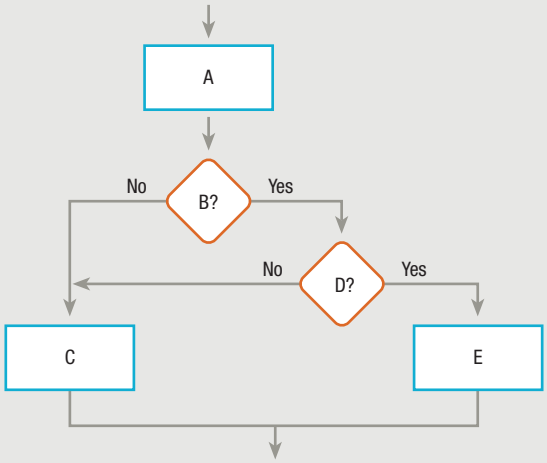
FIGURE 2-22: EXAMPLE 2



Yes, it is. It has a loop, and within the loop is a selection.

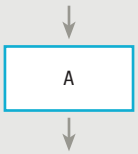
Is the flowchart segment in Figure 2-23 structured? (The symbols are lettered so you can better follow the discussion.)

FIGURE 2-23: EXAMPLE 3



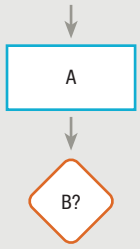
No, it isn't; it is not constructed from the three basic structures. One way to straighten out a flowchart segment that isn't structured is to use what you can call the "spaghetti bowl" method; that is, picture the flowchart as a bowl of spaghetti that you must untangle. Imagine you can grab one piece of pasta at the top of the bowl, and start pulling. As you "pull" each symbol out of the tangled mess, you can untangle the separate paths until the entire segment is structured. For example, with the diagram in Figure 2-23, if you start pulling at the top, you encounter a procedure box, labeled A. (See Figure 2-24.)

FIGURE 2-24: UNTANGLING EXAMPLE 3, FIRST STEP



A single process like A is part of an acceptable structure—it constitutes at least the beginning of a sequence structure. Imagine you continue pulling symbols from the tangled segment. The next item in the flowchart is a question that tests a condition labeled B, as you can see in Figure 2-25.

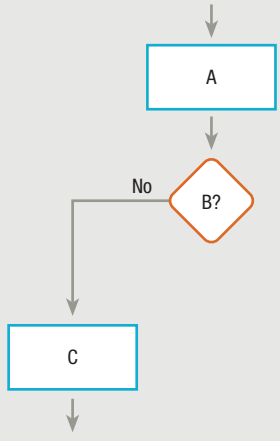
FIGURE 2-25: UNTANGLING EXAMPLE 3, SECOND STEP



At this point, you know the sequence that started with A has ended. Sequences never have decisions in them, so the sequence is finished; either a selection or a loop is beginning. A loop must return to the question at some later point. You can see from the original logic in Figure 2-23 that whether the answer to B is yes or no, the logic never returns to B. Therefore, B begins a selection structure, not a loop structure.

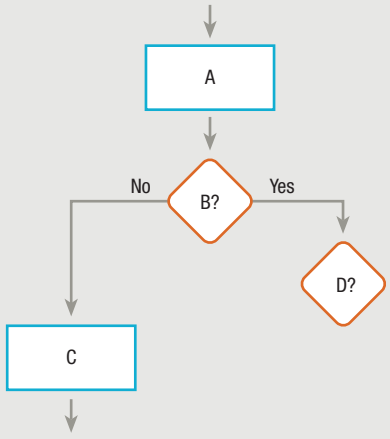
To continue detangling the logic, you (imaginarily) pull up on the flowline that emerges from the left side (the "No" side) of Question B. You encounter C, as shown in Figure 2-26. When you continue beyond C, you reach the end of the flowchart.

FIGURE 2-26: UNTANGLING EXAMPLE 3, THIRD STEP



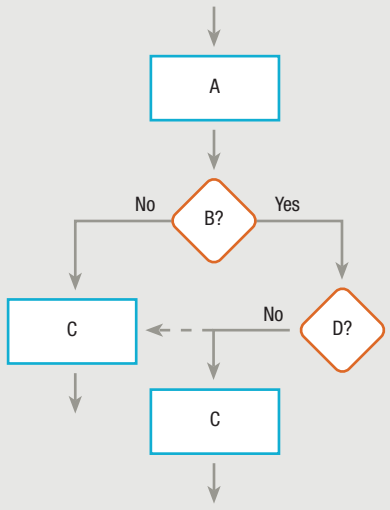
Now you can turn your attention to the "Yes" side (the right side) of the condition tested in B. When you pull up on the right side, you encounter Question D. (See Figure 2-27.)

FIGURE 2-27: UNTANGLING EXAMPLE 3, FOURTH STEP



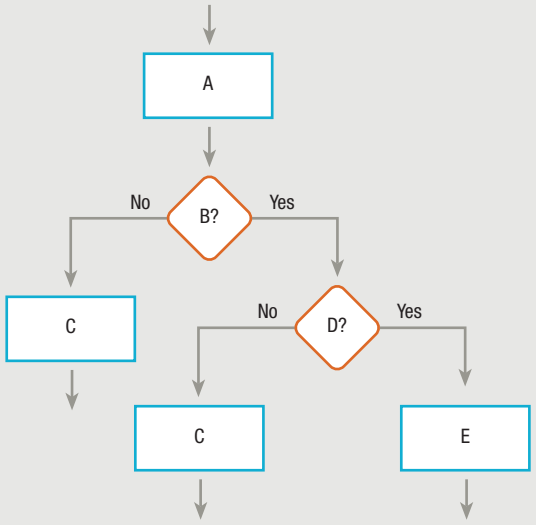
In Figure 2-23, follow the line on the left side of Question D. The line extending from the selection is attached to a task outside the selection. The line emerging from the left side of selection D is attached to Step C. You might say the D selection is becoming entangled with the B selection, so you must untangle the structures by repeating the step that is causing the tangle. (In this example, you repeat Step C to untangle it from the other usage of C.) Continue pulling on the flowline that emerges from Step C until you reach the end of the program segment, as shown in Figure 2-28.

FIGURE 2-28: UNTANGLING EXAMPLE 3, FIFTH STEP



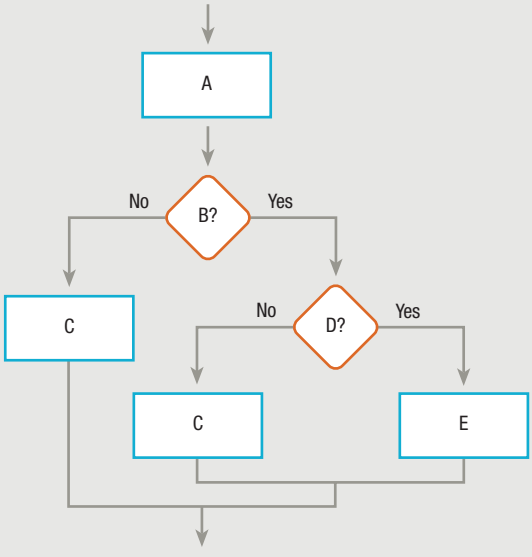
Now pull on the right side of Question D. Process E pops up, as shown in Figure 2-29; then you reach the end.

FIGURE 2-29: UNTANGLING EXAMPLE 3, SIXTH STEP



At this point, the untangled flowchart has three loose ends. The loose ends of Question D can be brought together to form a selection structure; then the loose ends of Question B can be brought together to form another selection structure. The result is the flowchart shown in Figure 2-30. The entire flowchart segment is structured—it has a sequence (A) followed by a selection inside a selection.

FIGURE 2-30: FINISHED FLOWCHART AND PSEUDOCODE FOR UNTANGLING EXAMPLE 3




```
do A
if B is true then
     if D is true then
          do E
     else
          do C
     endif
else
     do C
endif
```

TIP If you want to try structuring a very difficult example of an unstructured program, see Appendix A.

THREE SPECIAL STRUCTURES—CASE, DO WHILE, AND DO UNTIL

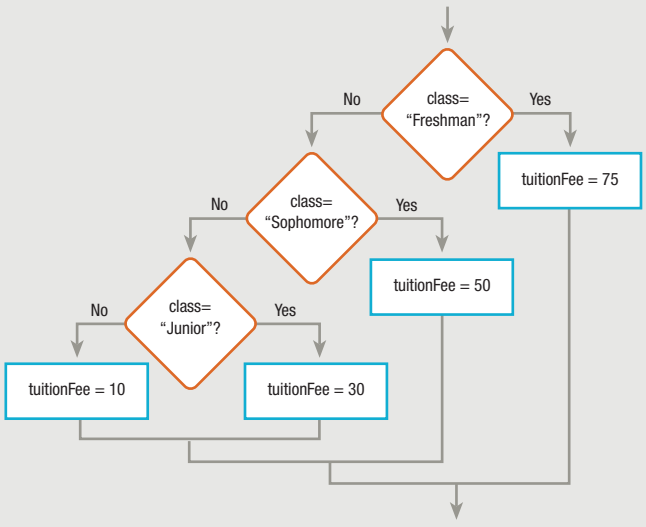
TIP You can skip this section for now without any loss in continuity. Your instructor may prefer to discuss the case structure with the Decision chapter (Chapter 5), and the do-while and do-until loops with the Looping chapter (Chapter 6).

You can solve any logic problem you might encounter using only the three structures: sequence, selection, and loop. However, many programming languages allow three more structures: the case structure and the do-while and do-until loops. These structures are never *needed* to solve any problem—you can always use a series of selections instead of the case structure, and you can always use a sequence plus a while loop in place of the do-while or do-until loops. However, sometimes these additional structures are convenient. Programmers consider them all to be acceptable, legal structures.

THE CASE STRUCTURE

You can use the **case structure** when there are several distinct possible values for a single variable you are testing, and each value requires a different course of action. Suppose you administer a school at which tuition is $75, $50, $30, or $10 per credit hour, depending on whether a student is a freshman, sophomore, junior, or senior. The structured flowchart and pseudocode in Figure 2-31 show a series of decisions that assigns the correct tuition to a student.

FIGURE 2-31: FLOWCHART AND PSEUDOCODE OF TUITION DECISIONS




```
if class = "Freshman" then
     tuitionFee = 75
else
     if class = "Sophomore" then
          tuitionFee = 50
     else
          if class = "Junior" then
               tuitionFee = 30
          else
               tuitionFee = 10
          endif
     endif
endif
```

TIP

The indentation in the pseudocode in Figure 2-31 reflects the nested nature of the decisions, as illustrated in the flowchart. For clarity, some programmers might prefer to write the pseudocode as follows:

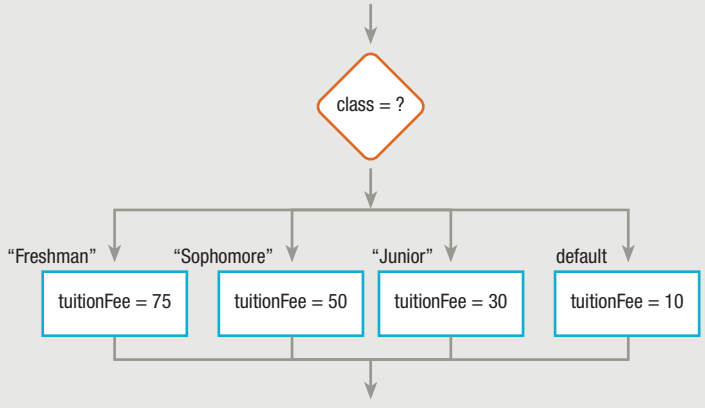
```
if class = "Freshman" then
   tuitionFee = 75
else if class = "Sophomore" then
   tuitionFee = 50
else if class = "Junior" then
   tuitionFee = 30
endif
```

This style, with `else` and the next `if` on the same line and a single `endif` at the end, is often preferred by Visual Basic programmers because it resembles a style they use in their programs. However, this book will use the style shown in Figure 2-31, with each `endif` aligned with its corresponding `if` statement.

The logic shown in Figure 2-31 is absolutely correct and completely structured. The `class="Junior"` selection structure is contained within the `class="Sophomore"` structure, which is contained within the `class="Freshman"` structure. Note that there is no need to ask if a student is a senior, because if a student is not a freshman, sophomore, or junior, it is assumed the student is a senior.

Even though the program segments in Figure 2-31 are correct and structured, many programming languages permit using a case structure, as shown in Figure 2-32. When using the case structure, you test a variable against a series of values, taking appropriate action based on the variable's value. To many, such programs seem easier to read, and the case structure is allowed because the same results *could* be achieved with a series of structured selections (thus making the program structured). That is, if the first program is structured and the second one reflects the first one point by point, then the second one must be structured also.

FIGURE 2-32: FLOWCHART AND PSEUDOCODE OF CASE STRUCTURE




```
case based on class
     case "Freshman"
          tuitionFee = 75
     case "Sophomore"
          tuitionFee = 50
     case "Junior"
          tuitionFee = 30
     default
          tuitionFee = 10
endcase
```

TIP The term "default" used in Figure 2-32 means "if none of the other cases were true." Each programming language you learn may use a different syntax for the default case.

Even though a programming language permits you to use the case structure, you should understand that the case structure is just a convenience that might make a flowchart, pseudocode, or actual program code easier to understand at first glance. When you write a series of decisions using the case structure, the computer still makes a series of individual decisions, just as though you had used many if-then-else combinations. In other words, you might prefer looking at the diagram in Figure 2-32 to understand the tuition fees charged by a school, but a computer actually makes the decisions as shown in Figure 2-31—one at a time. When you write your own programs, it is always acceptable to express a complicated decision-making process as a series of individual selections.

TIP You usually use the case structure only when a series of decisions is based on different values stored in a single variable. If multiple variables are tested, then most programmers use a series of decisions.

THE DO-WHILE AND DO-UNTIL LOOPS

Recall that a structured loop (often called a while loop) looks like Figure 2-33. A special-case loop called a do-while or do-until loop looks like Figure 2-34.

FIGURE 2-33: WHILE LOOP

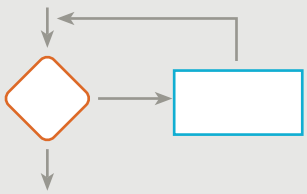
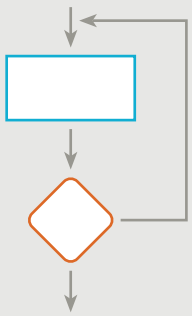


FIGURE 2-34: STRUCTURE OF A DO-WHILE OR DO-UNTIL (POSTTEST) LOOP



An important difference exists between these two structures. In a while loop, you ask a question and, depending on the answer, you might or might not enter the loop to execute the loop's procedure. Conversely, in **do-while** and **do-until loops**, you ensure that the procedure executes at least once; then, depending on the answer to the controlling question, the loop may or may not execute additional times. In a do-while loop, the loop body continues to execute as long as the answer to the controlling question is yes, or true. In a do-until loop, the loop body continues to execute as long as the answer to the controlling question is no, or false; that is, the body executes *until* the controlling question is yes or true.

TIP Notice that the word "do" begins the names of both the do-while and do-until loops. This should remind you that the action you "do" precedes testing the condition.

In a while loop, the question that controls a loop comes at the beginning, or "top," of the loop body. A while loop is also called a **pretest loop** because a condition is tested before entering the loop even once. In a do-while or do-until loop, the question that controls the loop comes at the end, or "bottom," of the loop body. Do-while and do-until loops are also called **posttest loops** because a condition is tested after the loop body has executed.

You encounter examples of do-until looping every day. For example:

```
do
     pay bills
until all bills are paid
```

and

```
do
     wash dishes
until all dishes are washed
```

Similarly, you encounter examples of do-while looping every day. For example:

```
do
     pay bills
while more bills remain to be paid
```

and

```
do
     wash dishes
while more dishes remain to be washed
```

In these examples, the activity (paying bills or washing dishes) must occur at least one time. You ask the question that determines whether you continue only after the activity has been executed at least once. The only difference in these structures is whether the answer to the bottom loop-controlling question must be false for the loop to continue (as in all bills are paid), which is a do-until loop, or true for the loop to continue (as in more bills remain to be paid), which is a do-while loop.

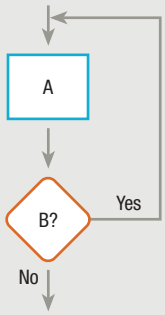
You are never required to use a posttest loop. You can duplicate the same series of actions generated by any posttest loop by creating a sequence followed by a standard, pretest while loop. For example, the following code performs the bill-paying task once, then asks the loop-controlling question at the top of a while loop, in which the action might be performed again:

```
pay bills
while there are more bills to pay
     pay bills
endwhile
```

Consider the flowcharts and pseudocode in Figures 2-35 and 2-36.

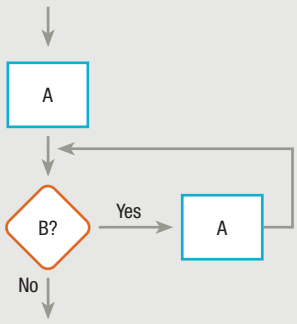
In Figure 2-35, A is done, and then B is asked. If B is yes, then A is done and B is asked again. In Figure 2-36, A is done, and then B is asked. If B is yes, then A is done and B is asked again. In other words, both flowcharts and pseudocode segments do exactly the same thing.

FIGURE 2-35: FLOWCHART AND PSEUDOCODE FOR DO-WHILE LOOP




```
do
     A
while B is true
```

FIGURE 2-36: FLOWCHART AND PSEUDOCODE FOR SEQUENCE FOLLOWED BY WHILE LOOP




```
do A
while B is true
     do A
endwhile
```

Because programmers understand that any posttest loop (do-while or do-until) can be expressed with a sequence followed by a while loop, most languages allow the posttest loop. (Frequently, languages allow one type of posttest loop or the other.) Again, you are never required to use a posttest loop; you can always accomplish the same tasks with a sequence followed by a pretest while loop.

Figure 2-37 shows an unstructured loop. It is neither a while loop (which begins with a decision and, after an action, returns to the decision) nor a do-while or do-until loop (which begins with an action and ends with a decision that might repeat the action). Instead, it begins like a posttest loop (a do-while or a do-until loop), with a process followed by a decision, but one branch of the decision does not repeat the initial process; instead, it performs an additional new action before repeating the initial process. If you need to use the logic shown in Figure 2-37—performing a task, asking a question, and perhaps performing an additional task before looping back to the first process—then the way to make the logic structured is to repeat the initial process within the loop, at the end of the loop. Figure 2-38 shows the same logic as Figure 2-37, but now it is structured logic, with a sequence of two actions occurring within the loop.

Does this diagram look familiar to you? It uses the same technique of repeating a needed step that you saw earlier in this chapter, when you learned the rationale for the priming read.

FIGURE 2-37: UNSTRUCTURED LOOP

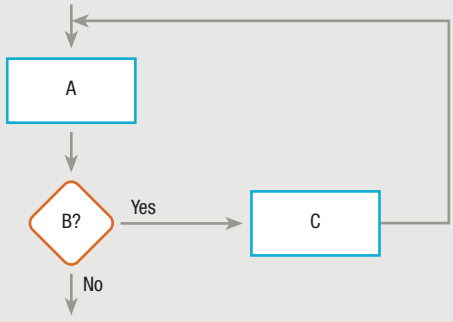
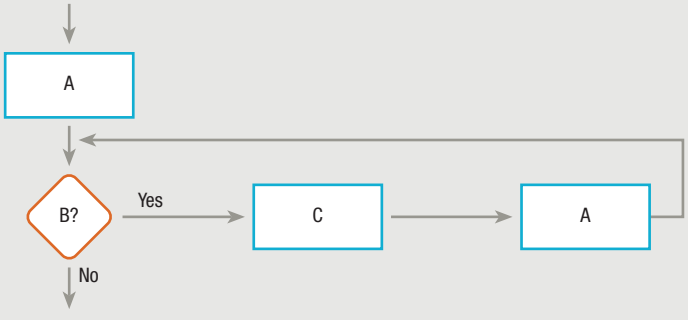


FIGURE 2-38: SEQUENCE AND STRUCTURED LOOP THAT ACCOMPLISH THE SAME TASKS AS FIGURE 2-37



It is difficult for beginning programmers to distinguish among while, do-while, and do-until loops. A while loop asks the question first—for example, while you are hungry, eat. The answer to the question might never be true and the loop body might never execute. A while loop is the only type of loop you ever need in order to solve a problem. You can think of a do-while loop as one that continues to execute while a condition remains true—for example, process records while not end of file is true, or eat food while hungry is true. On the other hand, a do-until loop continues while a condition is false, or, in other words, until the condition becomes true—for example, address envelopes until there are no more envelopes, or eat food until you are full. When you use a do-while or a do-until loop, at least one performance of the action always occurs.

TIP

Especially when you are first mastering structured logic, you might prefer to only use the three basic structures—sequence, selection, and while loop. Every logical problem can be solved using only these three structures, and you can understand all of the examples in the rest of this book using only these three.

CHAPTER SUMMARY

- The popular name for snarled program statements is spaghetti code.
- Clearer programs can be constructed using only three basic structures: sequence, selection, and loop. These three structures can be combined in an infinite number of ways by stacking and nesting them. Each structure has one entry and one exit point; one structure can attach to another only at one of these points.
- A priming read or priming input is the statement that reads the first input data record prior to starting a structured loop. The last step within the loop gets the next, and all subsequent, input values.
- You use structured techniques to promote clarity, professionalism, efficiency, and modularity.
- One way to straighten a flowchart segment that isn't structured is to imagine the flowchart as a bowl of spaghetti that you must untangle.
- You can use a case structure when there are several distinct possible values for a variable you are testing. When you write a series of decisions using the case structure, the computer still makes a series of individual decisions.
- In a pretest while loop, you ask a question and, depending on the answer, you might never enter the loop to execute the loop's body. In a posttest do-while loop (which executes as long as the answer to the controlling question is true) or a posttest do-until loop (which executes as long as the answer to the controlling question is false), you ensure that the loop body executes at least once. You can duplicate the same series of actions generated by any posttest loop by creating a sequence followed by a while loop.

KEY TERMS

Spaghetti code is snarled, unstructured program logic.

A **structure** is a basic unit of programming logic; each structure is a sequence, selection, or loop.

With a **sequence structure**, you perform an action or task, and then you perform the next action, in order. A sequence can contain any number of tasks, but there is no chance to branch off and skip any of the tasks.

With a **selection**, or **decision**, **structure**, you ask a question, and, depending on the answer, you take one of two courses of action. Then, no matter which path you follow, you continue with the next task.

An **if-then-else** is another name for a selection structure.

Dual-alternative ifs define one action to be taken when the tested condition is true, and another action to be taken when it is false.

Single-alternative ifs take action on just one branch of the decision.

The **null case** is the branch of a decision in which no action is taken.

With a **loop structure**, you continue to repeat actions based on the answer to a question.

Repetition and **iteration** are alternate names for a loop structure.

A **while...do**, or more simply, a **while** loop, is a loop in which a process continues while some condition continues to be true.

Attaching structures end-to-end is called **stacking** structures.

Placing a structure within another structure is called **nesting** the structures.

A **block** is a group of statements that execute as a single unit.

A **priming read** or **priming input** is the statement that reads the first input data record prior to starting a structured loop.

You can use the **case structure** when there are several distinct possible values for a single variable you are testing, and each requires a different course of action.

In **do-while** and **do-until loops**, you ensure that a procedure executes at least once; then, depending on the answer to the controlling question, the loop may or may not execute additional times.

A while loop is also called a **pretest loop** because a condition is tested before entering the loop even once.

Do-while and do-until loops are also called **posttest loops** because a condition is tested after the loop body has executed.

REVIEW QUESTIONS

1. **Snarled program logic is called _____ code.**
   a. snake
   b. spaghetti
   c. string
   d. gnarly

2. **A sequence structure can contain _____.**
   a. only one task
   b. exactly three tasks
   c. no more than three tasks
   d. any number of tasks

3. **Which of the following is not another term for a selection structure?**
   a. decision structure
   b. if-then-else structure
   c. loop structure
   d. dual-alternative if structure

4. **The structure in which you ask a question, and, depending on the answer, take some action and then ask the question again, can be called all of the following except _____.**
   a. if-then-else
   b. loop
   c. repetition
   d. iteration

5. **Placing a structure within another structure is called _____ the structures.**

   a. stacking
   b. nesting
   c. building
   d. untangling

6. **Attaching structures end-to-end is called _____.**

   a. stacking
   b. nesting
   c. building
   d. untangling

7. **The statement `if age >= 65 then seniorDiscount = "yes"` is an example of a _____.**

   a. single-alternative if
   b. loop
   c. dual-alternative if
   d. sequence

8. **The statement `while temperature remains below 60, leave the furnace on` is an example of a _____.**

   a. single-alternative if
   b. loop
   c. dual-alternative if
   d. sequence

9. **The statement `if age < 13 then movieTicket = 4.00 else movieTicket = 8.50` is an example of a _____.**

   a. single-alternative if
   b. loop
   c. dual-alternative if
   d. sequence

10. **Which of the following attributes do all three basic structures share?**

    a. Their flowcharts all contain exactly three processing symbols.
    b. They all contain a decision.
    c. They all begin with a process.
    d. They all have one entry and one exit point.

11. **When you read input data in a loop within a program, the input statement that precedes the loop _____.**

    a. is called a priming input
    b. cannot result in `eof`
    c. is the only part of a program allowed to be unstructured
    d. executes hundreds or even thousands of times in most business programs

12. A group of statements that execute as a unit is a _____.

a. cohort
b. family
c. chunk
d. block

13. Which of the following is acceptable in a structured program?

a. placing a sequence within the true half of a dual-alternative decision
b. placing a decision within a loop
c. placing a loop within one of the steps in a sequence
d. All of these are acceptable.

14. Which of the following is not a reason for enforcing structure rules in computer programs?

a. Structured programs are clearer to understand than unstructured ones.
b. Other professional programmers will expect programs to be structured.
c. Structured programs can be broken down into modules easily.
d. Structured programs usually are shorter than unstructured ones.

15. Which of the following is not a benefit of modularizing programs?

a. Modular programs are easier to read and understand than nonmodular ones.
b. Modular components are reusable in other programs.
c. If you use modules, you can ignore the rules of structure.
d. Multiple programmers can work on different modules at the same time.

16. Which of the following is true of structured logic?

a. Any task can be described using some combination of the three structures.
b. You can use structured logic with newer programming languages, such as Java and C#, but not with older ones.
c. Structured programs require that you break the code into easy-to-handle modules that each contain no more than five actions.
d. All of these are true.

17. The structure that you can use when you must make a decision with several possible outcomes, depending on the value of a single variable, is the _____.

a. multiple-alternative if structure
b. case structure
c. do-while structure
d. do-until structure

18. Which type of loop ensures that an action will take place at least one time?

a. a do-until loop
b. a while loop
c. a do-over loop
d. any structured loop

19. A do-until loop can always be converted to _____.

a. a while followed by a sequence
b. a sequence followed by a while
c. a case structure
d. a selection followed by a while

20. Which of the following structures is never required by any program?

a. a while
b. a do-until
c. a selection
d. a sequence

FIND THE BUGS

As you learned in Chapter 1, program errors have been called "bugs" since the early days of computer programming. The term is often said to have originated from an actual moth that was discovered trapped in the circuitry of a computer at Harvard University in 1945. Actually, the term "bug" was in use prior to 1945 to mean trouble with any electrical apparatus; even during Thomas Edison's life, it meant an "industrial defect." However, the process of finding and correcting program errors has come to be known as debugging.

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. This pseudocode segment is intended to describe determining whether you have passed or failed a course based on the average score of two classroom tests.

```
input midtermGrade
input finalGrade
average = (midGrade + finalGrade) / 2
print avg
if average >= 60 then
   print "Pass"
endif
else
   print "Fail"
```

2. This pseudocode segment is intended to describe computing the number of miles per gallon you get with your automobile. The program segment should continue as long as the user enters a positive value for miles traveled.

```
input gallonsOfGasUsed
input milesTraveled
while milesTraveled > 0
       milesPerGallon = gallonsOfGasUsed / milesTraveled
        print milesPerGal
endwhile
```

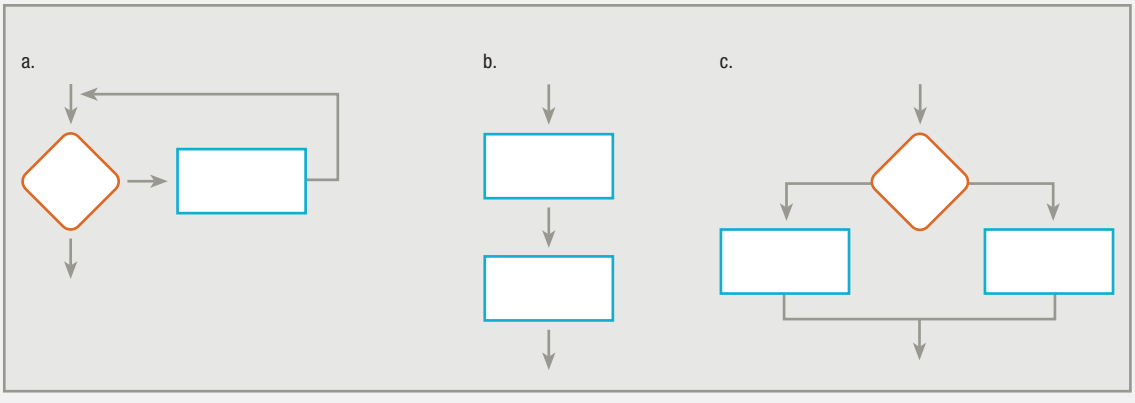
3. This pseudocode segment is intended to describe computing the cost per day for a vacation. The user enters a value for total dollars available to spend and can continue to enter new dollar amounts while the amount entered is not 0. For each new amount entered, if the amount of money available to spend per day is below $100, a message displays.

```
input totalDollarsAvailable
while totalDollarsAvailable not = 0
   dollarsPerDay = totalMoneyAvailable / 7
   print dollarsPerDay
endwhile
input totalDollarsAvailable
if dollarsPerDay > 100 then
   print "You better search for a bargain vacation"
endwhile
```

EXERCISES

1. Match the term with the structure diagram. (Because the structures go by more than one name, there are more terms than diagrams.)

1. sequence
2. selection
3. loop
4. do-while
5. decision
6. if-then-else
7. iteration



2. Match the term with the pseudocode segment. (Because the structures go by more than one name, there are more terms than pseudocode segments.)

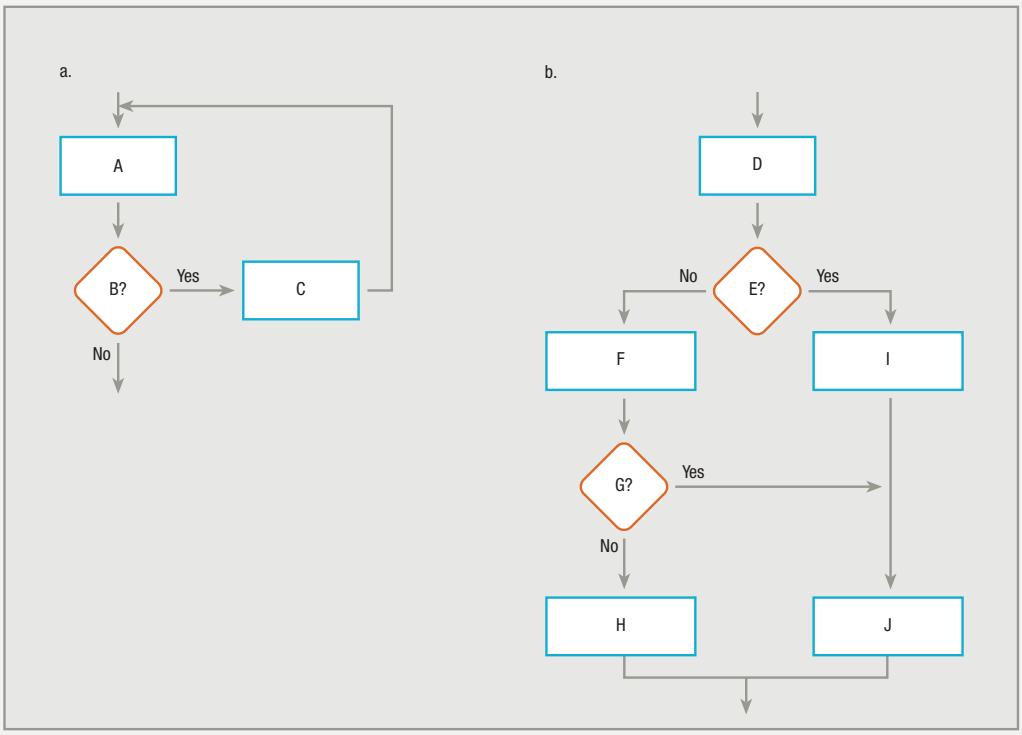
1. sequence
2. selection
3. loop
4. decision
5. if-then-else
6. iteration

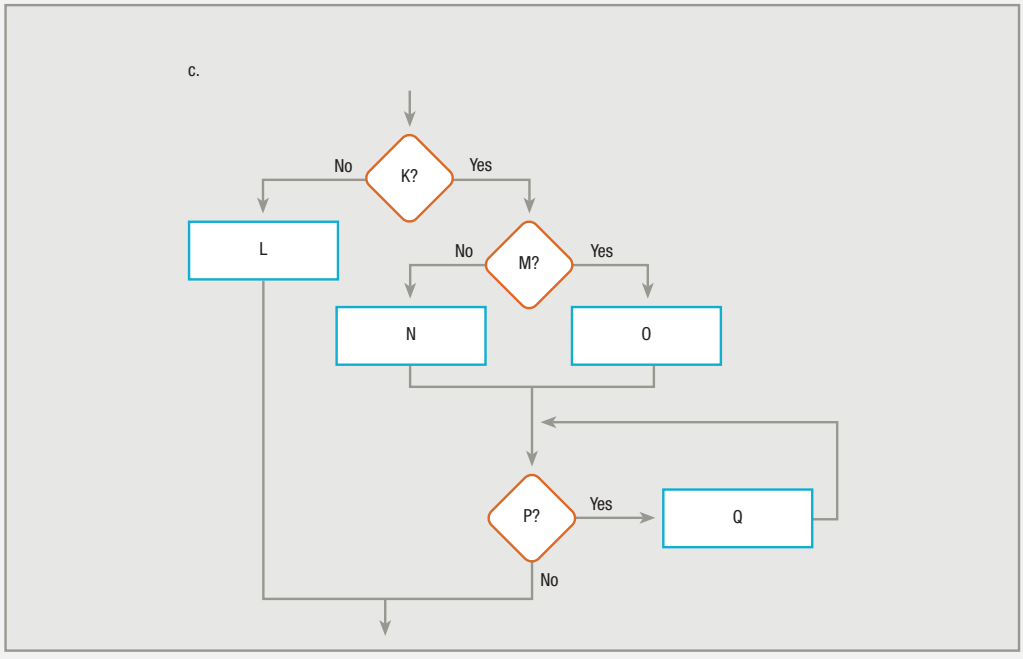
a.
```
while not eof
      print theAnswer
endwhile
```

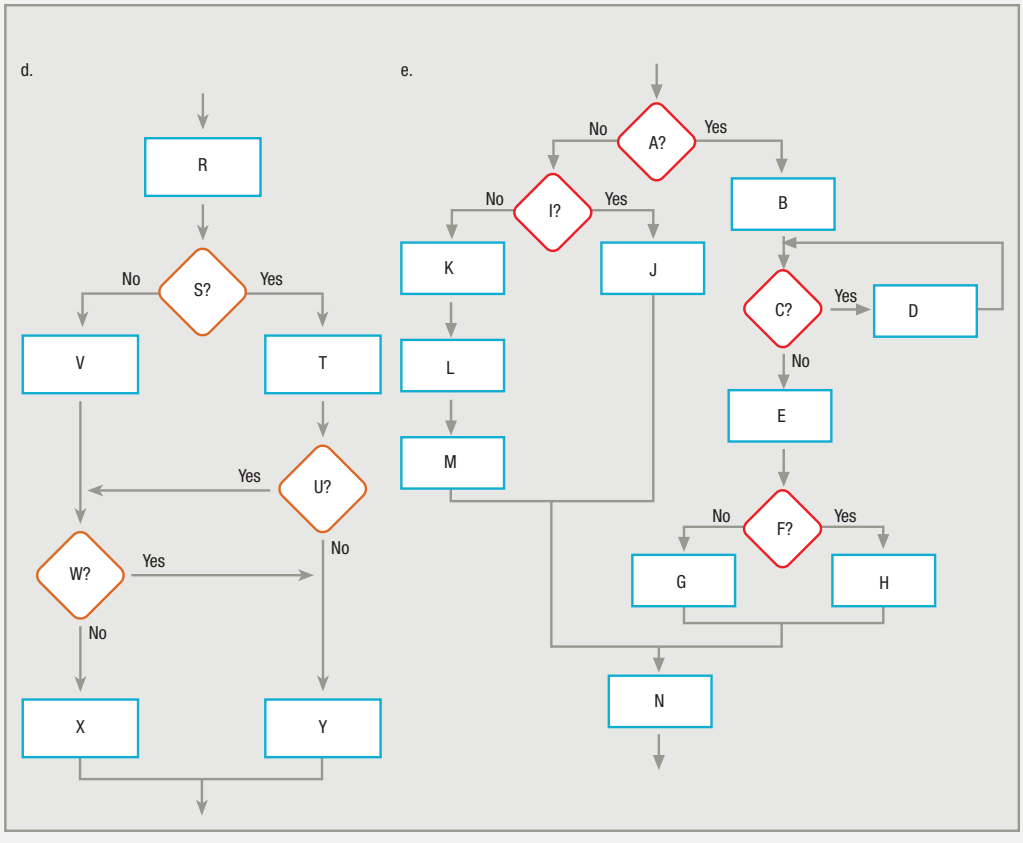
b.
```
if inventoryQuantity  >  0 then
      do fillOrderProcess
else
      do backOrderNotification
endif
```

c.
```
do localTaxCalculation
do stateTaxCalculation
do federalTaxCalculation
```

3. Is each of the following segments structured, or unstructured? If unstructured, redraw it so that it does the same thing but is structured.




c.
K?
No
Yes
L
M?
No
Yes
N
O
P?
Yes
Q
No


d.
R
S?
No
Yes
V
T
U?
Yes
No
W?
Yes
No
X
Y
e.
A?
No
Yes
I?
No
Yes
K
J
B
L
C?
Yes
D
No
M
E
F?
No
Yes
G
H
N

4. **Write pseudocode for each example (a through e) in Exercise 3.**

5. **Assume you have created a mechanical arm that can hold a pen. The arm can perform the following tasks:**

   - ☐ Lower the pen to a piece of paper.
   - ☐ Raise the pen from the paper.
   - ☐ Move the pen one inch along a straight line. (If the pen is lowered, this action draws a one-inch line from left to right; if the pen is raised, this action just repositions the pen one inch to the right.)
   - ☐ Turn 90 degrees to the right.
   - ☐ Draw a circle that is one inch in diameter.

   Draw a structured flowchart or write pseudocode describing the logic that would cause the arm to draw the following:

   a. a one-inch square
   b. a two-inch by one-inch rectangle
   c. a string of three beads

   Have a fellow student act as the mechanical arm and carry out your instructions.

6. **Assume you have created a mechanical robot that can perform the following tasks:**

   - ☐ Stand up.
   - ☐ Sit down.
   - ☐ Turn left 90 degrees.
   - ☐ Turn right 90 degrees.
   - ☐ Take a step.

   Additionally, the robot can determine the answer to one test condition:

   - ☐ Am I touching something?

   Place two chairs 20 feet apart, directly facing each other. Draw a structured flowchart or write pseudocode describing the logic that would allow the robot to start from a sitting position in one chair, cross the room, and end up sitting in the other chair.

   Have a fellow student act as the robot and carry out your instructions.

7. **Draw a structured flowchart or write structured pseudocode describing your preparation to go to work or school in the morning. Include at least two decisions and two loops.**

8. **Draw a structured flowchart or write structured pseudocode describing your preparation to go to bed at night. Include at least two decisions and two loops.**

9. **Choose a very simple children's game and describe its logic, using a structured flowchart or pseudocode. For example, you might try to explain Musical Chairs; Duck, Duck, Goose; the card game War; or the elimination game Eenie, Meenie, Minie, Moe.**

10. **Draw a structured flowchart or write structured pseudocode describing how your paycheck is calculated. Include at least two decisions.**

11. **Draw a structured flowchart or write structured pseudocode describing the steps a retail store employee should follow to process a customer purchase. Include at least two decisions.**

DETECTIVE WORK

1. **In this chapter, you learned what spaghetti code is. What is "ravioli code"?**

2. **Who was Edsger Dijkstra? What programming statement did he want to eliminate?**

3. **Who were Bohm and Jacopini? What contribution did they make to programming?**

UP FOR DISCUSSION

1. **Just because every logical program can be solved using only three structures (sequence, selection, and loop) does not mean there cannot be other useful structures. For example, the case, do-while, and do-until structures are never required, but they exist in many programming languages and can be quite useful. Try to design a new structure of your own and explain situations in which it would be useful.**



3 MODULES, HIERARCHY CHARTS, AND DOCUMENTATION

After studying Chapter 3, you should be able to:

- Describe the advantages of modularization
- Modularize a program
- Understand how a module can call another module
- Explain how to declare variables
- Create hierarchy charts
- Understand documentation
- Design output
- Interpret file descriptions
- Understand the attributes of complete documentation

MODULES, SUBROUTINES, PROCEDURES, FUNCTIONS, OR METHODS

Programmers seldom write programs as one long series of steps. Instead, they break down the programming problem into reasonable units, and tackle one small task at a time. These reasonable units are called **modules**. Programmers also refer to them as **subroutines**, **procedures**, **functions**, or **methods**.

TIP

The name that programmers use for their modules usually reflects the programming language they use. For example, Visual Basic programmers use "procedure" (or "subprocedure"). C and C++ programmers call their modules "functions," whereas C#, Java, and other object-oriented language programmers are more likely to use "method." Programmers in COBOL, RPG, and BASIC (all older languages) are most likely to use "subroutine."

The process of breaking down a large program into modules is called **modularization**. You are never required to break down a large program into modules, but there are at least four reasons for doing so:

- Modularization provides abstraction.
- Modularization allows multiple programmers to work on a problem.
- Modularization allows you to reuse your work.
- Modularization makes it easier to identify structures.

MODULARIZATION PROVIDES ABSTRACTION

One reason modularized programs are easier to understand is that they enable a programmer to see the big picture. **Abstraction** is the process of paying attention to important properties while ignoring nonessential details. Abstraction is selective ignorance. Life would be tedious without abstraction. For example, you can create a list of things to accomplish today:

```
Do laundry
Call Aunt Nan
Start term paper
```

Without abstraction, the list of chores would begin:

```
Pick up laundry basket
Put laundry basket in car
Drive to laundromat
Get out of car with basket
Walk into laundromat
Set basket down
Find quarters for washing machine
. . . and so on.
```

You might list a dozen more steps before you finish the laundry and move on to the second chore on your original list. If you had to consider every small, **low-level** detail of every task in your day, you would probably never make it out of bed in the morning. Using a higher-level, more abstract list makes your day manageable. Abstraction makes complex tasks look simple.

TIP Abstract artists create paintings in which they see only the "big picture"—color and form—and ignore the details. Abstraction has a similar meaning among programmers.

Likewise, some level of abstraction occurs in every computer program. Fifty years ago, a programmer had to understand the low-level circuitry instructions the computer used. But now, newer **high-level** programming languages allow you to use English-like vocabulary in which one broad statement corresponds to dozens of machine instructions. No matter which high-level programming language you use, if you display a message on the monitor, you are never required to understand how a monitor works to create each pixel on the screen. You write an instruction like `print message` and the details of the hardware operations are handled for you.

Modules or subroutines provide another way to achieve abstraction. For example, a payroll program can call a module named `computeFederalWithholdingTax.` You can write the mathematical details of the function later, someone else can write them, or you can purchase them from an outside source. When you plan your main payroll program, your only concern is that a federal withholding tax will have to be calculated; you save the details for later.

MODULARIZATION ALLOWS MULTIPLE PROGRAMMERS TO WORK ON A PROBLEM

When you dissect any large task into modules, you gain the ability to divide the task among various people. Rarely does a single programmer write a commercial program that you buy. Consider any word-processing, spreadsheet, or database program you have used. Each program has so many options, and responds to user selections in so many possible ways, that it would take years for a single programmer to write all the instructions. Professional software developers can write new programs in weeks or months, instead of years, by dividing large programs into modules and assigning each module to an individual programmer or programming team.

MODULARIZATION ALLOWS YOU TO REUSE YOUR WORK

If a subroutine or function is useful and well-written, you may want to use it more than once within a program or in other programs. For example, a routine that checks the current date to make sure it is valid (the month is not lower than 1 or higher than 12, the day is not lower than 1 or higher than 31 if the month is 1, and so on) is useful in many programs written for a business. A program that uses a personnel file containing each employee's birth date, hire date, last promotion date, and termination date can use the date-validation module four times with each employee record. Other programs in an organization can also use the module; these include programs that ship customer orders, plan employees' birthday parties, and calculate when loan payments should be made. If you write the date-checking instructions so they are entangled with other statements in a program, they are difficult to extract and reuse. On the other hand, if you place the instructions in their own module, the unit is easy to use and portable to other applications. The feature of modular programs that allows individual modules to be used in a variety of applications is known as **reusability**.

You can find many real-world examples of reusability. When you build a house, you don't invent plumbing and heating systems; you incorporate systems with proven designs. This certainly reduces the time and effort it takes to build a house. Assuming the plumbing and electrical systems you choose are also in service in other houses, they also improve the reliability of your house's systems—they have been tested under a variety of circumstances and have been proven to function correctly. Similarly, software that is reusable is more reliable. **Reliability** is the feature of programs that assures you a module has been tested and proven to function correctly. Reliable software saves time and money. If you create the functional components of your programs as stand-alone modules and test them in your current programs, much of the work will already be done when you use the modules in future applications.

MODULARIZATION MAKES IT EASIER TO IDENTIFY STRUCTURES

When you combine several programming tasks into modules, it may be easier for you to identify structures. For example, you learned in Chapter 2 that the selection structure looks like Figure 3-1.

When you work with a program segment that looks like Figure 3-2, you may question whether it is structured. If you can modularize some of the statements and give them a more abstract group name, as in Figure 3-3, it is easier to see that the program involves a major selection (whether the hours value is greater than 40) that determines the type of pay (regular or overtime). In Figure 3-3, it is also easier to see that the program segment is structured.

FIGURE 3-1: SELECTION STRUCTURE

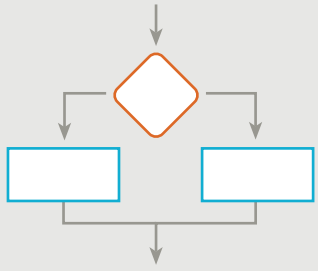


FIGURE 3-2: SECTION OF LOGIC FROM A PAYROLL PROGRAM

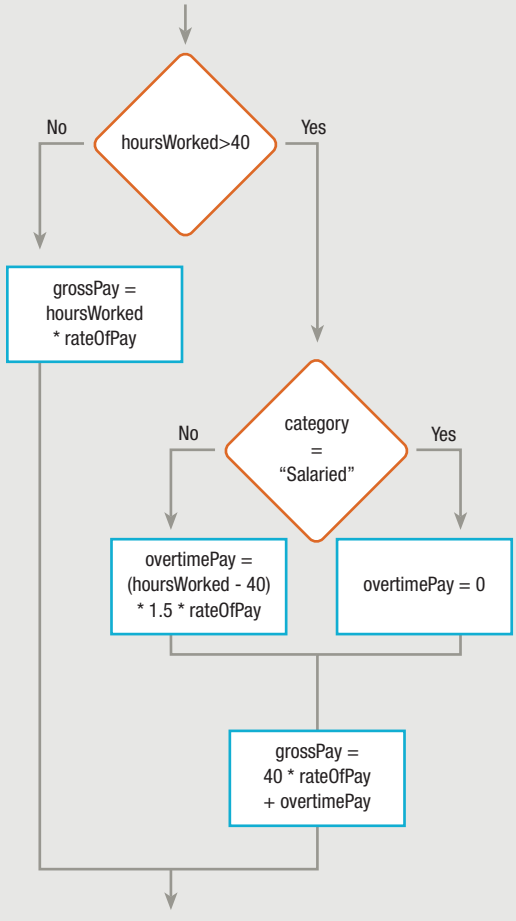
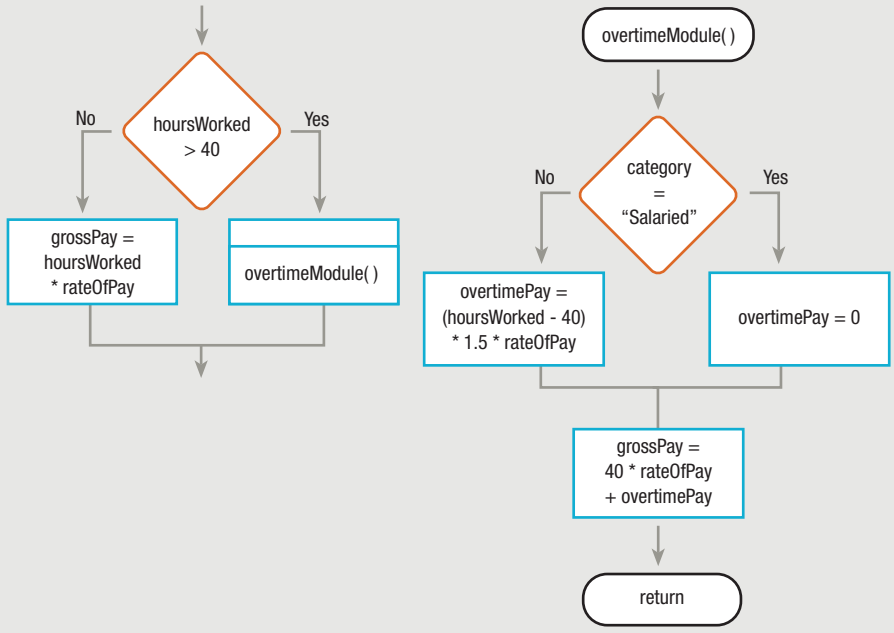


FIGURE 3-3: MODULARIZED LOGIC FROM A PAYROLL PROGRAM



The single program segment shown in Figure 3-2 accomplishes the same steps as the two program segments shown together in Figure 3-3; both program segments are structured. The structure may be more obvious in the program segments in Figure 3-3 because you can see two distinct parts—a decision structure calls a subroutine named `overtimeModule()`, and that module contains another decision structure, which is followed by a sequence. Neither of the program segments shown in Figures 3-2 and 3-3 is superior to the other in terms of functionality, but you may prefer to modularize to help you identify structures.

TIP A professional programmer will never modularize simply to *identify* whether a program is structured—he or she modularizes for reasons of abstraction, ease of dividing the work, and reusability. However, for a beginning programmer, being able to see and identify structure is important.

MODULARIZING A PROGRAM

Most programs contain a main module which contains the **mainline logic**; this module then accesses other modules or subroutines. When you create a module or subroutine, you give it a name. The rules for naming modules are different in every programming language, but they often are similar to the language's rules for variable names. In this text, module names follow the same two rules used for variable names:

- Module names must be one word.
- Module names should have some meaning.

Additionally, in this text, module names are followed by a set of parentheses. This will help you distinguish module names from variable names. This style corresponds to the way modules are named in many programming languages, such as Java, C++, and C#.

Table 3-1 lists some possible module names for a module that calculates an employee's gross pay, and provides a rationale for the appropriateness of each one.

TABLE 3-1: VALID AND INVALID MODULE NAMES FOR A MODULE THAT CALCULATES AN EMPLOYEE'S GROSS PAY

Suggested module names for a module that calculates an employee's gross pay	Comments
`calculateGrossPay()`	Good
`calculateGross()`	Good—most people would interpret "Gross" to be short for "Gross pay"
`calGrPy()`	Legal, but cryptic
`calculateGrossPayForOneEmployee()`	Legal, but awkward
`calculate gross()`	Not legal—embedded space
`calculategrosspay()`	Legal, but hard to read without camel casing

TIP As you learn more about modules in specific programming languages, you will find that you sometimes place variable names within the parentheses of module names. Any variables enclosed in the parentheses contain information you want to send to the module. For now, the parentheses we use at the end of module names will be empty.

TIP Most programming languages require that module names begin with an alphabetic character. This text follows that convention.

TIP Although it is not a requirement of any programming language, it frequently makes sense to use a verb as all or part of a module's name, because modules perform some action. Typical module names begin with words such as `get`, `compute`, and `print`. When you program in visual languages that use screen components such as buttons and text boxes, the module names frequently contain verbs representing user actions, such as `click` and `drag`.

When a program or module uses another module, you can refer to the main program as the **calling program** (or **calling module**), because it "calls" the module's name when it wants to use the module. The flowchart symbol used to call a module is a rectangle with a bar across the top. You place the name of the module you are calling inside the rectangle.

TIP When one module calls another, the called module is a **submodule**.

TIP Instead of placing only the name of the module they are calling in the flowchart, many programmers insert an appropriate verb, such as "perform" or "do," before the module name. These verbs help clarify that the module represents an action to be carried out.

TIP A module can call another module, and the called module can call another. The number of chained calls is limited only by the amount of memory available on your computer.

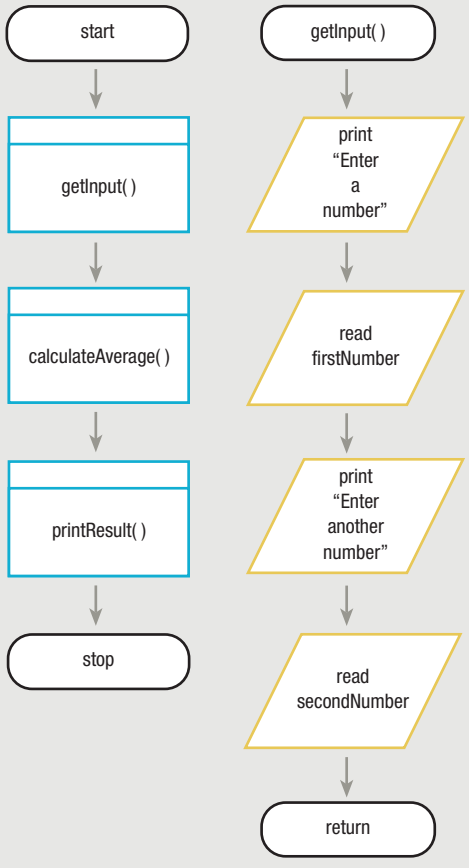
You draw each module separately with its own sentinel symbols. The symbol that is the equivalent of the `start` symbol in a program contains the name of the module. This name must be identical to the name used in the calling program. The symbol that is the equivalent of the `stop` symbol in a program does not contain "stop"; after all, the program is not ending. Instead, the module ends with a "gentler," less final term, such as `exit` or `return`. These words correctly indicate that when the module ends, the logical progression of statements will return to the calling program.

A flowchart and pseudocode for a program that calculates the arithmetic average of two numbers a user enters can look like Figure 3-4. Here the **main program**, or program that runs from start to stop and calls other modules, calls three modules: `getInput()`, `calculateAverage()`, and `printResult()`.

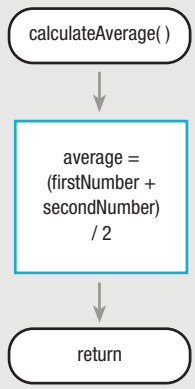
The logic of the program in Figure 3-4 proceeds as follows:

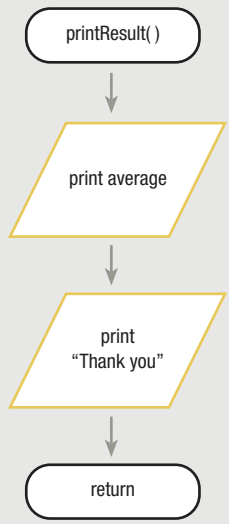
1. The main program starts.
2. The main program calls the `getInput()` module.
3. Within the `getInput()` module, the prompt "Enter a number" appears. A **prompt** is a message that is displayed on a monitor, asking the user for a response.
4. Within the `getInput()` module, the program accepts a value into the `firstNumber` variable.
5. Within the `getInput()` module, the prompt "Enter another number" appears.
6. Within the `getInput()` module, the program accepts a value into the `secondNumber` variable.
7. The `getInput()` module ends, and control returns to the main calling program.
8. The main program calls the `calculateAverage()` module.
9. Within the `calculateAverage()` module, a value for the variable `average` is calculated.
10. The `calculateAverage()` module ends, and control returns to the main calling program.
11. The main program calls the `printResult()` module.
12. Within the `printResult()` module, the value of `average` is displayed.
13. Within the `printResult()` module, a thank-you message is displayed.
14. The `printResult()` module ends, and control returns to the main calling program.
15. The main program ends.

FIGURE 3-4: FLOWCHART AND PSEUDOCODE FOR AVERAGING PROGRAM WITH MODULES




```
start
     perform getInput()
     perform calculateAverage()
     perform printResult()
stop

getInput()
     print "Enter a number"
     read firstNumber
     print "Enter another number"
     read secondNumber
return

calculateAverage()
     average = (firstNumber + secondNumber) / 2
return

printResult()
     print average
     print "Thank you"
return
```





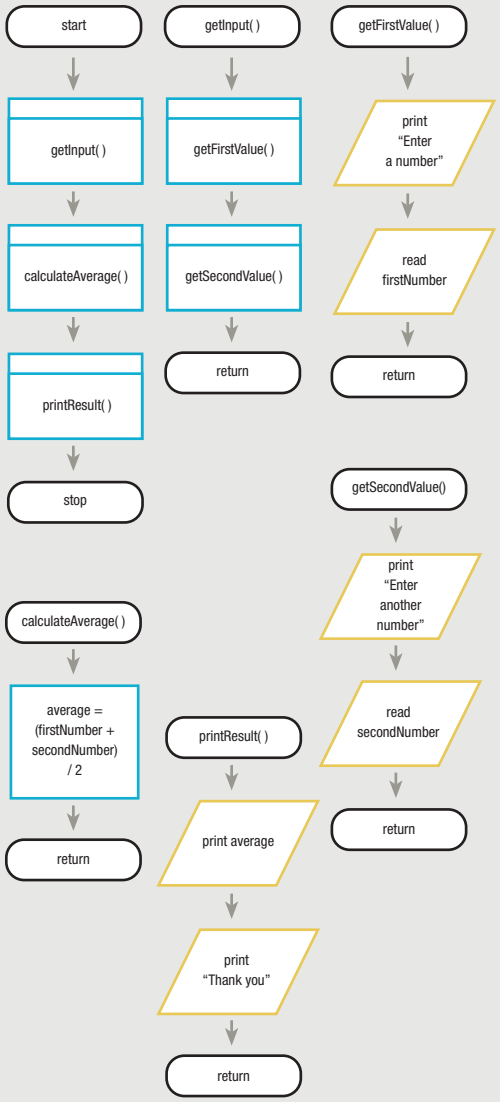
Whenever a main program calls a module, the logic transfers to the module. When the module ends, the logical flow transfers back to the main calling program and resumes where it left off.

TIP The computer keeps track of the correct memory address to which it should return after executing a module by recording the memory address in a location known as the *stack*.

MODULES CALLING OTHER MODULES

Just as a program can call a module or subroutine, any module can call another module. For example, the program illustrated in Figure 3-4 can be broken down further, as shown in Figure 3-5.

FIGURE 3-5: FLOWCHART AND PSEUDOCODE FOR AVERAGING PROGRAM WITH SUBMODULES




```
start
   perform getInput()
   perform calculateAverage()
   perform printResult()
stop

getInput()
   perform getFirstValue()
   perform getSecondValue()
return

getFirstValue()
   print "Enter a number"
   read firstNumber
return

getSecondValue()
   print "Enter another number"
   read secondNumber
return

calculateAverage()
   average = (firstNumber + secondNumber) / 2
return

printResult()
   print average
   print "Thank you"
return
```

After the program in Figure 3-5 begins:

1. The main program calls the `getInput()` module, and the logical flow transfers to that module.
2. From there, the `getInput()` module calls the `getFirstValue()` module, and the logical flow immediately transfers to the `getFirstValue()` module.
3. The `getFirstValue()` module displays a prompt and reads a number. When `getFirstValue()` ends, control passes back to `getInput()`, where `getSecondValue()` is called.
4. Control passes to `getSecondValue()`, which displays a prompt and retrieves a second value from the user. When this module ends, control passes back to the `getInput()` module.
5. When the `getInput()` module ends, control returns to the main program.
6. Then, `calculateAverage()` and `printResult()` execute as before.

Determining when to break down any particular module into its own subroutines or submodules is an art. Programmers do follow some guidelines when deciding how far to break down subroutines, or how much to put in each of them. Some companies may have arbitrary rules, such as "a subroutine should never take more than a page," or "a module should never have more than 30 statements in it," or "never have a method or function with only one statement in it."

Rather than use such arbitrary rules, a better policy is to place together statements that contribute to one specific task. The more the statements contribute to the same job, the greater the **functional cohesion** of the module. A routine that checks the validity of a `date` variable's value, or one that prompts a user and allows the user to type in a value, is considered cohesive. A routine that checks date validity, deducts insurance premiums, and computes federal withholding tax for an employee would be less cohesive.

TIP

Date-checking is an example of a commonly used module in business programs, and one that is quite functionally cohesive. In business programs, many dates are represented using six or eight digits in month-day-year format. For example, January 21, 2007 might be stored as 012107 or 01212007. However, you might also see day-month-year format, as in 21012007. The current International Organization for Standardization (ISO) standard for representing dates is to use eight digits, with the year first, followed by the month and day. For example, January 21, 2007 is 20070121 and would be displayed as 2007-01-21. The ISO creates standards for businesses that make products more reliable and trade between countries easier and fairer.

DECLARING VARIABLES

The primary work of most modules in most programs you write is to manipulate data—for example, to calculate the figures needed for a paycheck, customer bill, or sales report. You store your program data in variables.

Many program languages require you to declare all variables before you use them. **Declaring a variable** involves providing a name for the memory location where the computer will store the variable value, and notifying the computer of

what type of data to expect. Every programming language requires that you follow specific rules when declaring variables, but all the rules involve identifying at least two attributes for every variable:

- You must declare a data type.
- You must give the variable a name.

You learned in Chapter 1 that different programming languages provide different variable types, but that all allow at least the distinction between character and numeric data. The rest of this book uses just two data types—`num`, which holds number values, and `char`, which holds all other values, including those that contain letters and combinations of letters and numbers.

Remember, you also learned in Chapter 1 that variable names must not contain spaces, so this book uses statements such as `char lastName` and `num weeklySalary` to declare two variables of different types.

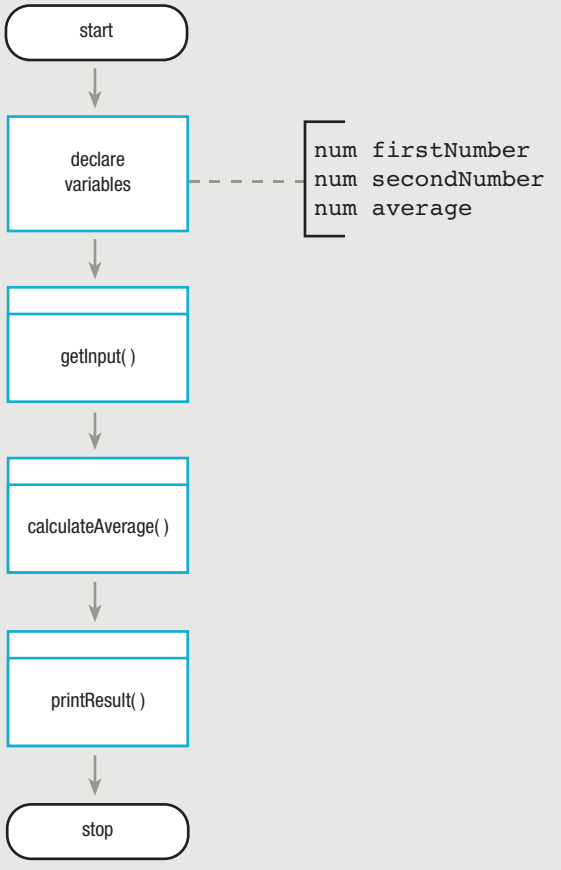
TIP Although it is not a requirement of any programming language, it usually makes sense to give a variable a name that is a noun, because it represents a thing.

Some programming languages, such as Visual Basic and BASIC, do not require you to name any variable until the first time you use it. However, other languages, including COBOL, C++, C#, and Java, require that you declare variables with a name and a data type. Some languages require that you declare all variables at the beginning of a program, before you write any executable statements; others allow you to declare variables at any point, but require the declaration before you can use the variable. For our purposes, this book follows the convention of declaring all variables at the beginning of a program.

In many modern programming languages, variables typically are declared within each module that uses them. Such variables are known as **local variables**. As you continue your study of programming logic, you will learn how to use local variables and understand their advantages. For now, this text will use **global variables**—variables that are given a type and name once, and then used in all modules of the program.

For example, to complete the averaging program shown in Figure 3-5 so that its variables are properly declared, you can redraw the main program flowchart to look like the one shown in Figure 3-6. Three variables are required: `firstNumber`, `secondNumber`, and `average`. The variables are declared as the first step in the program, before you use any of them, and each is correctly identified as numeric. They appear to the side of the "declare variables" step in an **annotation symbol** or **annotation box**, which is simply an attached box containing notes. You can use an annotation symbol any time you have more to write than you can conveniently fit within a flowchart symbol, or any time you want to add an explanatory comment to a flowchart.

FIGURE 3-6: FLOWCHART AND PSEUDOCODE FOR MAINLINE LOGIC FOR AVERAGING PROGRAM SHOWING DECLARED VARIABLES




```
start
  declare variables
      num firstNumber
      num secondNumber
      num average
  perform getInput()
  perform calculateAverage()
  perform printResult()
stop
```

TIP

Many programming languages support more specific numeric types with names like int (for integers or whole numbers), float or single (for single-precision, floating-point values; that is, values that contain one or more decimal-place digits), and double (for double-precision, floating-point values, which means more memory space is reserved). Many languages distinguish even more precisely. For example, in addition to whole-number integers, C++, C#, and Java allow short integers and long integers, which require less and more memory, respectively.

TIP

Many programming languages support more specific character types. Often, programming languages provide a distinction between single-character variables (such as an initial or a grade in a class) and string variables (such as a last name), which hold multiple characters.

Figure 3-6 also shows pseudocode for the same program. Because pseudocode is written and not drawn, you might choose to list the variable names below the `declare variables` statement, as shown.

Programmers sometimes create a **data dictionary**, which is a list of every variable name used in a program, along with its type, size, and description. When a data dictionary is created, it becomes part of the program documentation.

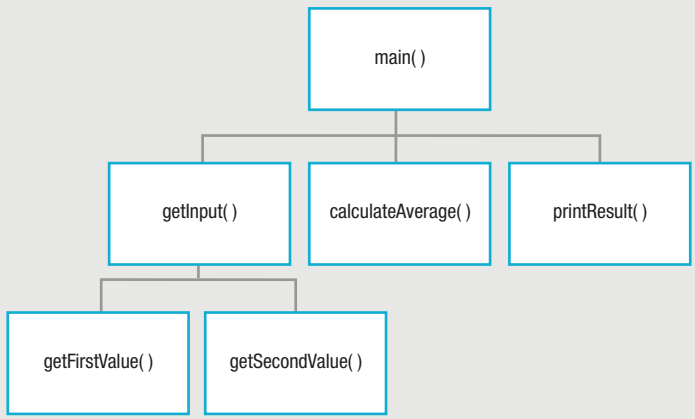
TIP After you name a variable, you must use that exact name every time you refer to the variable within your program. In many programming languages, even the case matters, so a variable name like `firstNumber` represents a different memory location than `firstnumber` or `FirstNumber`.

CREATING HIERARCHY CHARTS

Besides describing program logic with a flowchart or pseudocode, when a program has several modules calling other modules, programmers often use a tool to show the overall picture of how these modules are related to one another. You can use a **hierarchy chart** to illustrate modules' relationships. A hierarchy chart does not tell you what tasks are to be performed within a module; it doesn't tell you *when* or *how* a module executes. It tells you only which routines exist within a program and which routines call which other routines.

The hierarchy chart for the last version of the number-averaging program looks like Figure 3-7, and shows which modules call which others. You don't know *when* the modules are called or *why* they are called; that information is in the flowchart or pseudocode. A hierarchy chart just tells you *which* modules are called by other modules.

FIGURE 3-7: HIERARCHY CHART FOR NUMBER-AVERAGING PROGRAM IN FIGURE 3-6



You may have seen hierarchy charts for organizations, such as the one in Figure 3-8. The chart shows who reports to whom, not when or how often they report. Program hierarchy charts operate in an identical manner.

Figure 3-9 shows an example of a hierarchy chart for the billing program of a mail-order company. The hierarchy chart supplies module names only; it provides a general overview of the tasks to be performed, without specifying any details.

FIGURE 3-8: AN ORGANIZATIONAL HIERARCHY CHART

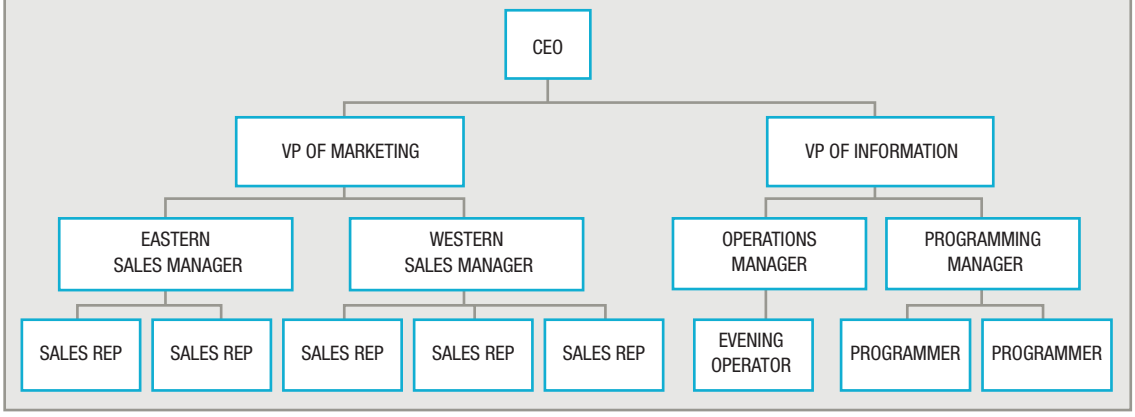
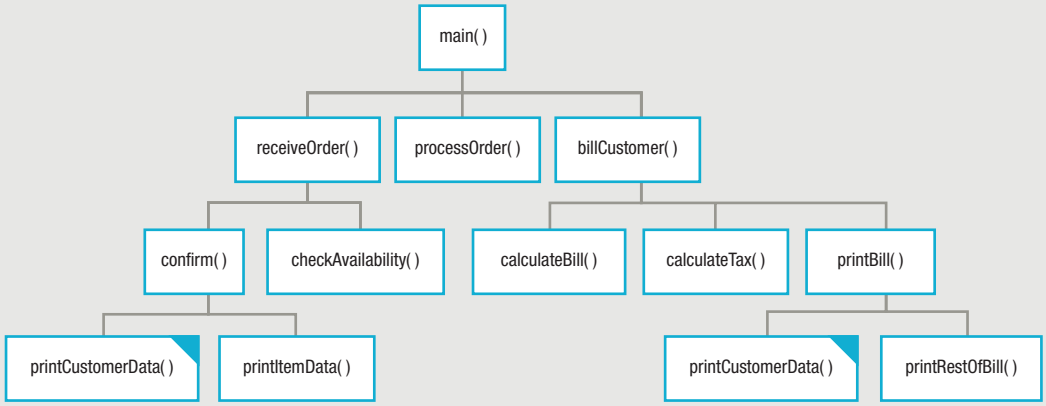


FIGURE 3-9: BILLING PROGRAM HIERARCHY CHART



Because program modules are reusable, a specific module may be called from several locations within a program. For example, in the billing program hierarchy chart in Figure 3-9, you can see that the `printCustomerData()` module is used twice. By convention, you blacken a corner of each box representing a module used more than once. This action alerts readers that any change to this module will affect more than one location.

The hierarchy chart can be a useful tool when a program must be modified months or years after the original writing. For example, if a tax law changes, a programmer might be asked to rewrite the `calculateTax()` module in the billing program diagrammed in Figure 3-9. As the programmer changes the `calculateTax()` routine, the hierarchy chart shows what other dependent routines might be affected. If a change is made to `printCustomerData()`, the programmer is alerted that changes will occur in multiple locations. A hierarchy chart is useful for "getting the big picture" in a complex program.

TIP

Hierarchy charts are used in procedural programming, but they are infrequently used in object-oriented programming. Other types of diagrams frequently are used in object-oriented environments. In Chapter 15 of the Comprehensive edition of this book, you learn about the Unified Modeling Language, which is a set of diagrams you use to describe a system.

UNDERSTANDING DOCUMENTATION

Documentation refers to all of the supporting material that goes with a program. Two broad categories of documentation are the documentation intended for users and the documentation intended for programmers. People who use computer programs are called **end users**, or **users** for short. Most likely, you have been the end user of an application such as a word-processing program or a game. When you purchase software that other programmers have written, you appreciate clearly written instructions on how to install and use the software. These instructions constitute user documentation. In a small organization, programmers may write user documentation, but in most organizations, systems analysts or technical writers produce end-user instructions. These instructions may take the form of a printed manual, or may be presented online through a Web site or on a compact disc.

When programmers begin to plan the logic of a computer program, they require instructions known as **program documentation**. End users never see program documentation; rather, programmers use it when planning or modifying programs.

Program documentation falls into two categories: internal and external. **Internal program documentation** consists of program **comments**, or nonexecuting statements that programmers place within their code to explain program statements in English. Comments serve only to clarify code; they do not affect the running of a program. Because methods for inserting comments vary, you will learn how to insert comments when you learn a specific programming language.

TIP

In Visual Basic, program comments begin with the letters REM (for REMark) or with a single apostrophe. In C++, C#, and Java, comments can begin with two forward slashes (//). Some newer programming languages such as C# and Java provide a tool that automatically converts the programmer's internal comments to external documentation.

External program documentation includes all the supporting paperwork that programmers develop before they write a program. Because most programs have input, processing, and output, usually there is documentation for each of these functions.

OUTPUT DOCUMENTATION

Output documentation is usually the first to be written. This may seem backwards, but if you're planning a trip, which do you decide first: how to get to your destination or where you're going?

Most requests for programs arise because a user needs particular information to be output, so the planning of program output is usually done in consultation with the person or persons who will be using it. Only after the desired output is known can the programmer hope to plan the processes needed to produce the output.

Often the programmer does not design the output. Instead, the user who requests the output presents the programmer (or programming team) with an example or sketch of the desired result. Then the programmer might work with the user to refine the request, suggest improvements in the design, or clarify the user's needs. If you don't determine precisely what the user wants or needs at this point, you will write a program that the user soon wants redesigned and rewritten.

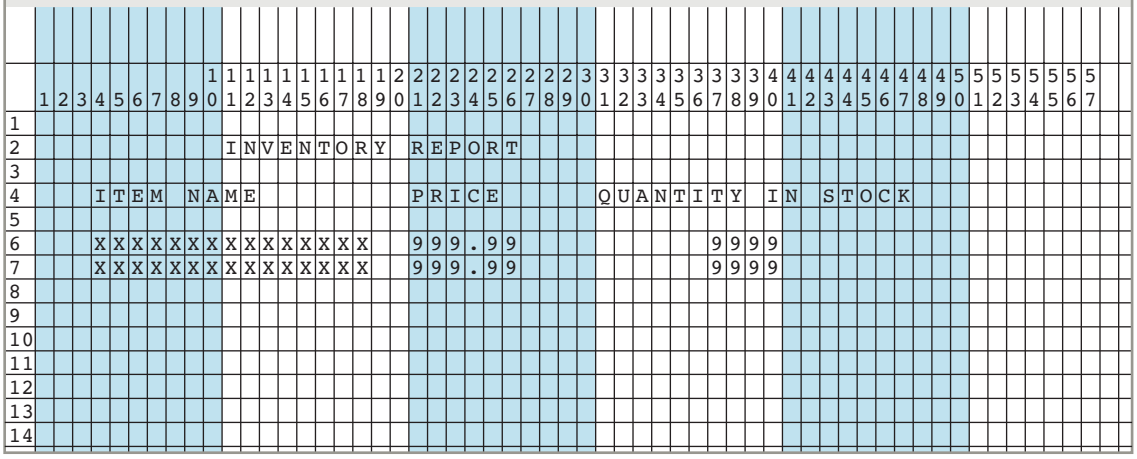
A very common type of output is a printed report. You can design a printed report on a **printer spacing chart**, which is also referred to as a **print chart** or a **print layout**. Figure 3-10 shows a printer spacing chart, which basically looks like graph paper. The chart has many boxes, and in each box the designer places one character that will be printed.

For example, suppose you want to create a printed report with the following features:

- A printed title, INVENTORY REPORT, that begins 11 spaces over from the left of the page and one line down
- Column headings for ITEM NAME, PRICE, and QUANTITY IN STOCK two lines below the title and centered over the actual data items that display
- Variable data appearing below each of the column headings

With these features, the print chart you create would resemble the one in Figure 3-10.

FIGURE 3-10: PLANNED PRINT CHART



The exact spacing and the use of uppercase or lowercase characters in the print chart make a difference. Notice that the constant data in the output, the items that do not vary but remain the same in every execution of the report, do not need to follow the same rules as variable names in the program. Within a report, constants like INVENTORY REPORT and ITEM NAME can contain spaces. These headings exist to help readers understand the information presented in the report—not for a computer to interpret; there is no need to run the names together, as you do when choosing identifiers for variables.

A print layout typically shows how the variable data will appear on the report. Of course, the data will probably be different every time the report is run. Thus, instead of writing in actual item names and prices, the users and programmers usually use Xs to represent generic variable character data and 9s to represent generic variable numeric data. (Some programmers use Xs for both character and numeric data.) Each line containing Xs and 9s representing data is a **detail line**, or a line that displays the data details. Detail lines typically appear many times per page, as opposed to **heading lines**, which contain the title and any column headings, and usually appear only once per page.

Even though an actual inventory report might eventually go on for hundreds or thousands of detail lines, writing two or three rows of Xs and 9s is sufficient to show how the data will appear. For example, if a report contains employee names and salaries, those data items will occupy the same print positions on output for line after line, whether the output eventually contains 10 employees or 10,000. A few rows of identically positioned Xs and 9s are sufficient to establish the pattern.

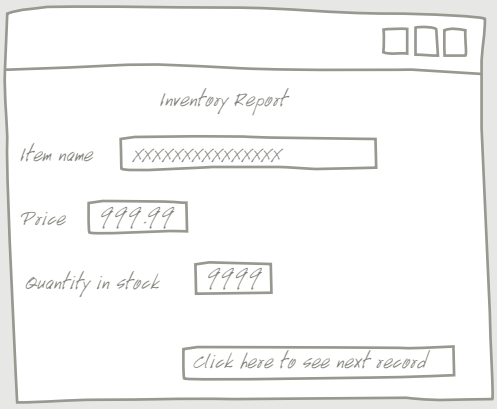
In any report layout, then, you write in constant data (such as headings) that will be the same on every run of the report. You write Xs and 9s to represent the variable data (such as the items, their prices, and their quantities) that will change from run to run.

Besides header lines and detail lines, reports often include special lines at the end of a report. These may contain a message that indicates the report is done (so that users do not worry there might be additional pages they are missing), or numeric statistics such as totals or averages. Even though lines at the end of a report don't always contain numeric totals, they are usually referred to generically as **total lines** or **summary lines**.

Printed reports do not necessarily contain detail lines. A report might contain only headers and summary lines. For example, a payroll report might contain only a heading and a total gross payroll figure for each department in the company, or a college might print a report showing how many students have declared each available major. These reports contain no detail—no information about individual employees or students—but they do contain summaries. Instead of creating a print chart, you might choose to create a less formal plan for output. For example, you might just sketch a plan using paper and pencil. Many programmers never use formal print charts, but they are discussed here so you will be familiar with them if you encounter them on the job. Besides using handwritten print charts, you also can design report layouts on a computer using a word-processing program or design software.

Not all program output takes the form of printed reports. If your program's output will appear on a monitor screen, particularly if you are working in a **GUI** (graphical user interface) environment like Windows, your design issues will differ. In a GUI program, the user sees a screen and can typically make selections using a mouse or other pointing device. Instead of a print chart, your output design might resemble a sketch of a screen. Figure 3-11 shows a hand-drawn sketch of a window that displays inventory records in a graphical environment. On a monitor, you might choose to allow the user to see only one or a few records at a time, so one concern is providing a means for users to scroll through displayed records. In Figure 3-11, records are accessed using a single button that the user can click to read the next record; in a more sophisticated design, the user might be able to "jump" to the first or last record, or look up a specific record.

FIGURE 3-11: INVENTORY RECORDS DISPLAYED IN A GUI ENVIRONMENT



TIP A printed report is also called a **hard copy**, whereas screen output is referred to as a **soft copy**.

TIP Achieving good screen design is an art that requires much study and thought to master. Besides being visually pleasing, good screen design also requires ease of use and accessibility.

TIP GUI programs often include several different screen formats that a user will see while running a program. In such cases, you would design several screens.

INPUT DOCUMENTATION

Once you have planned the design of the output, you need to know what input is available to produce this output. If you are producing a report from stored data, you frequently will be provided with a **file description** that describes the data contained in a file. You usually find a file's description as part of an organization's information systems documentation; physically, the description might be on paper in a binder in the Information Systems department, or it might be stored on a disk. If the file you will use comes from an outside source, the person requesting the report will have to provide you with a description of the data stored on the file. Figure 3-12 shows an example of an inventory file description.

FIGURE 3-12: INVENTORY FILE DESCRIPTION

```
INVENTORY FILE DESCRIPTION
File name: INVENTORY
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Name of item           Character    15 bytes
Price of item          Numeric      2 decimal places
Quantity in stock      Numeric      0 decimal places
```

TIP

Not all programs use previously stored input files. Some use interactive input data supplied by a user during the execution of a program. In the next chapter, you will see that whether input comes from a file or from user input, the process is very similar.

TIP

Some programs do not produce a printed report or screen display, but instead produce an output file that is stored directly on a storage device, such as a disk. If your program produces file output, you will create a file description for your output. Other programs then may use your output file description as an input description.

The inventory file description in Figure 3-12 shows that each item's name is character data that occupies the first 15 bytes of each record in the file. A **byte** is a unit of computer storage that can contain any of 256 combinations of 0s and 1s that often represent a character. The code of 0s and 1s depends on the type of computer system you are using. Popular coding schemes include ASCII (American Standard Code for Information Interchange), EBCDIC (Extended Binary Coded Decimal Interchange Code), and Unicode. Each of these codes uses a different combination of 1s and 0s to represent characters—you can see a listing of each code's values in Appendix B. For example, in ASCII, an uppercase "A" is represented by 01000001. Programmers seldom care about the code used; for example, if an "A" is stored as part of a person's name, the programmer's only concern is that the "A" in the name appears correctly on output—not the combination of 0s and 1s that represents it. This book assumes that one stored character occupies one byte in an input file.

Some item names may require all 15 positions allowed for the name in the input file—for example, "12 by 16 carpet", which contains exactly 15 characters, including spaces. Other item names require fewer than the allotted 15 positions—for example, "door mat". In such cases, the remaining allotted positions might remain blank, or the short description might be followed by a string-terminating character. (For example, in some systems, a string is followed by a special character in which all the bits are 0s.) On the other hand, when only 15 storage positions are allowed for a name, some names might be too long and have to be truncated or abbreviated. For example, "hand woven carpet" might be stored as "hand woven carp". Whether the item name requires all 15 positions or not, you can see from the input file description in Figure 3-12 that the price for each item begins after the description name, in position 16 of each input record.

The price of any item in the inventory file is numeric. In different storage systems, a number might occupy a different number of physical file positions. Additionally, numbers with decimal places frequently are stored using more bytes than integer numbers, even when the integer number is a "bigger" number. For example, in many systems, 5678 might be stored in a four-byte numeric integer field, while 2.2 might be stored in an eight-byte floating-point numeric field. When thinking logically about numeric fields, you do not care how many bytes of storage they occupy; what's important is that they hold numbers. For convenience, this book will simply designate numeric values as such, and let you know whether decimal places are included.

TIP

Repeated characters whose position is assumed frequently are not stored in data files. For example, dashes in Social Security numbers or telephone numbers, dollar signs on money amounts, or a period after a middle initial are seldom stored in data files. These symbols are used on printed reports, where it is important for the reader to be able to easily interpret these values.

Typically, programmers create one program variable for each field that is part of the input file. In addition to the field descriptions contained in the input documentation, the programmer might be given specific variable names to use for each field, particularly if such variable names must agree with the ones that other programmers working on the project are using. In many cases, however, programmers are allowed to choose their own variable names. Therefore, you can choose `itemName`, `nameOfItem`, `itemDescription`, or any other reasonable one-word variable name when you refer to the inventory item name within your program. The variable names you use within your program need not match constants, such as column headings, that might be printed on a hard copy report. Thus, the variable `itemName` might hold the characters that will print under the column heading NAME OF ITEM.

For example, examine the input file description in Figure 3-12. When this file is used for a project in which the programmer can choose variable names, he or she might choose the following variable declaration list:

```
char itemName
num itemPrice
num itemQuantity
```

Each data field in the list is declared using the data type that corresponds to the data type indicated in the file description, and has an appropriate, easy-to-read, single-word variable name.

TIP Some programmers argue that starting each field with a prefix indicating the file name (for example, "item" in `itemName` and `itemPrice`), helps to identify those variables as "belonging together." Others argue that repeating the "item" prefix is redundant and requires unnecessary typing by the programmer; these programmers would argue that "name", "price", and "quantity" are descriptive enough.

TIP When a programmer uses an identifier like `itemName`, that variable identifier exists in computer memory only for the duration of the program in which the variable is declared. Another program can use the same input file and refer to the same field as `nameOfItem`. Variable names exist in memory during the run of a program—they are not stored in the data file. Variable names simply represent memory addresses at which pieces of data are stored while a program executes.

Recall the data hierarchy relationship introduced in Chapter 1:

- Database
- File
- Record
- Field
- Character

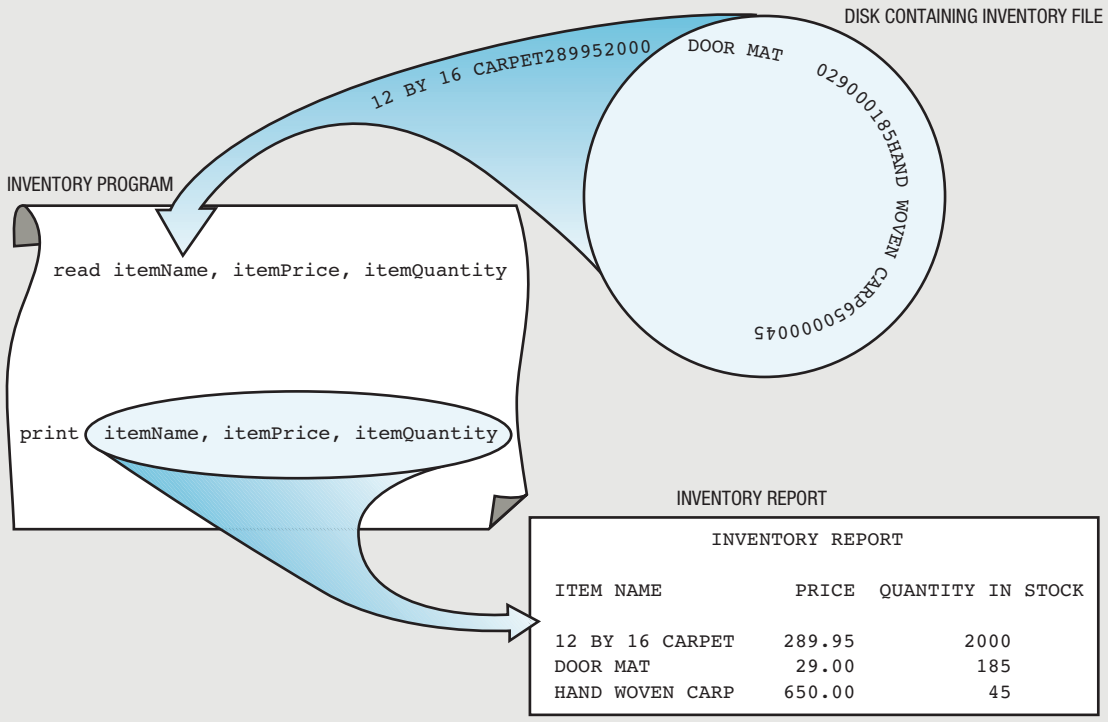
Whether the inventory file is part of a database or not, it will contain many records; each record will contain an item name, price, and quantity, which are fields. In turn, the field that holds the name of an item might contain up to 15 characters—for example, "12 by 16 carpet", "blue miniblinds", or "diskette holder".

Organizations may use different forms to relay the information about records and fields, but the very least the programmer needs to know is:

- What is the name of the file?
- What data fields does it contain, and in what order?
- What type of data can be stored in each field—character or numeric?

Notice that a data field's position on the input file never has to correspond with the same item's position in an output file or in a print chart. For example, you can use the data file described in Figure 3-12 to produce the report shown in Figure 3-10. In the input data file, the item name appears in positions 1 through 15. However, on the printed report, the same information appears in columns 4 through 18. In an input file, data are "squeezed" together—no human being will read this file, and there is no need for it to be attractively spaced. However, on printed output, you typically include spaces between data items so they are legible as well as attractive. Figure 3-13 illustrates how input fields are read by the program and converted to output fields.

FIGURE 3-13: STORAGE OF INPUT AND DISPLAY OF OUTPUT



TIP

You are never required to output all the available characters that exist in a field in an input record. For example, even though the item name in the input file description in Figure 3-12 shows that each item contains 15 stored characters, you might decide to display only 10 of them on output, especially if your output report contained many columns and you were "crunched" for space.

The inventory file description in Figure 3-12 contains all the data the programmer needs to create the output requested in Figure 3-10—the output lists each item's name, price, and quantity, and the input records clearly contain that data. Often, however, a file description more closely resembles the description in Figure 3-14.

FIGURE 3-14: EXPANDED INVENTORY FILE DESCRIPTION

```
INVENTORY FILE DESCRIPTION
File name: INVENTORY
FIELD DESCRIPTION          DATA TYPE    COMMENTS
Item Number                Numeric      0 decimal places
Name of item               Character    15 bytes
Size                       Numeric      0 decimal places
Manufacturing cost of item Numeric      2 decimal places
Retail price of item       Numeric      2 decimal places
Quantity in stock          Numeric      0 decimal places
Reorder point              Numeric      0 decimal places
Sales rep                  Character    10 bytes
Sales last year            Numeric      2 decimal places
```

The file description in Figure 3-14 contains nine fields. With this file description, it's harder to pinpoint the information needed for the report, but the necessary data fields are available, and you still can write the program. The input file contains more information than you need for the report you want to print, so you will ignore some of the input fields, such as Item Number and Sales rep. These fields certainly may be used in other reports within the company. Typically, data input files contain more data than any one program requires. For example, your credit card company stores historical data about your past purchases, but these are not included on every bill. Similarly, your school records contain more data than are printed on each report card or tuition bill.

However, if the input file description resembles Figure 3-15, there are not enough data items to produce the requested report. In the file description in Figure 3-15, there is no indication that the input file contains a value for quantity in stock. If the user really needs (or wants) the report as requested, it's out of the programmer's hands until the data can be collected from some source and stored in a file the programmer can use.

FIGURE 3-15: INSUFFICIENT INVENTORY FILE DESCRIPTION IF QUANTITY IN STOCK IS NEEDED FOR OUTPUT

```
INVENTORY FILE DESCRIPTION
File name: INVENTORY
FIELD DESCRIPTION          DATA TYPE    COMMENTS
Item Number                Numeric      0 decimal places
Name of item               Character    15 bytes
Size                       Numeric      0 decimal places
Manufacturing cost of item Numeric      2 decimal places
Retail price of item       Numeric      2 decimal places
Reorder point              Numeric      0 decimal places
Sales rep                  Character    10 bytes
Sales last year            Numeric      2 decimal places
```

Each field printed on a report does not need to exist on the input file. Assume that a user requests a report in the format shown in the example in Figure 3-16, which includes a column labeled "Profit", and that the input file description is the one in Figure 3-14. In this case, it's difficult to determine whether you can create the requested report, because the input file does not contain a `profit` field. However, because the input data include the company's cost and selling price for each item, you can (after consulting with the user to make sure you agree on the definition of "profit") calculate the `profit` within your program by subtracting the cost from the price, and then produce the desired output.

FIGURE 3-16: SAMPLE PROFIT REPORT

```
          Profit Report

Item Number       Price      Cost     Profit

  1265             9.99      8.50      1.49
  1288            15.00     12.62      2.38
  1376            18.89     16.00      2.89
  1644            21.99     14.50      7.49
```

COMPLETING THE DOCUMENTATION

When you have designed the output and confirmed that it is possible to produce it from the input, then you can plan the logic of the program, code the program, and test the program. The original output design, input description, flowchart or pseudocode, and program code all become part of the program documentation. These pieces of documentation are typically stored together in a binder within the programming department of an organization, where they can be studied later when program changes become necessary.

In addition to this program documentation, you typically must create user documentation. **User documentation** includes all the manuals or other instructional materials that nontechnical people use, as well as the operating instructions that computer operators and data-entry personnel need. It needs to be written clearly, in plain language, with reasonable expectations of the users' expertise. Within a small organization, the programmer may prepare the user documentation. In a large organization, user documentation is usually prepared by technical writers or systems analysts, who oversee programmers' work and coordinate programmers' efforts. These professionals consult with the programmer to ensure that the user documentation is complete and accurate.

The areas addressed in user documentation may include:

- How to prepare input for the program
- To whom the output should be distributed
- How to interpret the normal output
- How to interpret and react to any error message generated by the program
- How frequently the program needs to run

TIP

Complete documentation also might include operations support documentation. This type of documentation provides backup and recovery information, run-time instructions, and security considerations for computer center personnel who run large applications within data centers.

All these issues must be addressed before a program can be fully functional in an organization. When users throughout an organization can supply input data to computer programs and obtain the information they need in order to do their jobs well, then a skilled programmer has provided a complete piece of work.

CHAPTER SUMMARY

- Programmers break down programming problems into smaller, reasonable units called modules, subroutines, procedures, functions, or methods. Modularization provides abstraction, allows multiple programmers to work on a problem, makes it easy to reuse your work, and allows you to identify structures more easily.
- When you create a module or subroutine, you give the module a name that a calling program uses when the module is about to execute. The flowchart symbol used to call a subroutine is a rectangle with a bar across the top; the name of the module that you are calling is inside the rectangle. You draw a flowchart for each module separately, with its own sentinel symbols.
- A module can call other modules.
- Declaring a variable involves providing a name for the memory location where the computer will store the variable value, and notifying the computer of what type of data to expect.
- You can use a hierarchy chart to illustrate modules' relationships.
- Documentation refers to all of the supporting material that goes with a program.
- Output documentation is usually written first. You can design a printed report on a printer spacing chart to represent both constant and variable data. You also can design report layouts on a computer using a word-processing program or design software, or draw diagrams of planned screen output.
- A file description lists the data contained in a file, including a description, data type, and any other necessary information, such as number of decimal places in numeric data.
- In addition to program documentation, you typically must create user documentation, which includes the manuals or other instructional materials that nontechnical people use, as well as the operating instructions that computer operators and data-entry personnel may need.

KEY TERMS

Modules are small program units that you can use together to make a program. Programmers also refer to modules as **subroutines**, **procedures**, **functions**, or **methods**.

The process of breaking down a program into modules is called **modularization**.

Abstraction is the process of paying attention to important properties while ignoring nonessential details.

Low-level details are small, nonabstract steps.

High-level programming languages allow you to use English-like vocabulary in which one broad statement corresponds to dozens of machine instructions.

Reusability is the feature of modular programs that allows individual modules to be used in a variety of applications.

Reliability is the feature of modular programs that assures you that a module has been tested and proven to function correctly.

The **mainline logic** is the logic used in the main module that calls other program modules.

A **calling program** or **calling module** is one that calls a module.

A module that is called by another is a **submodule**.

A **main program** runs from start to stop and calls other modules.

A **prompt** is a message that is displayed on a monitor, asking the user for a response.

The **functional cohesion** of a module is a measure of the degree to which all the module statements contribute to the same task.

Declaring a variable involves providing a name for the memory location where the computer will store the variable value, and notifying the computer of what type of data to expect.

Local variables are declared within each module that uses them.

Global variables are given a type and name once, and then are used in all modules of the program.

An **annotation symbol** or **annotation box** is a flowchart symbol that represents an attached box containing notes.

A **data dictionary** is a list of every variable name used in a program, along with its type, size, and description.

A **hierarchy chart** is a diagram that illustrates modules' relationships to each other.

Documentation refers to all of the supporting material that goes with a program.

End users, or **users**, are people who use computer programs.

Program documentation is the set of instructions that programmers use when they begin to plan the logic of a program.

Internal program documentation is documentation within a program.

Program **comments** are nonexecuting statements that programmers place within their code to explain program statements in English.

External program documentation includes all the supporting paperwork that programmers develop before they write a program.

A **printer spacing chart**, which is also referred to as a **print chart** or a **print layout**, is a tool for planning program output.

A **detail line** on a report is a line that contains data details. Most reports contain many detail lines.

Heading lines on a report contain the title and any column headings, and usually appear only once per page.

Total lines or **summary lines** contain end-of-report information.

A **GUI**, or graphical user interface, environment uses screens to display program output. Users interact with GUI programs with a device such as a mouse.

A **hard copy** is a printed copy.

A **soft copy** is a screen copy.

A **file description** is a document that describes the data contained in a file.

A **byte** is a unit of computer storage that can contain any of 256 combinations of 0s and 1s that often represent a character.

User documentation includes all the manuals or other instructional materials that nontechnical people use, as well as the operating instructions that computer operators and data-entry personnel need.

REVIEW QUESTIONS

1. **Which of the following is *not* a term used as a synonym for "module" in any programming language?**
   a. structure
   b. procedure
   c. method
   d. function

2. **Which of the following is *not* a reason to use modularization?**
   a. Modularization provides abstraction.
   b. Modularization allows multiple programmers to work on a problem.
   c. Modularization allows you to reuse your work.
   d. Modularization eliminates the need for structure.

3. **What is the name for the process of paying attention to important properties while ignoring nonessential details?**
   a. structure
   b. iteration
   c. abstraction
   d. modularization

4. **All modern programming languages that use English-like vocabulary to create statements that correspond to dozens of machine instructions are referred to as _____.**
   a. high-level
   b. object-oriented
   c. modular
   d. obtuse

5. **Modularizing a program makes it _____ to identify structures.**
   a. unnecessary
   b. easier
   c. more difficult
   d. impossible

6. **Programmers say that one module can _____ another, meaning that the first module causes the second module to execute.**
   a. declare
   b. define
   c. enact
   d. call

7. **A message that appears on a monitor, asking the user for a response, is a _____.**
   a. call
   b. prompt
   c. command
   d. declaration

8. The more that a module's statements contribute to the same job, the greater the _____ of the module.

a. structure
b. modularity
c. functional cohesion
d. size

9. When you declare a variable, you must provide _____.

a. a name
b. a name and a type
c. a name, a type, and a value
d. a name, a type, a value, and a purpose

10. A _____ is a list of every variable name used in a program, along with its type, size, and description.

a. flowchart
b. hierarchy chart
c. data dictionary
d. variable map

11. A hierarchy chart tells you _____.

a. what tasks are to be performed within each program module
b. when a module executes
c. which routines call which other routines
d. all of the above

12. Two broad categories of documentation are the documentation intended for _____.

a. management and workers
b. end users and programmers
c. people and the computer
d. defining variables and defining actions

13. Nonexecuting statements that programmers place within their code to explain program statements in English are called _____.

a. comments
b. pseudocode
c. trivia
d. user documentation

14. The first type of documentation usually created when writing a program pertains to _____.

a. end users
b. input
c. output
d. data

15. Lines of output that never change, no matter what data values are input, are referred to as _____.

a. detail lines
b. headers
c. rigid
d. constant

16. Report lines that contain the information stored in individual data records are known as _____.

a. headers
b. footers
c. detail lines
d. X-lines

17. Summary lines appear _____.

a. at the end of every printed report
b. at the end of some printed reports
c. in printed reports, but never in screen output
d. only when detail lines also appear

18. If an input file description stores a first name followed by a last name, then _____.

a. the first name must appear first on any output
b. the first name must not appear first on any output
c. the first and last names must both appear on output
d. None of the above are true.

19. Of the following items, which does a programmer usually not need to know about an input file?

a. the name of the file
b. the number of records in the file
c. the order of the data fields in the file
d. whether each field in each record is numeric or character

20. A field holding a student's last name is stored in bytes 10 through 29 of each student record. Therefore, when you design a print chart for a report that contains each student's last name, _____.

a. the name must print in positions 10 through 29 of the print chart
b. the name must occupy exactly 20 positions on the print chart
c. Both of these are true.
d. Neither of these is true.

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **This pseudocode is intended to describe determining whether you have passed or failed a course based on the average score of two classroom tests. The main program calls three modules—one that gets the input values, one that performs the average calculation, and another that displays the results.**

```
start
   declare variables
      num test1Score
      num test2Score
      char letterGrade
   perform getInputValues()
   perform computeAvg()
   perform displayResults()
stop

getInput()
   input test1Score
   input test2Score
return

computeAverage()
   average = (test1Score + test2Score) / 2
   if average >= 60 then
      letterGrade = "P"
   else
      average = "F"
   endif
return

displayResults()
   print average
   print letter
return
```

2. **This pseudocode is intended to describe computing the number of miles per gallon you get with your automobile as well as the cost of gasoline per mile. The main program calls modules that allow the user to enter data, compute statistics, and display results.**

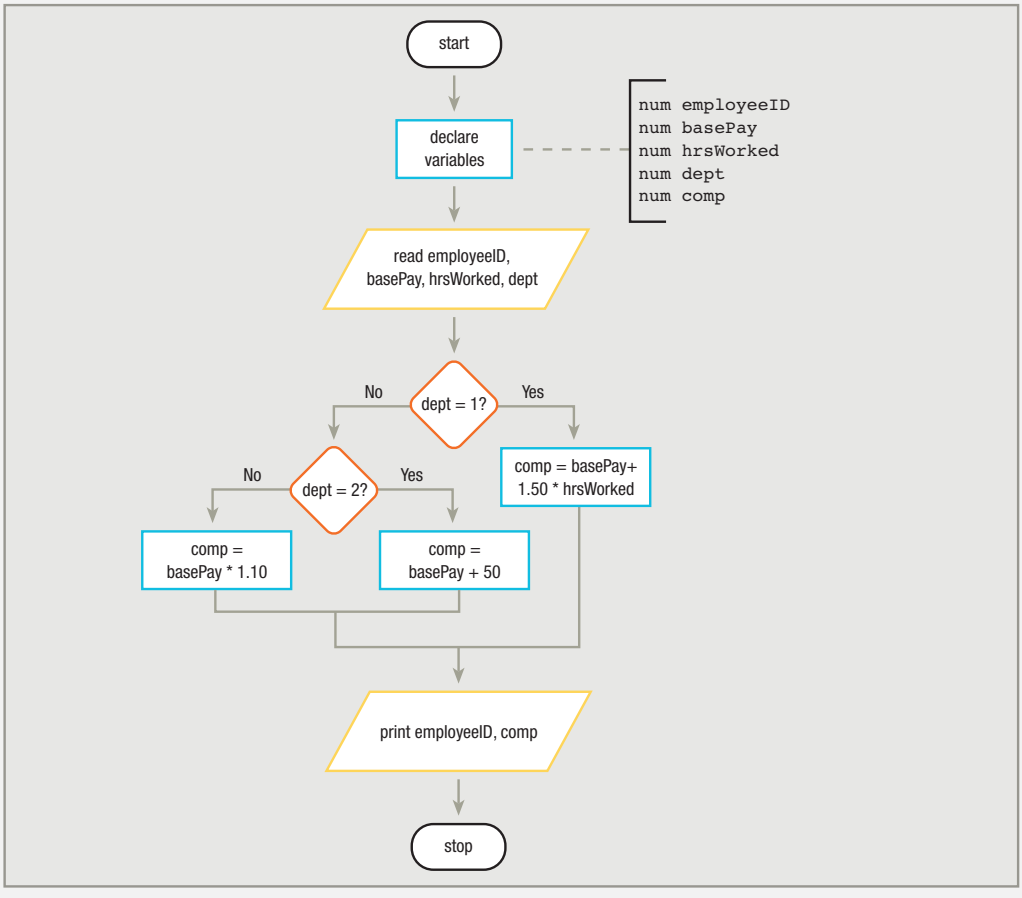
```
start
   declare variables
      num gallonsOfGasUsed
      num milesTraveled
      num pricePerGallon
      num milesPerGallon
      num costPerMile
   perform inputData()
   perform computeStatistics()
   perform displayResults()

inputData()
   input gallonsOfGasUsed
   input milesTravelled
   input pricePerGallonOfGas
return

computeStatistics()
   milesPerGallon = gallonsOfGasUsed / milesTraveled
   costPerMile = pricePerGallon - milesPerGallon
return

displayResults()
   print milesPerGal
   print costPerMile
return
stop
```

3. **This pseudocode segment is intended to describe computing the cost per day for a vacation. The user enters a value for total dollars available to spend and can continue to enter new dollar amounts while the amount entered is not 0. For each new amount entered, a module is called that calculates the amount of money available to spend per day.**

```
start
   declare variables
      num totalDollars
      num costPerDay
   input totalDollarsSpent
   while totalDollarsSpent = 0
      perform caclulateCost()
   endwhile
end
calculateCost()
   costPerDay = totalMoneySpent / 7
   print costPerDay
endwhile
```

EXERCISES

1. Redraw the following flowchart so that the decisions and compensation calculations are in a module.



2. Rewrite the following pseudocode so the discount decisions and calculations are in a module.

```
start
   read customerRecord
   if quantityOrdered > 100 then
        discount = .20
   else
        if quantityOrdered > 12 then
             discount = .10
        endif
   endif
   total = priceEach * quantityOrdered
   total = total - discount * total
   print total
stop
```

3. What are the final values of variables a, b, and c after the following program runs?

```
start
     a = 2
     b = 4
     c = 10
     while c > 6
          perform changeBAndC()
     endwhile
     if a = 2 then
          perform changeAAndB()
     endif
     if c = 10 then
          perform changeAAndB()
     else
          perform changeBAndC()
     endif
     print a, b, c
stop
changeBAndC()
     b = b + 1
     c = c - 1
return
changeAAndB()
     a = a + 1
     b = b - 1
return
```

4. What are the final values of variables d, e, and f after the following program runs?

```
start
     d = 1
     e = 3
     f = 100
     while e > d
          perform module1()
     endwhile
     if f > 0 then
          perform module2()
     else
          d = d + 5
     endif
     print d, e, f
stop
module1()
     f = f - 50
     e = e + 1
     d = d + 3
return

module2()
     f = f + 13
     d = d * 10
return
```

5. **Draw a typical hierarchy chart for a paycheck-producing program. Try to think of at least 10 separate modules that might be included. For example, one module might calculate an employee's dental insurance premium.**

6. **a.** Design a print chart for a payroll roster that is intended to list the following items for every employee: employee's first name, last name, and salary.
   b. Design sample output for the same report, including at least three lines of data.

7. **a.** Design a print chart for a payroll roster that is intended to list the following items for every employee: employee's first name, last name, hours worked, rate per hour, gross pay, federal withholding tax, state withholding tax, union dues, and net pay.
   b. Design sample output for the same report, including at least three lines of data.

8. **Given the following input file description, determine whether there is enough information provided to produce each of the requested reports:**

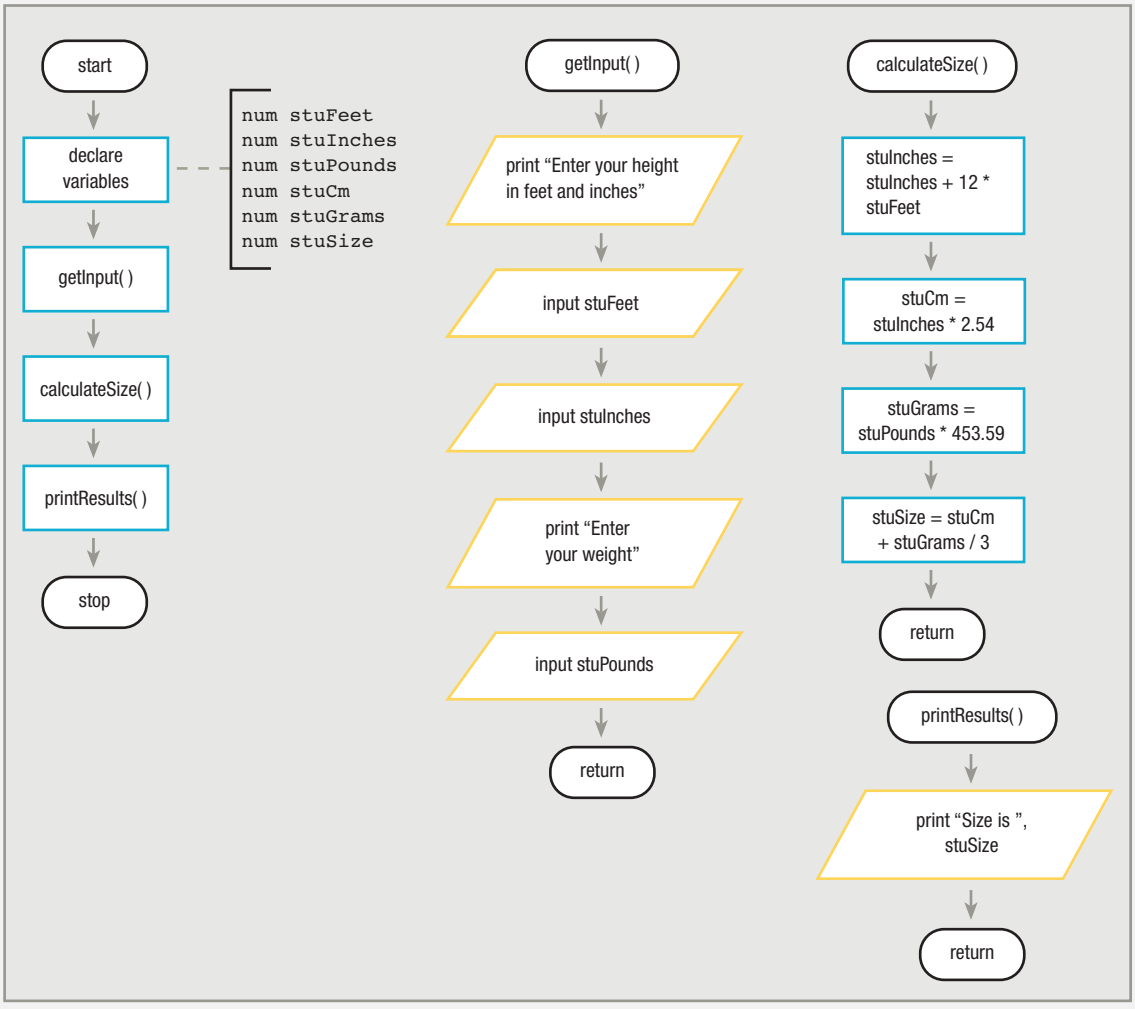
```
INSURANCE PREMIUM LIST
File name: INSPREM
FIELD DESCRIPTION             DATA TYPE    COMMENTS
Name of insured driver        Character    40 bytes
Birth date                    Numeric      8 digits (for example, 19820624)
Gender                        Numeric      1 or 2 for male or female
Make of car                   Character    10 bytes
Year of car                   Numeric      4 digits
Miles driven per year         Numeric      0 decimal places
Number of traffic tickets     Numeric      0 decimal places
Balance owed                  Numeric      2 decimal places
```

   a. a list of the names of all insured drivers
   b. a list of very high-risk insured drivers, defined as male, under 25 years old, with more than two tickets
   c. a list of low-risk insured drivers, defined as those with no tickets in the last three years, and over 30 years old
   d. a list of insured drivers to contact about a special premium offer for those with a passenger car who drive under 10,000 miles per year
   e. a list of the names of female drivers whose balance owed is more than $99.99

9. **Given the INSPREM file description in Exercise 8, design a print chart or sample report to satisfy each of the following requests:**

   a. a list of every driver's name and make of car
   b. a list of the names of all insured drivers who drive more than 20,000 miles per year
   c. a list of the name, gender, make of car, and year of car for all drivers who have more than two tickets
   d. a report that summarizes the number of tickets held by drivers who were born in 1940 or before, from 1941–1960, from 1961–1980, and from 1981 on
   e. a report that summarizes the number of tickets held by drivers in the four birth-date categories listed in part d, grouped by gender

10. A program calculates the gown size that a student needs for a graduation ceremony. The program accepts as input a student's height in feet and inches and weight in pounds. It converts the student's height to centimeters and weight to grams. Then, it calculates the graduation gown size needed by adding ⅛ of the weight in grams to the value of the height in centimeters. Finally, the program prints the results. There are 2.54 centimeters in an inch and 453.59 grams in a pound. Write the pseudocode that matches the following flowchart.



11. A program calculates the service charge a customer owes for writing a bad check. The program accepts a customer's name, the date the check was written (year, month, and day), the current date (year, month, and day), and the amount of the check in dollars and cents. The service charge is $20 plus 2 percent of the amount of the check, plus $5 for every month that has passed since the check was written. Draw the flowchart that matches the pseudocode.

(This pseudocode assumes that all checks entered are already written—that is, their dates are prior to today's date. Additionally, a check is one month late as soon as a new month starts—so a bad check written on September 30 is one month overdue on October 1.)

```
start
     declare variables
          char custName
          num checkYear
          num checkMonth
          num checkDay
          num todayYear
          num todayMonth
          num todayDay

          num checkAmount
          num serviceCharge
          num baseCharge
          num extraCharge
          num yearsLate
          num monthsLate
          num todayWorkField
     perform getInput()
     perform calculateServiceCharge()
     perform printResults()

stop

getInput()
     print "Enter customer name"
     input custName
     perform getDates()
     print "Enter check amount"
     input checkAmount
return

getDates()
    print "Enter the date of the check"
    input checkYear
    input checkMonth
    input checkDay
    print "Enter today's date"
    input todayYear
    input todayMonth
    input todayDay

return

calculateServiceCharge()
    baseCharge = 20.00
    extraCharge = .02 * checkAmount
    yearsLate = todayYear - checkYear
    todayWorkField = yearsLate * 12 +
        todayMonth
    monthsLate = todayWorkField -
        checkMonth
    serviceCharge = baseCharge +
        extraCharge + monthsLate * 5
return


printResults()
    print custName, serviceCharge
return
```

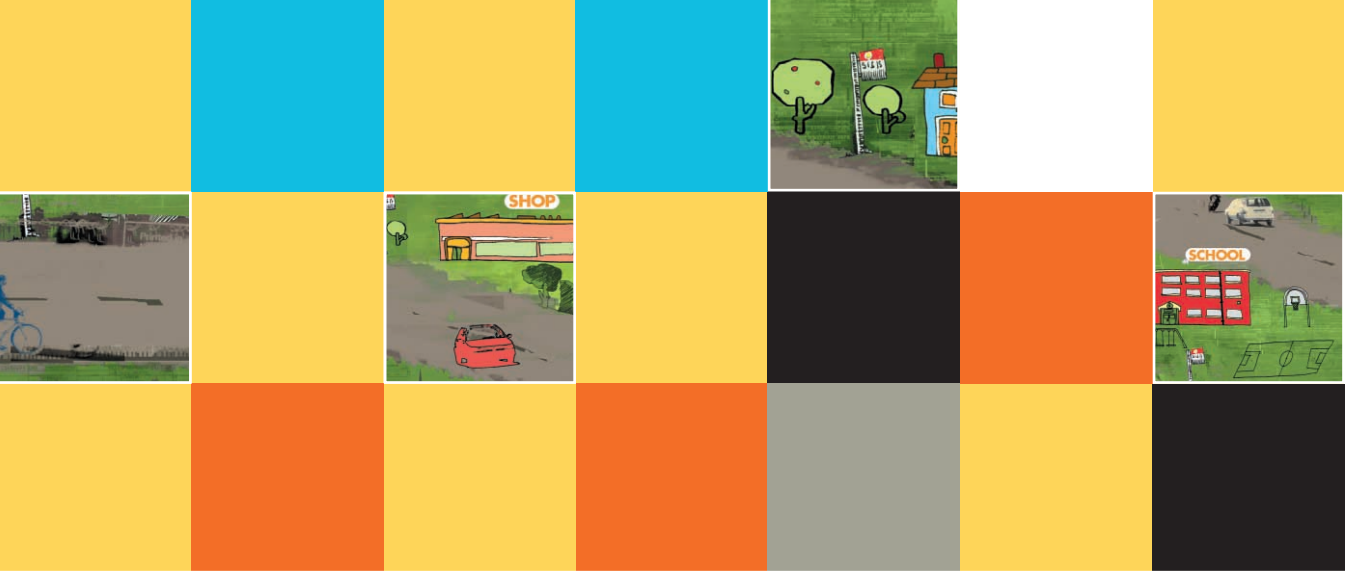
12. Draw the hierarchy chart that corresponds to the pseudocode presented in Exercise 11.

DETECTIVE WORK

1. **Explore the job opportunities in technical writing. What are the job responsibilities? What is the average starting salary? What is the outlook for growth?**
2. **What is subject-oriented programming?**

UP FOR DISCUSSION

1. **Would you prefer to be a programmer, write documentation, or both? Why?**
2. **Would you prefer to write a large program by yourself, or work on a team in which each programmer produces one or more modules? Why?**
3. **Can you think of any disadvantages to providing program documentation for other programmers or for the user?**



4 DESIGNING AND WRITING A COMPLETE PROGRAM

After studying Chapter 4, you should be able to:

- Plan the mainline logic for a complete program
- Describe typical housekeeping tasks
- Describe tasks typically performed in the main loop of a program
- Describe tasks performed in the end-of-job module
- Understand the need for good program design
- Appreciate the advantages of storing program components in separate files
- Select superior variable and module names
- Design clear module statements
- Understand the need for maintaining good programming habits

UNDERSTANDING THE MAINLINE LOGICAL FLOW THROUGH A PROGRAM

In the first chapters of this book, you gained an understanding of programming structures, and learned about the documentation needed for program input, processing, and output. Now, you're ready to plan the logic for your first complete computer program. The output is an inventory report; a print chart is shown in Figure 4-1. The report lists inventory items along with the price, cost, and profit of each item.

FIGURE 4-1: PRINT CHART FOR INVENTORY REPORT

```
                    1         2         3         4         5         6
          1234567890123456789012345678901234567890123456789012345678901
 1
 2                            INVENTORY REPORT
 3
 4        ITEM                RETAIL PRICE    MANUFACTURING    PROFIT PER
 5        DESCRIPTION         EACH            COST EACH        ITEM
 6
 7        XXXXXXXXXXXXXXX     999.99          999.99           999.99
 8        XXXXXXXXXXXXXXX     999.99          999.99           999.99
 9
10
11
12
13
14
```

Figure 4-2 shows the input INVENTORY file description, Figure 4-3 shows some typical data that might exist in the input file, and Figure 4-4 shows how the output would actually look if the input file in Figure 4-3 were used.

FIGURE 4-2: INVENTORY FILE DESCRIPTION

```
INVENTORY FILE DESCRIPTION
File name: INVENTORY
FIELD DESCRIPTION       DATA TYPE     COMMENTS
Item name               Character     15 bytes
Price                   Numeric       2 decimal places
Cost                    Numeric       2 decimal places
Quantity in stock       Numeric       0 decimal places
```

FIGURE 4-3: TYPICAL DATA THAT MIGHT BE STORED IN INVENTORY FILE

```
cotton shirt     01995     01457     2500
wool scarf       01450     01125     0060
silk blouse      16500     04850     0525
cotton shorts    01750     01420     1500
```

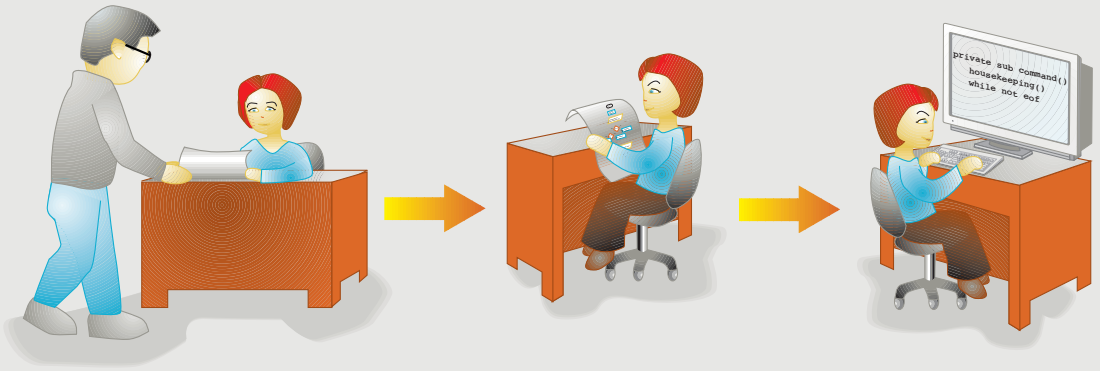
FIGURE 4-4: TYPICAL OUTPUT FOR INVENTORY REPORT PROGRAM

```
                    INVENTORY REPORT

ITEM              RETAIL PRICE  MANUFACTURING  PROFIT PER
DESCRIPTION       EACH          COST EACH      ITEM

cotton shirt       19.95          14.57           5.38
wool scarf         14.50          11.25           3.25
silk blouse       165.00          48.50         116.50
cotton shorts      17.50          14.20           3.30
```

TIP In some older operating systems, file names are limited to eight characters, in which case INVENTORY might be an unacceptable file name.

Examine the print chart and the input file description. Your first task is to make sure you understand what the report requires; your next job is to determine whether you have all the data you need to produce the report. (Figure 4-5 shows this process.) The output requires the item name, price, and cost, and you can see that all three are data items in the input file. The output also requires a profit figure for each item; you need to understand how profit is calculated—which could be done differently in various companies. If there is any doubt as to what a term used in the output means or how a value is calculated, you must ask the **user**, or your **client**—the person who has requested the program and who will read and use the report to make management decisions. In this case, suppose you are told you can determine the profit by subtracting an item's cost from its selling price. The input record contains an additional field, "Quantity in stock". Input records often contain more data than an application needs; in this example, you will not use the quantity field. You have all the necessary data, so you can begin to plan the program.

FIGURE 4-5: STEPS TO CREATING A PROGRAM



Understand the user's needs. Examine input and output specifications.

Develop the logic that will produce the desired output.

Code the logic using a programming language.

TIP

It is very common for input records to contain more data than an application uses. For example, although your doctor stores your blood pressure in your patient record, that field does not appear on your bill, and although your school stores your grades from your first semester, they do not appear on your report card for your second semester.

Where should you begin? It's wise to try to understand the big picture first. You can write a program that reads records from an input file and produces a printed report as a **procedural program**—that is, a program in which one procedure follows another from the beginning until the end. You write the entire set of instructions for a procedural program, and when the program executes, instructions take place one at a time, following your program's logic. The overall logic, or **mainline logic**, of almost every procedural computer program can follow a general structure that consists of three distinct parts:

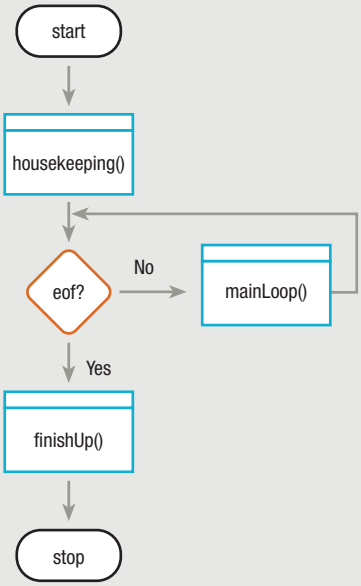
1. Performing housekeeping, or initialization tasks. **Housekeeping** includes steps you must perform at the beginning of a program to get ready for the rest of the program.
2. Performing the main loop repeatedly within the program. The **main loop** contains the instructions that are executed for every record until you reach the end of the input of records, or `eof`.
3. Performing the end-of-job routine. The **end-of-job routine** holds the steps you take at the end of the program to finish the application.

TIP

Not all programs are procedural; some are object-oriented. A distinguishing feature of many (but not all) object-oriented programs is that they are event-driven; often the user determines the timing of events in the main loop of the program by using an input device such as a mouse. As you advance in your knowledge of programming, you will learn more about object-oriented techniques.

You can write any procedural program as one long series of programming language statements, but programs are easier to understand if you break their logic down into at least three parts, or modules. The main program can call the three major modules, as shown in the flowchart and pseudocode in Figure 4-6. Of course, the names of the modules, or subroutines, are entirely up to the programmer.

FIGURE 4-6: FLOWCHART AND PSEUDOCODE OF MAINLINE LOGIC




```
start
   perform housekeeping()
   while not eof
      perform mainLoop()
   endwhile
   perform finishUp()
stop
```

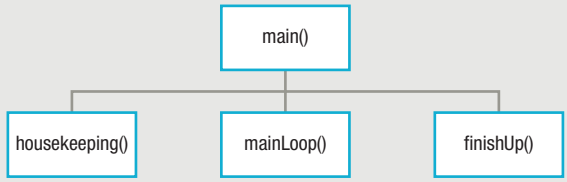
TIP Reducing a large program into more manageable modules is sometimes called **functional decomposition**.

TIP In later examples, this book will use more descriptive names for the `mainLoop()` module. For example, in this program, appropriate names for the `mainLoop()` might be `processRecord()` or `createInventoryReport()`.

Figure 4-7 shows the hierarchy chart for this program.

In summary, breaking down a big program into three basic procedures, or modularizing the program, helps keep the job manageable, allowing you to tackle a large job one step at a time. Dividing the work into routines also might allow you to assign the three major procedures to three different programmers, if you choose. It also helps you keep the program structured.

FIGURE 4-7: HIERARCHY CHART FOR INVENTORY REPORT PROGRAM



HOUSEKEEPING TASKS

Housekeeping tasks include all the steps that must take place at the beginning of a program. Very often, this includes four major tasks:

- You declare variables.
- You open files.
- You perform any one-time-only tasks that should occur at the beginning of the program, such as printing headings at the beginning of a report.
- You read the first input record.

DECLARING VARIABLES

Your first task in writing any program is to declare variables. When you declare variables, you assign reasonable names (identifiers) to memory locations, so you can store and retrieve data there. Declaring a variable involves selecting a name and a type. When you declare a variable in program code, the operating system reserves space in memory to hold the contents of the variable. It uses the type (`num` or `char`) to determine how to store the information; it stores numeric and character values in different formats.

For example, within the inventory report program, you need to supply variable names for the data fields that appear in each input record. You might decide on the variable names and types shown in Figure 4-8.

FIGURE 4-8: VARIABLE DECLARATIONS FOR THE INVENTORY FILE

```
char   invItemName
num    invPrice
num    invCost
num    invQuantity
```

TIP

Some languages require that you provide storage size, in addition to a type and name, for each variable. Other languages provide a predetermined amount of storage based on the variable type: for example, four bytes for an integer or one byte for a character. Also, many languages require you to provide a length for strings of characters. For simplicity, this book just declares variables as either character or numeric.

You can provide any names you choose for your variables. When you write another program that uses the same input file, you are free to choose completely new variable names. Similarly, other programmers can write programs that use the same file and choose their own variable names. The variable names just represent memory positions, and are internal to your program. The files do not contain any variable names; files contain only data. When you read the characters "cotton shirt" from an input file, it doesn't matter whether you store those characters at a memory location named `invItemName`, `nameOfItem`, `productDescription`, or any other one-word variable name. The variable name is simply an easy-to-remember name for a specific memory address where those characters are stored.

TIP

Programmers always must decide between descriptive, but long, variable names and cryptic, but short, variable names. In general, more descriptive names are better, but certain abbreviations are almost always acceptable in the business world. For example, SSN is commonly used as an abbreviation for Social Security number, and if you use it as a variable name, it will be interpreted correctly by most of your associates who read your program.

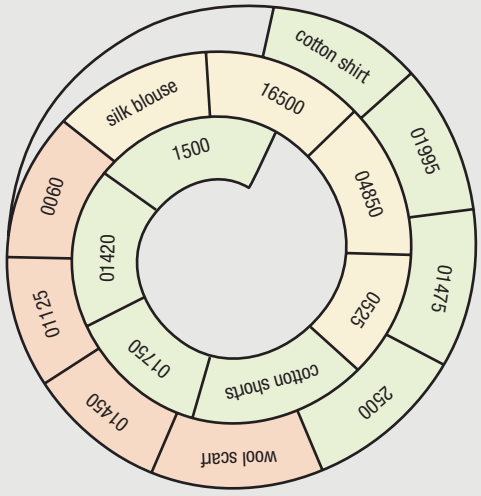
Each of the four variable declarations in Figure 4-8 contains a type (character or numeric) and an identifier. You can choose any one-word name to identify the variable, but a typical practice involves beginning similar variables with a common **prefix**—for example, `inv`. In a large program in which you eventually declare dozens of variables, the `inv` prefix will help you immediately identify a variable as part of the inventory file.

TIP

Organizations sometimes enforce different rules for programmers to follow when naming variables. Some use a variable-naming convention called **Hungarian notation**, in which a variable's data type or other information is stored as part of the name. For example, a numeric field might always start with the prefix `num`.

Creating the inventory report as planned in Figure 4-1 involves using the `invItemName`, `invPrice`, and `invCost` fields, but you do not need to use the `invQuantity` field in this program. However, the information regarding quantity does take room in the input file, so you typically declare the variable to allocate space for it when it is read into memory. If you imagine the surface of a disk as pictured in Figure 4-9, you can envision how the data fields follow one another in the file.

FIGURE 4-9: HOW TYPICAL DATA ITEMS LOOK WITHIN AN INVENTORY FILE



When you ask the program to read an inventory record, four "chunks" of data will be transferred from the input device to the computer's main memory: name, price, cost, and quantity. When you declare the variables that represent the input data, you must provide a memory position for each of the four pieces of data, whether or not they all are used within this program.

TIP

Some languages do not require you to use a unique name for each data field in an input record. For example, in COBOL, you can use the generic name FILLER for all unused data positions. This frees you from the task of creating variable names for items you do not intend to use. Because it is common to do so using newer languages, the examples in this book always provide a unique identifier for each variable in a file.

TIP

Considering that dozens of programs within the organization might access the INVENTORY file, some organizations create the data file descriptions for you. This system is efficient because the description of variable names and types is stored in one location, and each programmer who uses the file simply imports the data file description into his or her own program. Of course, the organization must provide the programmer with documentation specifying and describing the chosen names.

In most programming languages, you can give a group of associated variables a **group name**. This allows you to handle several associated variables using a single instruction. Just as it is easier to refer to "The Andersons" than it is to list "Nancy, Bud, Jim, Tom, Julie, Jane, Kate, and John," the benefit of using a group name is the ability to reference several variables with one all-encompassing name. For example, if you group four fields together and call them `invRecord`, then you can write a statement such as `read invRecord`. This is simpler than writing `read invItemName`, `invPrice`, `invCost`, and `invQuantity`. The way you assign a group name to several variables differs in each programming language. This book follows the convention of underlining any group name and indenting the group members beneath, as shown in Figure 4-10.

FIGURE 4-10: VARIABLE DECLARATIONS FOR THE INVENTORY FILE INCLUDING A GROUP NAME

```
invRecord
   char   invItemName
   num    invPrice
   num    invCost
   num    invQuantity
```

TIP A group of variables is often called a *data structure*, or more simply, a *structure*. Some object-oriented languages refer to a group as a *class*, although a class often contains method definitions as well as variables.

TIP In many programming languages, you can use the group name along with the field name, separated by a dot. For example, you might refer to `invRecord.invItemName`. This book will use the field name only, for simplicity.

TIP The ability to group variable names does not automatically provide you with the ability to perform every sort of operation with a group. For example, you cannot multiply or divide one `invRecord` by another (unless, with some languages, you write special code to do so). In this book, assume that you can use one input or output statement on a set of fields that constitute a record.

In addition to declaring variables, sometimes you want to provide a variable with an initial value. Providing a variable with a value when you create it is known as **initializing**, or **defining**, **the variable**. For example, for the inventory report print chart shown in Figure 4-1, you might want to create a variable named `mainHeading` and store the value "INVENTORY REPORT" in that variable. The declaration is `char mainHeading = "INVENTORY REPORT"`. This indicates that `mainHeading` is a character variable, and that the character contents are the words "INVENTORY REPORT".

TIP *Declaring* a variable provides it with a name and type. *Defining*, or declaring and initializing, a variable also provides it with a value. If you declare a variable, but do not provide a value, you can always initialize it later.

TIP In some programming languages, you can declare a variable such as `mainHeading` to be constant, or never changing. Even though `invItemName`, `invPrice`, and the other fields in the input file will hold a variety of values when a program executes, the `mainHeading` value will never change.

In many programming languages, if you do not provide an initial value when declaring a variable, then the value is unknown, or **garbage**. Some programming languages do provide you with an automatic starting value; for example, in Java, Visual Basic, BASIC, or RPG, all numeric variables automatically begin with the value zero. However, in C++, C#, Pascal, and COBOL, variables generally do not receive any initial value unless you provide one. No matter which programming language you use, it is always clearest to provide a value for those variables that require them.

TIP Be especially careful to make sure all variables you use in calculations have initial values. If you attempt to perform arithmetic with garbage values, either the program will fail to execute, or worse, the result will also contain garbage.

When you declare the variables `invItemName`, `invPrice`, `invCost`, and `invQuantity`, you do not provide them with any initial value. The values for these variables will be assigned when the first file record is read into memory. It would be *legal* to assign a value to input file record variables—for example, `invItemName = "cotton shirt"`—but it would be a waste of time and might mislead others who read your program. The first `invItemName` will come from an input device, and may or may not be "cotton shirt".

The report illustrated in Figure 4-1 contains three individual heading lines. The most common practice is to declare one variable or constant for each of these lines. The three declarations are as follows:

```
char mainHeading = "INVENTORY REPORT"
char columnHead1 = "ITEM          RETAIL PRICE
    MANUFACTURING       PROFIT PER"
char columnHead2 = "DESCRIPTION  EACH
    COST EACH           ITEM"
```

Within the program, when it is time to write the heading lines to an output device, you will code:

```
print mainHeading
print columnHead1
print columnHead2
```

You are not required to create variables for your headings. Your program can contain the following statements, in which you use literal strings of characters instead of variable names. The printed results are the same either way.

```
print "INVENTORY REPORT"
print "ITEM          RETAIL PRICE   MANUFACTURING    PROFIT PER"
print "DESCRIPTION   EACH           COST EACH        ITEM"
```

Using variable names, as in `print mainHeading`, is usually more convenient than spelling out the heading's contents within the statement that prints, especially if you will use the headings in multiple locations within your program. Additionally, if the contents of all of a program's heading lines can be found in one location at the start of the program, it is easier to locate them all if changes need to be made in the future.

TIP

When you write a program, you type spaces between the words within column headings so the spacing matches the print chart you created for the program. For convenience, some languages provide you with a tab character. Other languages let you specify a numeric position where a column heading will display. The goal is to provide well-spaced output in readable columns.

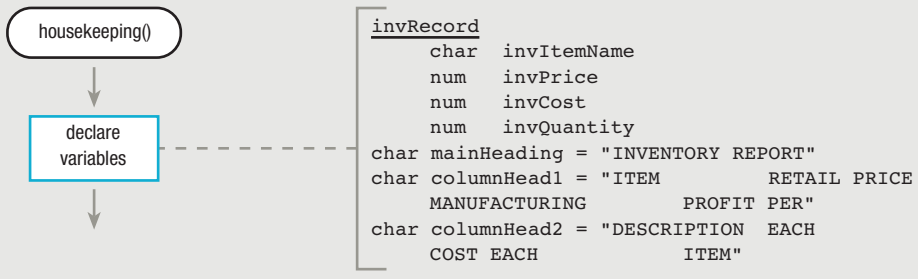
Dividing the headings into three lines is not required either, but it is a common practice. In most programming languages, you could write all the headings in one statement, using a code that indicates a new line at every appropriate position. Alternatively, most programming languages let you produce a character for output without advancing to a new line. You could write out the headings using separate print statements to display one character at a time, advancing to a

new line only after all the line's characters were individually printed, although this approach seems painstakingly detailed. Storing and writing one complete line at a time is a reasonable compromise.

Every programming language provides you with a means to physically advance printer paper to the top of a page when you print the first heading. Similarly, every language provides you with a means to produce double- and triple-spaced lines of text by sending specific codes to the printer or monitor. Because the methods and codes differ from language to language, examples in this book assume that if a print chart or sample output shows a heading that prints at the top of the page and then skips a line, any corresponding variable you create, such as `mainHeading`, will also print in this manner. You can add the appropriate language-specific codes to implement the `mainHeading` spacing when you write the actual computer program. Similarly, if you create a print chart that shows detail lines as double-spaced, assume your detail lines will double-space when you execute the step to write them.

Often, you must create dozens of variables when you write a computer program. If you are using a flowchart to diagram the logic, it is physically impossible to fit the variables in one flowchart box. Therefore, you might want to use an annotation symbol. The beginning of a flowchart for the `housekeeping()` module of the inventory report program is shown in Figure 4-11.

FIGURE 4-11: BEGINNING OF FLOWCHART FOR `housekeeping()` MODULE FOR THE INVENTORY REPORT PROGRAM



TIP You learned about the annotation symbol in Chapter 3.

Notice that the three heading variables defined in Figure 4-11 are not indented under `invRecord` as the `invRecord` fields are. This shows that although `invItemName`, `invPrice`, `invCost`, and `invQuantity` are part of the `invRecord` group, `mainHeading`, `columnHead1`, and `columnHead2` are not.

In Figure 4-11, notice that `columnHead1` contains only the words that appear in the first line of column headings, in row 4 of the print chart in Figure 4-1: "ITEM RETAIL PRICE MANUFACTURING PROFIT PER". Similarly, `columnHead2` contains only the words that appear in the second row of column headings.

OPENING FILES

If a program will use input files, you must tell the computer where the input is coming from—for example, a specific disk drive, CD, or tape drive. You also must indicate the name (and possibly the path, the list of folders or directories in which the file resides) for the file. Then you must issue a command to **open the file**, or prepare it for reading. In many languages, if no input file is opened, input is accepted from a default or **standard input device**, most often the keyboard.

If a program will have output, you must also open a file for output. Perhaps the output file will be sent to a disk or tape. Although you might not think of a printed report as a file, computers treat a printer as just another output device, and if output will go to a printer, then you must open the printer output device as well. Again, if no file is opened, a default or **standard output device**, usually the monitor, is used.

When you create a flowchart, you usually write the command to open the files within a parallelogram. You use the parallelogram because it is the input/output symbol, and you are opening the input and output devices. You can use an annotation box to list the files that you open, as shown in Figure 4-12.

FIGURE 4-12: SPECIFYING FILES THAT YOU OPEN

A ONE-TIME-ONLY TASK—PRINTING HEADINGS

Within a program's housekeeping module, besides declaring variables and opening files, you perform any other tasks that occur only at the beginning of the program. A common housekeeping task involves printing headings at the top of a report. In the inventory report example, three lines of headings appear at the beginning of the report. In this example, printing the heading lines is straightforward:

```
print mainHeading
print columnHead1
print columnHead2
```

READING THE FIRST INPUT RECORD

The last task you execute in the housekeeping module of most computer programs is to read the first data record into memory. In this example, the input data is read from a stored file. Other applications might be **interactive applications**—that is, applications that interact with a user who types data at a keyboard. When you write your first computer programs, you probably will use interactive input so that you don't have to complicate the programs by including the statements necessary to locate and open an input file. To read the necessary data interactively from the user, you could issue a statement such as the following:

```
read invItemName, invPrice, invCost, invQuantity
```

The statement would pause program execution until the user typed four values from the keyboard, typically separating them with a **delimiter**, or character produced by a keystroke that separates data items. Depending on the programming language, the delimiter might be the Enter key, the tab character, or a comma.

Requiring a user to type four values in the proper order is asking a lot. More frequently, the read statement would be separated into four distinct read statements, each preceded by an output statement called a **prompt** that asks the user for a specific item. For example, the following set of statements prompts the user for and accepts each of the necessary data items for the inventory program:

```
print "Please enter the inventory item name"
read invItemName
print "Enter the price"
read invPrice
print "Enter the cost of the item"
read invCost
print "Enter the quantity in stock"
read invQuantity
```

If the four data fields have already been stored and are input from a data file instead of interactively, then no prompts are needed, and you can write the following:

```
read invItemName, invPrice, invCost, invQuantity
```

In most programming languages, if you have declared a group name such as `invRecord`, it is simpler to obtain values for all the data fields by writing the following:

```
read invRecord
```

This statement fills the entire group item with values from the input file. Using the group name is a shortcut for writing each field name. When you write your first programs, you might get your data interactively, in which case you will write prompts and separate input statements, or you might obtain input from a data file, but delay studying how to create group items, so you might list each field separately. For simplicity, most of the input statements in this book will assume the data comes from files and is grouped; this assumption will allow the book to use the shortest version of the statement that simply means "obtain all the data fields this application needs."

CHECKING FOR THE END OF THE FILE

The last task within the `housekeeping()` module is to read the first `invRecord`; the first task following `housekeeping()` is to check for `eof` on the file that contains the inventory records. If the program is an interactive one, the user might indicate that input is complete by typing a predetermined value from the keyboard, or using a mouse to select a screen option indicating completion of data entry. If the program reads data from an input file stored on a disk, tape, or other storage device, the input device recognizes that it has reached the end of a file when it

attempts to read a record and finds no records available. Recall the mainline logic of the inventory report program from Figure 4-6—`eof` is tested immediately after `housekeeping()` ends.

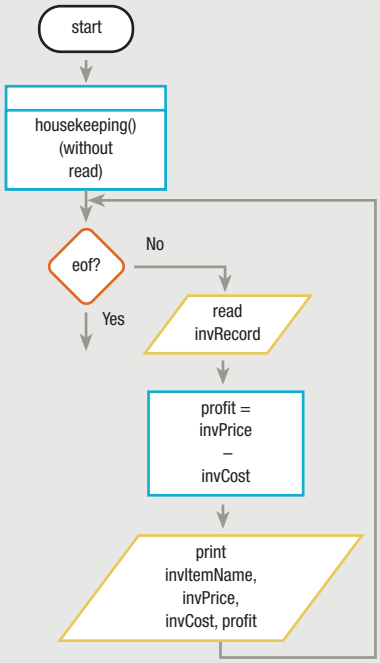
If the input file has no records, when you read the first record the computer recognizes the end-of-file condition and proceeds to the `finishUp()` module, never executing `mainLoop()`. More commonly, an input file does have records, and after the first `read` the computer determines that the `eof` condition is false, and the logic proceeds to `mainLoop()`.

Immediately after reading from a file, the next step always should determine whether `eof` was encountered. Notice in Figure 4-6 that the `eof` question always follows both the `housekeeping()` module and the `mainLoop()` module. When the last instruction in each of these modules reads a record, then the `eof` question correctly follows each `read` instruction immediately.

Not reading the first record within the `housekeeping()` module is a mistake. If `housekeeping()` does not include a step to read a record from the input file, you must read a record as the first step in `mainLoop()`, as shown on the left side of Figure 4-13. In this program, a record is read, a profit is calculated, and a line is printed. Then, if it is not `eof`, another record is read, a profit calculated, and a line printed. The program works well, reading records, calculating profits, and printing information until reaching a `read` command in which the computer encounters the `eof` condition. When this last read occurs, the next steps involve computing a profit and writing a line—but there isn't any data to process. Depending on the programming language you use, either garbage data will calculate and print, or a repeat of the data from the last record before `eof` will print.

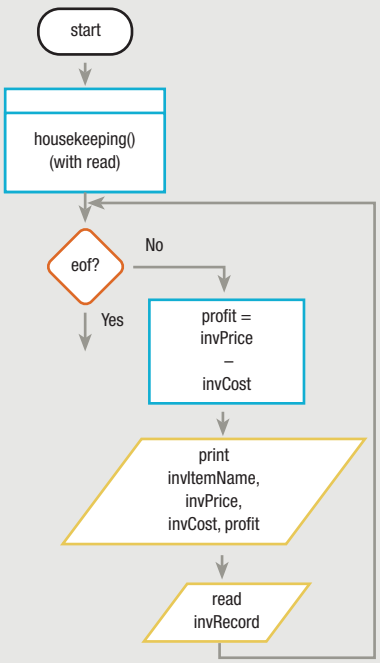
FIGURE 4-13: COMPARING FAULTY AND CORRECT RECORD-READING LOGIC

FAULTY RECORD-READING LOGIC




```
start
     perform housekeeping() (without read)
     while not eof
          read invRecord
          profit = invPrice - invCost
          print invItemName, invPrice, invCost, profit
     endwhile
```

CORRECT RECORD-READING LOGIC




```
start
     perform housekeeping() (with read)
     while not eof
          profit = invPrice - invCost
          print invItemName, invPrice, invCost, profit
          read invRecord
     endwhile
```

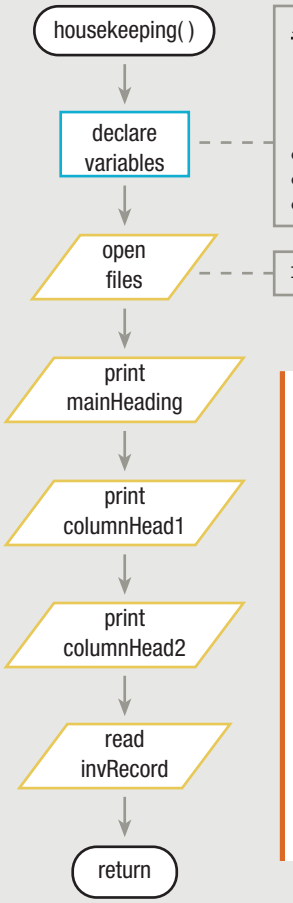
TIP Reading an input record in the `housekeeping()` module is an example of a priming read. You learned about the priming read in Chapter 2.

TIP In some modern programming languages, such as Visual Basic, file read commands can look ahead to determine if the *next* record is empty. With these languages, the priming read is no longer necessary. Because most languages do not currently have this type of read statement, and because the priming read is always necessary when input is based on user response rather than reading from a file, this book uses the conventional priming read.

The flowchart in the lower part of Figure 4-13 shows correct record-reading logic. The appropriate place for the priming record **`read`** is at the end of the preliminary housekeeping steps, and the appropriate place for all subsequent reads is at the end of the main processing loop.

Figure 4-14 shows a completed **`housekeeping()`** routine for the inventory program in both flowchart and pseudocode versions.

FIGURE 4-14: FLOWCHART AND PSEUDOCODE FOR **`housekeeping()`** ROUTINE IN INVENTORY REPORT PROGRAM



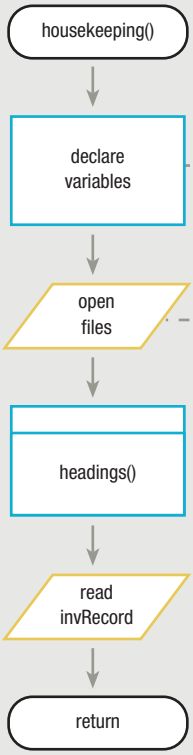

```
invRecord
     char  invItemName
     num   invPrice
     num   invCost
     num   invQuantity
char mainHeading = "INVENTORY REPORT"
char columnHead1 = "ITEM RETAIL PRICE MANUFACTURING PROFIT PER"
char columnHead2 = "DESCRIPTION EACH    COST EACH     ITEM"
```

```
INVENTORY, Printer
```

```
housekeeping()
   declare variables
      invRecord
         char invItemName
         num  invPrice
         num  invCost
         num  invQuantity
      char mainHeading = "INVENTORY REPORT"
      char columnHead1 =
       "ITEM     RETAIL PRICE  MANUFACTURING  PROFIT PER"
      char columnHead2 =
        "DESCRIPTION EACH        COST EACH  ITEM"
   open files
   INVENTORY, Printer
   print mainHeading
   print columnHead1
   print columnHead2
   read invRecord
return
```

As an alternative to including `print mainHeading`, `print columnHead1`, and `print columnHead2` within the `housekeeping()` module, you can place the three heading line statements in their own module. In this case, the flowchart and pseudocode for `housekeeping()` will look like Figure 4-15, with the steps in the newly created `headings()` module appearing in Figure 4-16. Either approach is fine; the logic of the program is the same whether or not the heading line statements are segregated into their own routine. The programmer can decide on the program organization that makes the most sense.

FIGURE 4-15: FLOWCHART AND PSEUDOCODE FOR ALTERNATIVE `housekeeping()` MODULE THAT CALLS `headings()` MODULE

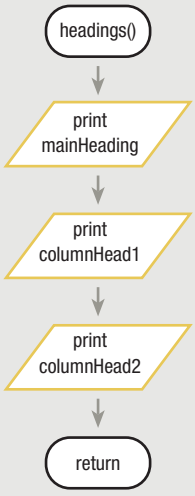



```
invRecord
     char  invItemName
     num   invPrice
     num   invCost
     num   invQuantity
char mainHeading = "INVENTORY REPORT"
char columnHead1 = "ITEM RETAIL PRICE MANUFACTURING PROFIT PER"
char columnHead2 = "DESCRIPTION EACH  COST EACH     ITEM"
```

```
INVENTORY, Printer
```

```
housekeeping()
     declare variables
          invRecord
              char invItemName
              num invPrice
              num invCost
              num invQuantity
          char mainHeading = "INVENTORY REPORT"
          char columnHead1 = "ITEM   RETAIL PRICE   MANUFACTURING
               PROFIT PER"
          char columnHead2 = "DESCRIPTION EACH COST EACH    ITEM"
     open files
          INVENTORY, Printer
     perform headings()
     read invRecord
return
```

FIGURE 4-16: FLOWCHART AND PSEUDOCODE FOR `headings()` MODULE CALLED BY MAINLINE IN FIGURE 4-15




```
headings()
   print mainHeading
   print columnHead1
   print columnHead2
return
```

WRITING THE MAIN LOOP

After you declare the variables for a program and perform the housekeeping tasks, the "real work" of the program begins. The inventory report described at the beginning of this chapter and depicted in Figure 4-1 needs just one set of variables and one set of headings, yet there might be hundreds or thousands of inventory items to process. The main loop of a program, controlled by the `eof` decision, is the program's "workhorse." Each data record will pass once through the main loop, where calculations are performed with the data and the results printed.

TIP If the inventory report contains more records than will fit on a page of output, you probably will want to print a new set of headings at the top of each page. You will learn how to do this in Chapter 7.

For the inventory report program to work, the `mainLoop()` module must include three steps:

1. Calculate the profit for an item.
2. Print the item information on the report.
3. Read the next inventory record.

At the end of `housekeeping()`, you read one data record into the computer's memory. As the first step in `mainLoop()`, you can calculate an item's profit by subtracting its manufacturing cost from its retail price: `profit = invPrice - invCost`. The name `profit` is the programmer-created variable name for a new spot in computer memory where the value of the profit is stored. Although it is legal to use any variable name to represent profit, naming it `invProfit` would be misleading. Using the `inv` prefix would lead those who read your program to

believe that profit was part of the input record, like the other variable names that start with `inv`. The profit value is not part of the input record, however; it represents a memory location used to store the arithmetic difference between two other variables.

TIP Recall that the standard way to express mathematical statements is to assign values from the right side of an assignment operator to the left. That is, `profit = invPrice - invCost` assigns a value to `profit`. The statement `invPrice - invCost = profit` is an illegal statement.

Because you have a new variable, you must add `profit` to the list of declared variables at the beginning of the program. Programmers often work back and forth between the variable list and the logical steps during the creation of a program, listing some of the variables they will need as soon as they start to plan, and adding others later as they think of them. Because `profit` will hold the result of a mathematical calculation, you should declare it as a numeric variable when you add it to the variable list, as shown in Figure 4-17. Notice that, like the headings, `profit` is not indented under `invRecord`. You want to show that `profit` is not part of the `invRecord` group; instead, it is a separate variable that you are declaring to store a calculated value.

FIGURE 4-17: VARIABLE LIST FOR INVENTORY REPORT PROGRAM, INCLUDING PROFIT

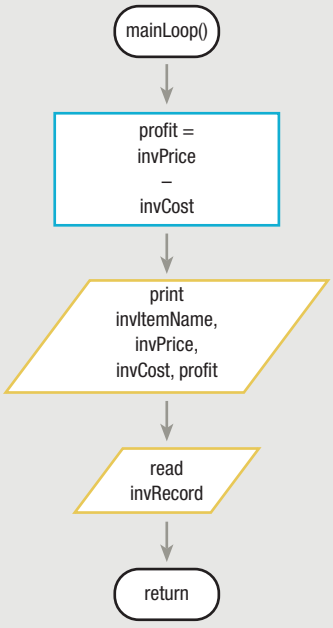
```
invRecord
   char  invItemName
   num   invPrice
   num   invCost
   num   invQuantity
char mainHeading = "INVENTORY REPORT"
char columnHead1 = "ITEM            RETAIL PRICE     MANUFACTURING     PROFIT PER"
char columnHead2 = "DESCRIPTION     EACH             COST EACH         ITEM"
num profit
```

TIP You can declare `mainHeading`, `columnHead1`, `columnHead2`, and `profit` in any order. The important point is that none of these four variables is part of the `invRecord` group.

After you determine an item's profit, you can write a detail line of information on the inventory report: `print invItemName, invPrice, invCost, profit`. Notice that in the flowchart and pseudocode for the `mainLoop()` routine in Figure 4-18, the output statement is not `print invRecord`. For one thing, the entire `invRecord` is not printed—the quantity is not part of the report. Also, the calculated profit is included in the detail line—it does not appear on the input record. Even if the report detail lines listed each of the `invRecord` fields in the exact same order as on the input file, the print statement still would most often be written listing the individual fields to be printed. Usually, you would include a formatting statement with each printed field to control the spacing within the detail line. Because the way you space fields on detail lines differs greatly in programming languages, discussion of the syntax to space fields is not included in this book. However, the fields that are printed are listed separately, as you would usually do when coding in a specific programming language.

The last step in the `mainLoop()` module of the inventory report program involves reading the next `invRecord`. Figure 4-18 shows the flowchart and pseudocode for `mainLoop()`.

FIGURE 4-18: FLOWCHART AND PSEUDOCODE FOR `mainLoop()` OF INVENTORY REPORT PROGRAM




```
mainLoop()
   profit = invPrice - invCost
   print invItemName, invPrice, invCost, profit
   read invRecord
return
```

Just as headings are printed one full line at a time, detail lines are also printed one line at a time. You can print each field separately, as in the following code, but it is clearer and more efficient to write one full line at a time, as shown in Figure 4-18.

```
print invItemName
print invPrice
print invCost
print profit
```

In most programming languages, you also have the option of calculating the profit and printing it in one statement, as in the following:

```
print invItemName, invPrice, invCost, invPrice - invCost
```

If the language you use allows this type of statement, in which a calculation takes place within the output statement, it is up to you to decide which format to use. Performing the arithmetic as part of the `print` statement allows you to avoid declaring a `profit` variable. However, if you need the `profit` figure for further calculations, then it makes

sense to compute the profit and store it in a `profit` field. Using a separate **work variable**, or **work field**, such as `profit` to temporarily hold a calculation is never wrong, and often it's the clearest course of action.

TIP As with performing arithmetic within a print statement, different languages often provide multiple ways to combine several steps into one. For example, many languages allow you to print multiple lines of output or read a record and check for the end of the file using one statement. This book uses only the most common combinations, such as performing arithmetic within a print statement.

Although a language may allow you to combine actions into a single statement, you are never required to do so. If the program is clearer using separate statements, then that is what you should do.

After the detail line containing the item name, price, cost, and profit has been written, the last step you take before leaving the `mainLoop()` module is to read the next record from the input file into memory. When you exit `mainLoop()`, the logic flows back to the `eof` question in the mainline logic. If it is not `eof`—that is, if an additional data record exists—then you enter `mainLoop()` again, compute profit on the second record, print the detail line, and read the third record.

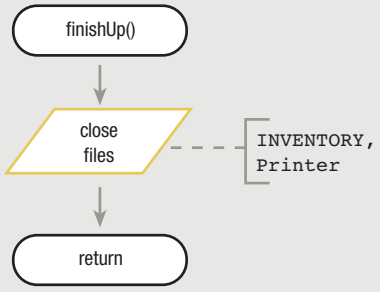
Eventually, during an execution of `mainLoop()`, the program will read a new record and encounter the end of the file. Then, when you ask the `eof` question in the mainline of the program, the answer will be *yes*, and the program will not enter `mainLoop()` again. Instead, the program logic will enter the `finishUp()` routine.

PERFORMING END-OF-JOB TASKS

Within any program, the end-of-job routine holds the steps you must take at the end of the program, after all input records are processed. Some end-of-job modules print summaries or grand totals at the end of a report. Others might print a message such as "End of Report", so readers can be confident that they have received all the information that should be included. Such end-of-job message lines often are called **footer lines**, or **footers** for short. Very often, end-of-job modules must close any open files.

The end-of-job module for the inventory report program is very simple. The print chart does not indicate that any special messages, such as "Thank you for reading this report", print after the detail lines end. Likewise, there are no required summary or total lines; nothing special happens. Only one task needs to be performed in the end-of-job routine that this program calls `finishUp()`. In `housekeeping()`, you opened files; in `finishUp()`, you close them. The complete `finishUp()` module is flowcharted and written in pseudocode in Figure 4-19.

FIGURE 4-19: FLOWCHART AND PSEUDOCODE OF `finishUp()` MODULE




```
finishUp()
  close files
     INVENTORY, Printer
return
```

Many programmers wouldn't bother with a subroutine for just one statement, but as you create more complicated programs, your end-of-job routines will get bigger, and it will make more sense to see the necessary job-finishing tasks together in a module.

For your convenience, Figure 4-20 shows the flowchart and pseudocode for the entire inventory report program. Make sure you understand the importance of each flowchart symbol and each pseudocode line. There is nothing superfluous—each is included to accomplish a specific part of the program that creates the completed inventory report.

FIGURE 4-20: FLOWCHART AND PSEUDOCODE FOR INVENTORY REPORT PROGRAM

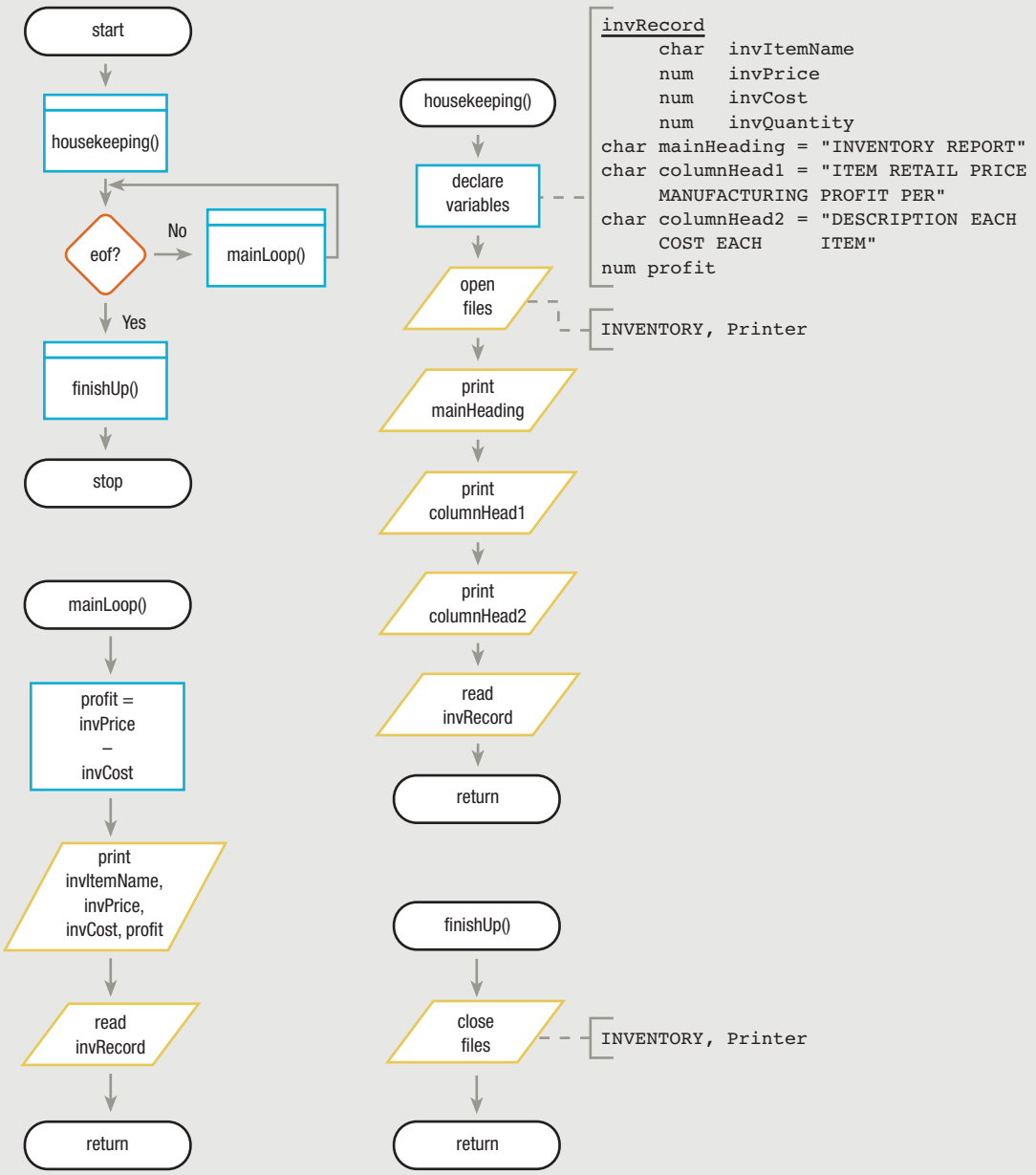


FIGURE 4-20: FLOWCHART AND PSEUDOCODE FOR INVENTORY REPORT PROGRAM (CONTINUED)

```
start
   perform housekeeping()
   while not eof
        perform mainLoop()
   endwhile
   perform finishUp()
stop

housekeeping()
   declare variables
      invRecord
           char  invItemName
           num   invPrice
           num   invCost
           num   invQuantity
      char mainHeading = "INVENTORY REPORT"
      char columnHead1 =
       "ITEM        RETAIL PRICE  MANUFACTURING  PROFIT PER"
      char columnHead2 =
       "DESCRIPTION EACH           COST EACH     ITEM"
      num profit
   open files
      INVENTORY, Printer
   print mainHeading
   print columnHead1
   print columnHead2
   read invRecord
return

mainLoop()
   profit = invPrice - invCost
   print invItemName, invPrice, invCost,  profit
   read invRecord
return

finishUp()
  close files
    INVENTORY, Printer
return
```

UNDERSTANDING THE NEED FOR GOOD PROGRAM DESIGN

As your programs become larger and more complicated, the need for good planning and design increases. Think of an application you use, such as a word processor or a spreadsheet. The number and variety of user options are staggering. Not only would it be impossible for a single programmer to write such an application, but without thorough planning and design, the components would never work together properly. Ideally, each program module you design needs to work well as a stand-alone module and as an element of larger systems. Just as a house with poor plumbing or a car with bad brakes is fatally flawed, a computer-based application can be great only if each component is designed well.

STORING PROGRAM COMPONENTS IN SEPARATE FILES

When you start to work on professional programs, you will see that many of them are quite lengthy, with some containing hundreds of variables and thousands of lines of code. Earlier in this chapter, you learned you can manage lengthy procedural programs by breaking them down into modules. Although modularization helps you to organize your programs, sometimes it is still difficult to manage all of a program's components.

Most modern programming languages allow you to store program components in separate files. If you write a module and store it in the same file as the program that uses it, your program files become large and hard to work with, whether you are trying to read them on a screen or on multiple printed pages. In addition, when you define a useful module, you might want to use it in many programs. Of course, you can copy module definitions from one file to another, but this method is time-consuming as well as prone to error. A better solution (if you are using a language that allows it) is to store your modules in individual files and use an instruction to include them in any program that uses them. The statement needed to access modules from separate files varies from language to language, but it usually involves using a verb such as *include*, *import*, or *copy*, followed by the name of the file that contains the module.

For example, suppose your company has a standard employee record definition, part of which is shown in Figure 4-21. Files with the same format are used in many applications within the organization—personnel reports, production reports, payroll, and so on. It would be a tremendous waste of resources if every programmer rewrote this file definition in multiple applications. Instead, once a programmer writes the statements that constitute the file definition, those statements should be imported in their entirety into any program that uses a record with the same structure. For example, Figure 4-22 shows how the data fields in Figure 4-21 would be defined in the C++ programming language. If the statements in Figure 4-22 are saved in a file named Employees, then any C++ program can contain the statement `#include Employees` and all the data fields are automatically declared.

TIP When you include a file in a C++ program, all the fields in the file are automatically declared. However, they might not be accessible without further manipulation because the fields are private by default. You will learn more about making data public or private and how to handle each type when you study object-oriented programming in Chapter 12.

TIP The pound sign (#) is used with the `include` statement in C++ to notify the compiler that it is part of a special type of statement called a *`pre-processor directive`*.

FIGURE 4-21: PARTIAL EMPLOYEES FILE DESCRIPTION

```
EMPLOYEES FILE DESCRIPTION
File name: EMPLOYEES
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Employee ID            Character    5 bytes
Last Name              Character    20 bytes
First Name             Character    15 bytes
Hire Date              Numeric      8 digits yyyymmdd
Hourly Wage            Numeric      2 decimal places
Birth Date             Numeric      8 digits yyyymmdd
Termination Date       Numeric      8 digits yyyymmdd
```

FIGURE 4-22: DATA FIELDS IN FIGURE 4-21 DEFINED IN THE C++ LANGUAGE

```
class Employee
{
      int employeeID;
      string lastName;
      string firstName;
      long hireDate;
      double hourlyWage;
      long birthDate;
      long terminationDate;
};
```

TIP

Don't be concerned with the syntax used in the file description in Figure 4-22. The words `class`, `int`, `string`, `long`, and `double` are all part of the C++ programming language and are not important to you now. Simply concentrate on how the variable names reflect the field descriptions in Figure 4-21.

Suppose you write a useful module that checks dates to guarantee their validity. For example, the two digits that represent a month can be neither less than 01 nor greater than 12, and the two digits that represent the day can contain different possible values, depending on the month. Any program that uses the employee file description shown in Figure 4-21 might want to call the date-validating module several times in order to validate any employee's hire date, birth date, and termination date. Not only do you want to call this module from several locations within any one program, you want to call it from many programs. For example, programs used for company ordering and billing would each contain several dates. If the date-validating module is useful and well-written, you might even want to market it to other companies. By storing the module in its own file, you enable its use to be flexible. When you write a program of any length, you should consider storing each of its components in its own file.

Storing components in separate files can provide an advantage beyond ease of reuse. When you let others use your programs or modules, you often provide them with only the compiled (that is, machine-language) version of your code, not the **source code**, which is composed of readable statements. Storing your program statements in a separate, non-readable, compiled file is an example of **implementation hiding**, or hiding the details of how the program or module works. Other programmers can use your code, but cannot see the statements you used to create it. A programmer who cannot see your well-designed modules is more likely to use them simply as they were intended; the programmer also will not be able to attempt to make adjustments to your code, thereby introducing error. Of course, in order to work with your modules or data definitions, a programmer must know the names and types of data you are using. Typically, you provide programmers who use your definitions with written documentation of the data names and purposes.

TIP

Recall from Chapter 1 that when you write a program in a programming language, you must compile or interpret it into machine language before the computer can actually carry out your instructions.

SELECTING VARIABLE AND MODULE NAMES

An often-overlooked element in program design is the selection of good data and module names (sometimes generically called **identifiers**). In Chapter 1, you learned that every programming language has specific rules for the construction of names—some languages limit the number of characters, some allow dashes, and so on—but there are other general guidelines:

- Use meaningful names. Creating a data field named `someData` or a module named `firstModule()` makes a program cryptic. Not only will others find it hard to read your programs, but you will forget the purpose of these identifiers even within your own programs. All programmers occasionally use short, nondescriptive names such as `x` or `temp` in a quick program written to test a procedure; however, in most cases, data and module names should be meaningful. Programmers refer to programs that contain meaningful names as **self-documenting**. This means that even without further documentation, the program code explains itself to readers.
- Usually, you should use pronounceable names. A variable name like `pzf` is neither pronounceable nor meaningful. A name that looks meaningful when you write it might not be as meaningful when someone else reads it; for instance, `preparead()` might mean "Prepare ad" to you, but "Prep a read" to others. Look at your names critically to make sure they are pronounceable. Very standard abbreviations do not have to be pronounceable. For example, most business people would interpret `ssn` as Social Security number.

TIP

Don't forget that not all programmers share your culture. An abbreviation whose meaning seems obvious to you might be cryptic to someone in a different part of the world.

- Be judicious in your use of abbreviations. You can save a few keystrokes when creating a module called `getStat()`, but is its purpose to find the state in which a city is located, output some statistics, or determine the status of some variables? Similarly, is a variable named `fn` meant to hold a first name, file number, or something else?

TIP

To save typing time when you develop a program, you can use a short name like `efn`. After the program operates correctly, you can use an editor's Search and Replace feature to replace your coded name with a more meaningful name such as `employeeFirstName`. Some newer compilers support an automatic statement completion feature that saves typing time. After the first time you use a name like `employeeFirstName`, you need to type only the first few letters before the compiler editor offers a list of available names from which to choose. The list is constructed from all the names you have used in the file that begin with the same characters.

- Usually, avoid digits in a name. Zeroes get confused with the letter "O", and lowercase "l"s are misread as the numeral 1. Of course, use your judgment: `budgetFor2007` is probably not going to be misinterpreted.
- Use the system your language allows to separate words in long, multiword variable names. For example, if the programming language you use allows dashes or underscores, then use a method name like `initialize-data()` or `initialize_data()`, which is easier to read than `initializedata()`. If you use a language that allows camel casing, then use `initializeData()`. If you use a language that is case sensitive, it is legal but confusing to use variable names that differ only in case—for example, `empName`, `EmpName`, and `Empname`.
- Consider including a form of the verb *to be*, such as *is* or *are*, in names for variables that are intended to hold a status. For example, use `isFinished` as a flag variable that holds a "Y" or "N" to indicate whether a file is exhausted. The shorter name `finished` is more likely to be confused with a module that executes when a program is done.

When you begin to write programs, the process of determining what data variables and modules you will need and what to name them all might seem overwhelming. The design process is crucial, however. When you acquire your first professional programming assignment, the design process might very well be completed already. Most likely, your first assignment will be to write or make modifications to one small member module of a much larger application. The more the original programmers stuck to these guidelines, the better the original design was, and the easier your job of modification will be.

DESIGNING CLEAR MODULE STATEMENTS

In addition to selecting good identifiers, you can use the following tactics to contribute to the clarity of the statements within your program modules:

- Avoid confusing line breaks.
- Use temporary variables to clarify long statements.
- Use constants where appropriate.

AVOIDING CONFUSING LINE BREAKS

Some older programming languages require that program statements be placed in specific columns. Most modern programming languages are free-form; you can arrange your lines of code any way you see fit. As in real life, with freedom comes responsibility; when you have flexibility in arranging your lines of code, you must take care to make sure your meaning is clear. With free-form code, programmers often do not provide enough line breaks, or they provide inappropriate ones.

Figure 4-23 shows an example of code (part of the `housekeeping()` module from Figure 4-14) that does not provide enough line breaks for clarity. If you have been following the examples used throughout this book, the code in Figure 4-24 looks clearer to you; it will also look clearer to most other programmers.

FIGURE 4-23: PART OF A `housekeeping()` MODULE WITH INSUFFICIENT LINE BREAKS

```
open files  print mainHeading  print columnHead1
 print columnHead2  read invRecord
```

FIGURE 4-24: PART OF A `housekeeping()` MODULE WITH APPROPRIATE LINE BREAKS

```
open files
print mainHeading
print columnHead1
print columnHead2
read invRecord
```

Figure 4-24 shows that more, but shorter, lines usually improve your ability to understand a program's logic; appropriately breaking lines will become even more important as you introduce decisions and loops into your programs in the next chapters.

USING TEMPORARY VARIABLES TO CLARIFY LONG STATEMENTS

When you need several mathematical operations to determine a result, consider using a series of temporary variables to hold intermediate results. For example, Figure 4-25 shows two ways to calculate a value for a real estate `salespersonCommission` variable. Each method achieves the same result—the salesperson's commission is based on the square feet multiplied by the price per square foot, plus any premium for a lot with special features, such as a wooded or waterfront lot. However, the second example uses two temporary variables, `sqFootPrice` and `totalPrice`. When the computation is broken down into less complicated, individual steps, it is easier to see how the total price is calculated. In calculations with even more computation steps, performing the arithmetic in stages would become increasingly helpful.

FIGURE 4-25: TWO WAYS OF ACHIEVING THE SAME `salespersonCommission` RESULT

```
salespersonCommission = (sqFeet * pricePerSquareFoot + lotPremium) * commissionRate
```

```
sqFootPrice = sqFeet * pricePerSquareFoot
totalPrice = sqFootPrice + lotPremium
salespersonCommission = totalPrice * commissionRate
```

A statement, or part of a statement, that performs arithmetic and has a resulting value is called an **arithmetic expression**. For example, 2 + 3 is an arithmetic expression with the value 5.

Programmers might say using temporary variables, like the example in Figure 4-25, is *cheap*. When executing a lengthy arithmetic statement, even if you don't explicitly name temporary variables, the programming language compiler creates them behind the scenes, so declaring them yourself does not cost much in terms of program execution time.

USING CONSTANTS WHERE APPROPRIATE

Whenever possible, use named values in your programs. If your program contains a statement like `salesTax = price * taxRate` instead of `salesTax = price * .06`, you gain two benefits:

- It is easier for readers to know that the price is being multiplied by a tax rate instead of a discount, commission, or some other rate represented by .06.
- When the tax rate changes, you make one change to the value where `taxRate` is defined, rather than searching through a program for every instance of .06.

Named values can be variables or constants. For example, if a `taxRate` is one value when a price is over $100 and a different value when the price is not over $100, then you can store the appropriate value in a variable named `taxRate`, and use it when computing the sales tax. A named value also can be declared to be a **named constant**, meaning its value will never change during the execution of the program. For example, the program segment in Figure 4-26 uses the constants TUITION_PER_CREDIT_HOUR and ATHLETIC_FEE. Because the fields are declared to be constant, using the modifier `const`, you know that their values will not change during the execution of the program. If the values of either of these should change in the future, then the values assigned to the constants can be made in the declaration list, the code can be recompiled, and the actual program statements that perform the arithmetic with the values do not have to be disturbed. By convention, many programmers use all capital letters in constant names, so they stand out as distinct from variables.

FIGURE 4-26: PROGRAM SEGMENT THAT CALCULATES STUDENT BALANCE DUE USING DEFINED CONSTANTS

```
declare variables
   studentRecord
      num studentId
      num creditsEnrolled
   num tuitionDue
   num totalDue
   const num TUITION_PER_CREDIT_HOUR = 74.50
   const num ATHLETIC_FEE = 25.00
read studentRecord
tuitionDue = creditsEnrolled * TUITION_PER_CREDIT_HOUR
totalDue = tuitionDue + ATHLETIC_FEE
```

TIP Some programmers refer to unnamed numeric constants as "magic numbers." They feel that using magic numbers should always be avoided, and that you should provide a descriptive name for every numeric constant you use.

MAINTAINING GOOD PROGRAMMING HABITS

When you learn a programming language and begin to write lines of program code, it is easy to forget the principles you have learned in this text. Having some programming knowledge and a keyboard at your fingertips can lure you into typing lines of code before you think things through. But every program you write will be better if you plan before you code. If you maintain the habits of first drawing flowcharts or writing pseudocode, as you have learned here, your future programming projects will go more smoothly. If you walk through your program logic on paper (called **desk-checking**) before starting to type statements in C++, COBOL, Visual Basic, or Java, your programs will run correctly sooner. If you think carefully about the variable and module names you use, and design your program statements so they are easy for others to read, you will be rewarded with programs that are easier to get up and running, and are easier to maintain as well.

CHAPTER SUMMARY

- When you write a complete program, you first determine whether you have all the necessary data to produce the output. Then, you plan the mainline logic, which usually includes modules to perform housekeeping, a main loop that contains the steps that repeat for every record, and an end-of-job routine.
- Housekeeping tasks include all steps that must take place at the beginning of a program. These tasks include declaring variables, opening files, performing any one-time-only tasks—such as printing headings at the beginning of a report—and reading the first input record.
- The main loop of a program is controlled by the `eof` decision. Each data record passes once through the main loop, where calculations are performed with the data and results are printed.
- Within any program, the end-of-job module holds the steps you must take at the end of the program, after all the input records have been processed. Typical tasks include printing summaries, grand totals, or final messages at the end of a report, and closing all open files.
- As your programs become larger and more complicated, the need for good planning and design increases.
- Most modern programming languages allow you to store program components in separate files and use instructions to include them in any program that uses them. Storing components in separate files can provide the advantages of easy reuse and implementation hiding.
- When selecting data and module names, use meaningful, pronounceable names. Be judicious in your use of abbreviations, avoid digits in a name, and visually separate words in multiword names. Consider including a form of the verb *to be*, such as *is* or *are*, in names for variables that are intended to hold a status.
- When writing program statements, you should avoid confusing line breaks, use temporary variables to clarify long statements, and use constants where appropriate.

KEY TERMS

A **user**, or **client**, is a person who requests a program, and who will actually use the output of the program.

A **procedural program** is a program in which one procedure follows another from the beginning until the end.

The **mainline logic** of a program is the overall logic of the main program from beginning to end.

A **housekeeping** module includes steps you must perform at the beginning of a program to get ready for the rest of the program.

The **main loop** of a program contains the steps that are repeated for every record.

The **end-of-job routine** holds the steps you take at the end of the program to finish the application.

Functional decomposition is the act of reducing a large program into more manageable modules.

A **prefix** is a set of characters used at the beginning of related variable names.

Hungarian notation is a variable-naming convention in which a variable's data type or other information is stored as part of its name.

A **group name** is a name for a group of associated variables.

Initializing, or **defining**, **a variable** is the process of providing a variable with a value, as well as a name and a type, when you create it.

Garbage is the unknown value of an undefined variable.

Opening a file is the process of telling the computer where the input is coming from, the name of the file (and possibly the folder), and preparing the file for reading.

The **standard input device** is the default device from which input comes, most often the keyboard.

The **standard output device** is the default device to which output is sent, usually the monitor.

Interactive applications are applications that interact with a user who types data at a keyboard.

A **delimiter** is a keystroke that separates data items.

An output statement called a **prompt** asks the user for a specific item.

A **work variable**, or **work field**, is a variable you use to temporarily hold a calculation.

Footer lines, or **footers**, are end-of-job message lines.

Source code is the readable statements of a program, written in a programming language.

Implementation hiding is hiding the details of the way a program or module works.

Identifiers are the names of variables and modules.

Self-documenting programs are those that contain meaningful data and module names that describe the programs' purpose.

An **arithmetic expression** is a statement, or part of a statement, that performs arithmetic and has a value.

A **named constant** holds a value that never changes during the execution of a program.

Desk-checking is the process of walking through a program's logic on paper.

REVIEW QUESTIONS

1. **Input records usually contain _____.**
   a. less data than an application needs
   b. more data than an application needs
   c. exactly the amount of data an application needs
   d. none of the data an application needs

2. A program in which one operation follows another from the beginning until the end is a _____ program.

a. modular
b. functional
c. procedural
d. object-oriented

3. The mainline logic of many computer programs contains _____.

a. calls to housekeeping, record processing, and finishing routines
b. steps to declare variables, open files, and read the first record
c. arithmetic instructions that are performed for each record in the input file
d. steps to print totals and close files

4. Modularizing a program _____.

a. keeps large jobs manageable
b. allows work to be divided easily
c. helps keep a program structured
d. all of the above

5. Which of the following is not a typical housekeeping module task?

a. declaring variables
b. printing summaries
c. opening files
d. performing a priming read

6. When a programmer uses a data file and names the first field stored in each record `idNumber`, then other programmers who use the same file _____ in their programs.

a. must also name the field `idNumber`
b. might name the field `idNumber`
c. cannot name the field `idNumber`
d. cannot name the field

7. If you use a data file containing student records, and the first field is the student's last name, then you can name the field _____.

a. `stuLastName`
b. `studentLastName`
c. `lastName`
d. any of the above

8. If a field in a data file used for program input contains "Johnson", then the best choice among the following names for a programmer to use when declaring a memory location for the data is _____.

a. Johnson
b. n
c. `lastName`
d. A programmer cannot declare a variable name for this field; it is already called Johnson.

9. The purpose of using a group name is _____.

a. to be able to handle several variables with a single instruction
b. to eliminate the need for machine-level instructions
c. to be able to use both character and numeric values within the same program
d. to be able to use multiple input files concurrently

10. Defining a variable means the same as _____ it and providing a starting value for it.

a. declaring
b. initializing
c. deleting
d. assigning

11. In most programming languages, the initial value of unassigned variables is _____.

a. 0
b. spaces
c. 0 or spaces, depending on whether the variable is numeric or character
d. unknown

12. The types of variables you usually do not initialize are _____.

a. those that will never change value during a program
b. those representing fields in an input file
c. those that will be used in mathematical statements
d. those that will not be used in mathematical statements

13. The name programmers use for unknown variable values is _____.

a. default
b. trash
c. naive
d. garbage

14. Preparing an input device to deliver data records to a program is called _____ a file.

a. prompting
b. opening
c. refreshing
d. initializing

15. A computer system's standard input device is most often a _____.

a. mouse
b. floppy disk
c. keyboard
d. compact disc

16. The last task performed in a housekeeping module is most often to _____.

a. open files
b. close files
c. check for `eof`
d. read an input record

17. Most business programs contain a _____ that executes once for each record in an input file.

a. housekeeping module
b. main loop
c. finish routine
d. terminal symbol

18. Which of the following pseudocode statements is equivalent to this pseudocode:

```
salePrice = salePrice - discount
finalPrice = salePrice + tax
print finalPrice
```

a. `print salePrice + tax`
b. `print salePrice - discount`
c. `print salePrice - discount + tax`
d. `print discount + tax - salePrice`

19. Common end-of-job module tasks in programs include all of the following except _____.

a. opening files
b. printing totals
c. printing end-of-job messages
d. closing files

20. Which of the following is least likely to be performed in an end-of-job module?

a. closing files
b. checking for `eof`
c. printing the message "End of report"
d. adding two values

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **This pseudocode should create a report containing first-quarter profit statistics for a retail store. Input records contain a department name (for example, "Cosmetics"), expenses for each of the months January, February, and March, and sales for each of the same three months. Profit is determined by subtracting total expenses from total sales. The main program calls three modules—`housekeeping()`, `mainLoop()`, and `finishUp()`. The `housekeeping()` module calls `printHeadings()`.**

```
start
   perform housekeeping()
   while eof
      perform mainLoop()
   perform finishUp()
stop

housekeeping()
   declare variables
        profitRec
            char department
            num janExpenses
            num febExpenses
            num marExpenses
            num janSales
            num febSales
            num marSales
        char mainHeader = "First Quarter Profit Report"
        char columnHeaders = "Department       Profit"
   open files
   perform headings()
   read profitRec
stop

printHeadings()
   print mainHeader
   print columnHeaders
return

mainLoop()
   totalSales = janSales + febSales + febSales
   totalExpenses = janExpenses + marExpenses + marExpenses
   profit = totalSales - totalExpenses
   print department, totalProfit
return

finishUp()
   close files
return
```

2. This pseudocode should create a report containing rental agents' commissions at an apartment complex. Input records contain each salesperson's ID number and name, as well as number of three-bedroom, two-bedroom, one-bedroom, and studio apartments rented during the month. The commission for each apartment rented is $50 times the number of bedrooms, except for studio apartments, for which the commission is $35. The main program calls three modules— `housekeeping()`, `calculateCommission()`, **and** `finishUp()`. **The** `housekeeping()` **module calls** `displayHeaders()`.

```
start
   perform housekeeping()
   while not eof
      perform calcCommission()
   perform finishUp()
stop

housekeeping()
   declare variables
        rentalRecord
            num salesPersonID
            char salesPersonName
            num numThreeBedroomAptsRented
            num numTwoBedroomApts
            num numOneBedroomAptsRented
            num numStudioAptsRented
       char mainHeader = "Commission Report"
       char columnHeaders =
            "Salesperson ID        Name       Commission Earned"
       num commissionEarned
       num regRate = 50.00
       char studioRate = 35.00
   open files
   perform displayHeaders()
stop

displayHeader()
   print mainHeader
   print columnHeaders
return

calculateCommission()
   commissionEarned = (numThreeBedroomAptsRented * 2 +
      numTwoBedroomAptsRented
 * 3 + numOneBedroomAptsRented) * regRate +
      (numStudioAptsRented * studioRate)
   print salespersonID, salespersonName, commissionEarned
return

finishUp()
   close files
return
```

EXERCISES

1. **A pet store owner needs a weekly sales report. The output consists of a printed report titled PET SALES, with column headings TYPE OF ANIMAL and PRICE. Fields printed on output are: type of animal and price. After all records print, a footer line END OF REPORT prints. The input file description is shown below.**

```
File name: PETS
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Type of Animal        Character     20 characters
Price of Animal       Numeric       2 decimal places
```

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Draw the flowchart for this program.
   d. Write the pseudocode for this program.

2. **An employer wants to produce a personnel report. The output consists of a printed report titled ACTIVE PERSONNEL. Fields printed on output are: last name of employee, first name of employee, and current weekly salary. Include appropriate column headings and a footer. The input file description is shown below.**

```
File name: PERSONNEL
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Last Name             Character     15 characters
First Name            Character     15 characters
Soc. Sec. Number      Numeric       9 digits, 0 decimal places
Department            Numeric       2 digits, 0 decimal places
Current Salary        Numeric       2 decimal places
```

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Draw the flowchart for this program.
   d. Write the pseudocode for this program.

3. **An employer wants to produce a personnel report that shows the end result if she gives everyone a 10 percent raise in salary. The output consists of a printed report entitled PROJECTED RAISES. Fields printed on output are: last name of employee, first name of employee, current weekly salary, and projected weekly salary. The input file description is shown below.**

```
File name: PERSONNEL
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Last Name             Character     15 characters
First Name            Character     15 characters
Soc. Sec. Number      Numeric       9 digits, 0 decimal places
Department            Numeric       2 digits, 0 decimal places
Current Salary        Numeric       2 decimal places
```

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Draw the flowchart for this program.
   d. Write the pseudocode for this program.

4. A furniture store maintains an inventory file that includes data about every item it sells. The manager wants a report that lists each stock number, description, and profit, which is the retail price minus the wholesale price. The fields include a stock number, description, wholesale price, and retail price. The input file description is shown below.

```
File name: FURNITURE
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Stock Number          Numeric       4 digits, 0 decimal places
Description           Character     25 characters
Wholesale Price       Numeric       2 decimal places
Retail Price          Numeric       2 decimal places
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

5. A summer camp keeps a record for every camper, including first name, last name, birth date, and skill scores that range from 1 to 10 in four areas: swimming, tennis, horsemanship, and crafts. (The birth date is stored in the format YYYYMMDD without any punctuation. For example, January 21, 1991 is 19910121.) The camp wants a printed report listing each camper's data, plus a total score that is the sum of the camper's four skill scores. The input file description is shown below.

```
File name: CAMPERS
FIELD DESCRIPTION     DATA TYPE     COMMENTS
First Name            Character     15 characters
Last Name             Character     15 characters
Birth Date            Numeric       8 digits, 0 decimals
Swimming Skill        Numeric       0 decimals
Tennis Skill          Numeric       0 decimals
Horsemanship Skill    Numeric       0 decimals
Crafts Skill          Numeric       0 decimals
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

6. **An employer needs to determine how much tax to withhold for each employee. This withholding amount computes as 20 percent of each employee's weekly pay. The output consists of a printed report titled WITHHOLDING FOR EACH EMPLOYEE. Fields printed on output are: last name of employee, first name of employee, hourly pay, weekly pay based on a 40-hour workweek, and withholding amount per week. The input file description is shown below.**

```
File name: EMPLOYEES
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Company ID            Numeric       5 digits, 0 decimals
First Name            Character     12 characters
Last Name             Character     12 characters
Hourly Rate           Numeric       2 decimal places
```

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Draw the flowchart for this program.
   d. Write the pseudocode for this program.

7. **A baseball team manager wants a report showing her players' batting statistics. A batting average is computed as hits divided by at-bats, and it is usually expressed to three decimal positions (for example, .235). The output consists of a printed report titled TEAM STATISTICS. Fields printed on output are: player number, first name, last name, and batting average. The input file description is shown below.**

```
File name: BASEBALL
FIELD DESCRIPTION     DATA TYPE     COMMENTS
Player Number         Numeric       2 digits, 0 decimals
First Name            Character     16 characters
Last Name             Character     17 characters
At-bats               Numeric       never more than 999, 0 decimals
Hits                  Numeric       never more than 999, 0 decimals
```

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Draw the flowchart for this program.
   d. Write the pseudocode for this program.

8. A car rental company manager wants a report showing the revenue earned per mile on vehicles rented each week. An automobile's miles traveled are computed by subtracting the odometer reading when the car is rented from the odometer reading when the car is returned. The amount earned per mile is computed by dividing the rental fee by the miles traveled. The output consists of a printed report titled CAR RENTAL REVENUE STATISTICS. Fields printed on output are: vehicle identification number, odometer reading out, odometer reading in, miles traveled, rental fee, and amount earned per mile. The input file description is shown below.

```
File name: AUTORENTALS
FIELD DESCRIPTION                    DATA TYPE     COMMENTS
Vehicle Identification Number        Numeric       12 digits
Odometer Reading Out                 Numeric       0 decimals
Odometer Reading In                  Numeric       0 decimals
Rental fee                           Numeric       2 decimals
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

9. Professor Smith provides her programming logic students with a final grade that is based on their performance in attendance (a percentage based on 16 class meetings), homework (a percentage based on 10 assignments that might total up to 100 points), and exams (a percentage based on two 100-point exams). A student's final percentage for the course is determined using a weighted average of these figures, with exams counting twice as much as attendance or homework. For example, a student who attended 12 class meetings (75%), achieved 90 points on homework assignments (90%), and scored an average of 60% on tests would have a final average of 71.25% (75 + 90 + 2 * 60) / 4. Professor Smith wants a report that shows each student's ID number and his or her final percentage score.

```
File name: STUDENTSCORES
FIELD DESCRIPTION    DATA TYPE    COMMENTS
Student ID Number    Numeric      6 digits, 0 decimal places
Classes attended     Numeric      a value of 16 or lower, 0 decimals
Homework 1           Numeric      a value of 10 or lower, 0 decimals
Homework 2           Numeric      a value of 10 or lower, 0 decimals
Homework 3           Numeric      a value of 10 or lower, 0 decimals
Homework 4           Numeric      a value of 10 or lower, 0 decimals
Homework 5           Numeric      a value of 10 or lower, 0 decimals
Homework 6           Numeric      a value of 10 or lower, 0 decimals
Homework 7           Numeric      a value of 10 or lower, 0 decimals
Homework 8           Numeric      a value of 10 or lower, 0 decimals
Homework 9           Numeric      a value of 10 or lower, 0 decimals
Homework 10          Numeric      a value of 10 or lower, 0 decimals
Test 1               Numeric      a value of 100 or lower, 2 decimals
Test 2               Numeric      a value of 100 or lower, 2 decimals
```

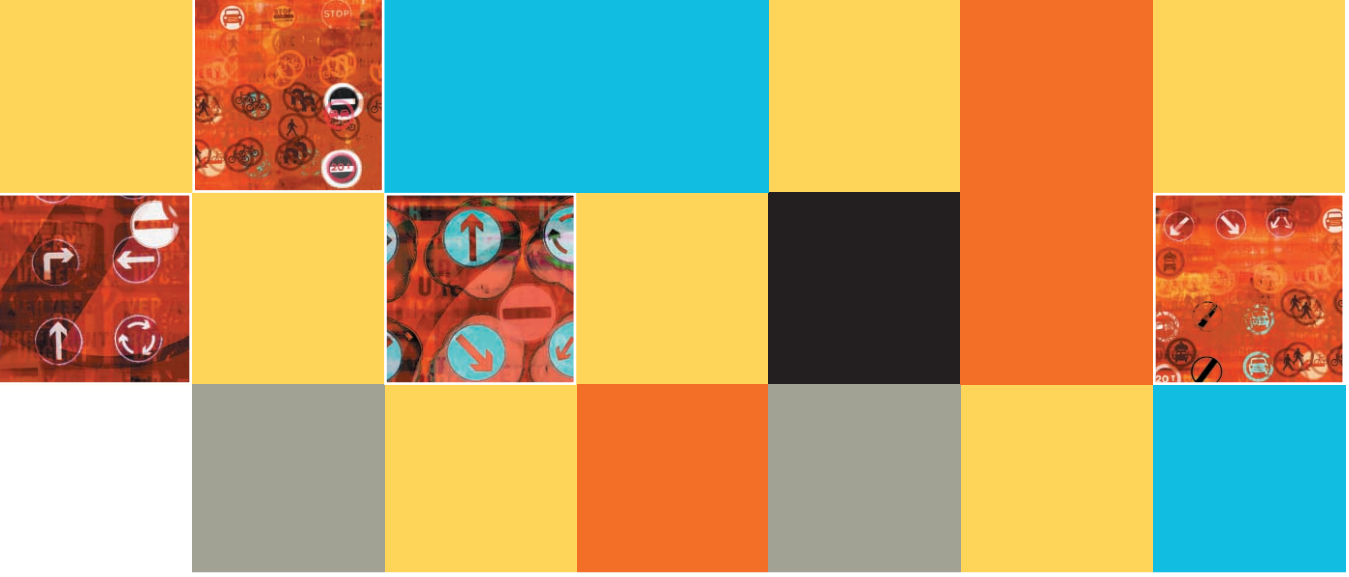
a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

DETECTIVE WORK

1. **Explore the job opportunities in programming. What are the job responsibilities? What is the average starting salary? What is the outlook for growth?**
2. **Many style guides are published on the Web. These guides suggest good identifiers, standard indentation rules, and similar issues in specific programming languages. Find style guides for at least two languages (for example, C++, Java, Visual Basic, C#, COBOL, RPG, or Pascal) and list any differences you notice.**

UP FOR DISCUSSION

1. **When you write computer programs, you will generate errors. Syntax errors are errors in the language—for example, misspellings. Logical errors are caused by statements with correct syntax but that perform an incorrect task, or a correct task at the wrong time. Which is more dangerous? How could the number of occurrences of both types of errors be reduced?**
2. **Extreme programming is a system for rapidly developing software. One of its tenets is that all production code is written by two programmers sitting at one machine. Is this a good idea? Does working this way as a programmer appeal to you?**



5 MAKING DECISIONS

After studying Chapter 5, you should be able to:

- Evaluate Boolean expressions to make comparisons
- Use the relational comparison operators
- Understand AND logic
- Understand OR logic
- Use selections within ranges
- Understand precedence when combining AND and OR selections
- Understand the case structure
- Use decision tables

EVALUATING BOOLEAN EXPRESSIONS TO MAKE COMPARISONS

One reason people think computers are smart lies in a computer program's ability to make decisions. For example, a medical diagnosis program that can decide if your symptoms fit various disease profiles seems quite intelligent, as does a program that can offer you potential vacation routes based on your destination.

The selection structure (also called the decision structure) involved in such programs is not new to you—it's one of the basic structures of structured programming. See Figures 5-1 and 5-2.

FIGURE 5-1: THE DUAL-ALTERNATIVE SELECTION STRUCTURE

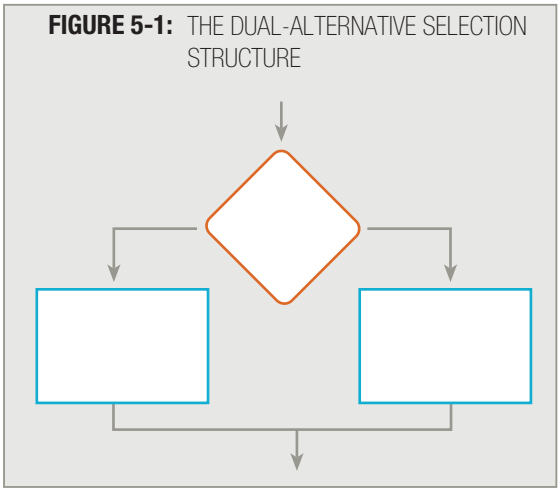
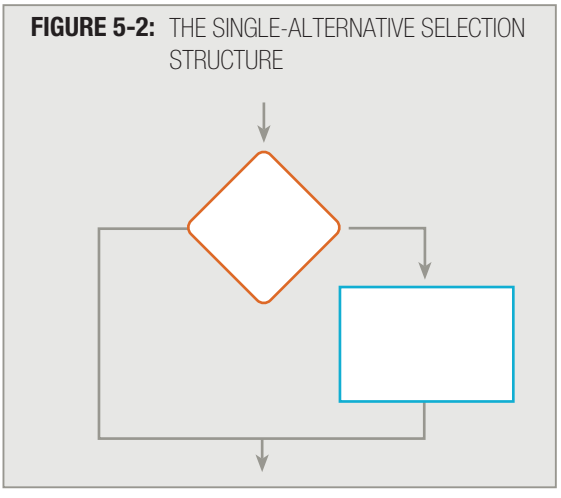


FIGURE 5-2: THE SINGLE-ALTERNATIVE SELECTION STRUCTURE



You can refer to the structure in Figure 5-1 as a **dual-alternative**, or **binary**, selection because there is an action associated with each of two possible outcomes. Depending on the answer to the question represented by the diamond, the logical flow proceeds either to the left branch of the structure or to the right. The choices are mutually exclusive; that is, the logic can flow only to one of the two alternatives, never to both. This selection structure is also called an **if-then-else** structure because it fits the statement:

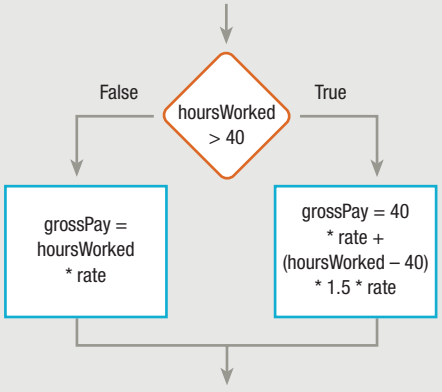
```
if the answer to the question is yes, then
    do something
else
    do somethingElse
endif
```

The flowchart segment in Figure 5-2 represents a **single-alternative**, or **unary**, selection where action is required for only one outcome of the question. You call this form of the if-then-else structure an **if-then**, because no alternative or "else" action is included or necessary.

TIP You can call a single-alternative decision (or selection) a *single-sided decision*. Similarly, a dual-alternative decision (or selection) is a *double-sided decision*.

For example, Figure 5-3 shows the flowchart and pseudocode for a typical if-then-else decision in a business program. Many organizations pay employees time and a half (one and one-half times their usual hourly rate) for hours in excess of 40 per week. The logic segments in the figure show this decision.

FIGURE 5-3: FLOWCHART AND PSEUDOCODE FOR OVERTIME PAY DECISION

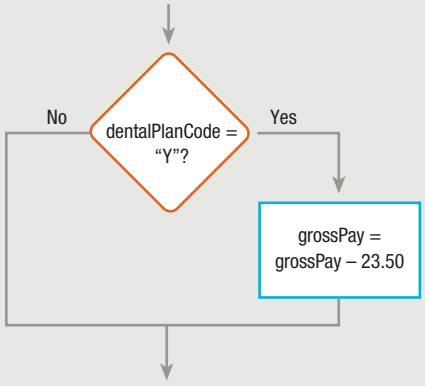



```
if hoursWorked > 40 then
      grossPay = 40 * rate +
        (hoursWorked - 40) * 1.5 * rate
else
      grossPay = hoursWorked * rate
endif
```

In the example in Figure 5-3, the longer calculation that adds a time-and-a-half factor to an employee's gross pay executes only when the expression `hoursWorked > 40` is true. The overtime calculation exists in the **if clause** of the decision—the part of the decision that holds the action or actions that execute when the tested condition in the decision is true. The shorter, regular pay calculation, which produces `grossPay` by multiplying `hoursWorked` by `rate`, constitutes the **else clause** of the decision—the part that executes only when the tested condition in the decision is false.

The typical if-then decision in Figure 5-4 shows an employee's paycheck being reduced if the employee participates in the dental plan. No action is taken if the employee is not a dental plan participant.

FIGURE 5-4: FLOWCHART AND PSEUDOCODE FOR DENTAL PLAN DECISION




```
if dentalPlanCode = "Y" then
     grossPay = grossPay - 23.50
endif
```

The expressions `hoursWorked > 40` and `dentalPlanCode = "Y"` that appear in Figures 5-3 and 5-4, respectively, are Boolean expressions. In Chapter 4, you learned that in programming, an expression is a statement, or part of a statement, that has a value. For example, an arithmetic expression is one that performs arithmetic, resulting in a value. A **Boolean expression** is one that represents only one of two states, usually expressed as true or false. Every decision you make in a computer program involves evaluating a Boolean expression. True/false evaluation is "natural" from a computer's standpoint, because computer circuitry consists of two-state, on-off switches, often represented by 1 or 0. Every computer decision yields a true-or-false, yes-or-no, 1-or-0 result.

TIP

George Boole was a mathematician who lived from 1815 to 1864. He approached logic more simply than his predecessors did, by expressing logical selections with common algebraic symbols. He is considered a pioneer in mathematical logic, and Boolean (true/false) expressions are named for him.

USING THE RELATIONAL COMPARISON OPERATORS

Usually, you can compare only values that are of the same type; that is, you can compare numeric values to other numbers and character values to other characters. You can ask every programming question by using one of only six types of comparison operators in a Boolean expression. For any two values that are the same type, you can decide whether:

- The two values are equal.
- The first value is greater than the second value.
- The first value is less than the second value.
- The first value is greater than or equal to the second value.
- The first value is less than or equal to the second value.
- The two values are not equal.

TIP

Usually, character variables are not considered to be equal unless they are identical, including the spacing and whether they appear in uppercase or lowercase. For example, "black pen" is *not* equal to "blackpen", "BLACK PEN", or "Black Pen".

TIP

Some programming languages allow you to compare a character to a number. If this is the case, then a single character's numeric code value is used in the comparison. For example, most microcomputers use either the ASCII or Unicode coding system. In both of these systems, an uppercase "A" is represented numerically as a 65, an uppercase "B" is a 66, and so on. See Appendix B for more information on ASCII code and how numbers are used to store data.

In any Boolean expression, the two values used can be either variables or constants. For example, the expression `currentTotal = 100?` compares the value stored in a variable, `currentTotal`, to a numeric constant, `100`. Depending on the `currentTotal` value, the expression is true or false. In the expression `currentTotal = previousTotal?` both values are variables, and the result is also true or false depending on the values stored in each of the two variables. Although it's legal to do so, you would never use expressions in which you compare two

unnamed constants—for example, `20 = 20?` or `30 = 40?`. Such expressions are considered **trivial** because each will always evaluate to the same result: true for the first expression and false for the second.

Each programming language supports its own set of **relational comparison operators**, or comparison symbols, that express these Boolean tests. For example, many languages such as Visual Basic and Pascal use the equal sign (=) to express testing for equivalency, so `balanceDue = 0` compares `balanceDue` to zero. COBOL programmers can use the equal sign, but they also can spell out the expression, as in `balanceDue equal to 0`. RPG programmers use the two-letter operator `EQ` in place of a symbol. C#, C++, and Java programmers use two equal signs to test for equivalency, so they write `balanceDue == 0` to compare the two values. Although each programming language supports its own syntax for comparing values' equivalency, all languages provide for the same logical concept of equivalency.

TIP

Visual Basic uses the single equal sign both for assignment and when testing for equivalency; the interpretation of the operator depends on the context. The reason some languages use two equal signs for comparisons is to avoid confusion with assignment statements such as `balanceDue = 0`. In C++, C#, or Java, this statement only assigns the value 0 to `balanceDue`; it does not compare `balanceDue` to zero.

TIP

Whenever you use a comparison operator, you must provide a value on each side of the operator. Comparison operators are sometimes called *`binary operators`* because of this requirement. Some programmers use the terms "comparison operator," "relational operator," and "**logical operator**" interchangeably. However, many prefer to reserve the term "logical operator" for manipulations on single bits.

Most languages allow you to use the algebraic signs for greater than (>) and less than (<) to make the corresponding comparisons. Additionally, COBOL, which is very similar to English, allows you to spell out the comparisons in expressions such as `daysPastDue is greater than 30` or `packageWeight is less than maximumWeightAllowed`. RPG uses the two-letter abbreviations `GT` and `LT` to represent greater than or less than. When you create a flowchart or pseudocode, you can use any form of notation you want to express "greater than" and "less than." It's simplest to use the symbols > and < if you are comfortable with their meaning. As with equivalency, the syntax changes when you change languages, but the concepts of greater than and less than exist in all programming languages.

Most programming languages allow you to express "greater than or equal to" by typing a greater-than sign immediately followed by an equal sign (>=). When you are drawing a flowchart or writing pseudocode, you might prefer a greater-than sign with a line under it (≥) because mathematicians use that symbol to mean "greater than or equal to." However, when you write a program, you type **>=** as two separate characters, because no single key on the keyboard expresses this concept. Similarly, "less than or equal to" is written with two symbols, < immediately followed by =.

TIP

The operators >= and <= are always treated as a single unit; no spaces separate the two parts of the operator. Also, the equal sign always appears second. No programming language allows => or =< as a comparison operator.

Any logical situation can be expressed using just three types of comparisons: equal, greater than, and less than. You never need the three additional comparisons (greater than or equal to, less than or equal to, or not equal to), but using them often makes decisions more convenient. For example, assume you need to issue a 10 percent discount to any customer whose age is 65 or greater, and charge full price to other customers. You can use the greater-than-or-equal-to symbol to write the logic as follows:

```
if customerAge >= 65 then
    discount = 0.10
else
    discount = 0
endif
```

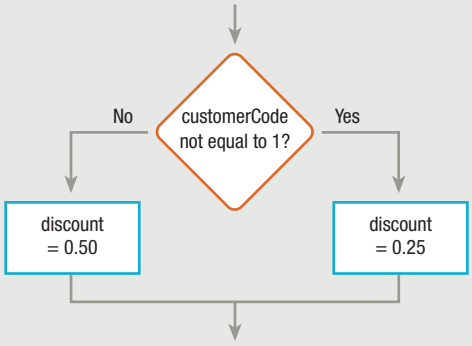
As an alternative, if you want to use only one of the three basic comparisons (=, >, and <), you can express the same logic by writing:

```
if customerAge < 65 then
    discount = 0
else
    discount = 0.10
endif
```

In any decision for which `a >= b` is true, then `a < b` is false. Conversely, if `a >= b` is false, then `a < b` is true. By rephrasing the question and swapping the actions taken based on the outcome, you can make the same decision in multiple ways. The clearest route is often to ask a question so the positive or true outcome results in the unusual action. For example, assume that charging a customer full price is the ordinary course, and that providing a discount is the unusual occurrence. When your company policy is to "provide a discount for those who are 65 and older," the phrase "greater than or equal to" comes to mind, so it is the most natural to use. Conversely, if your policy is to "provide no discount for those under 65," then it is more natural to use the "less than" syntax. Either way, the same people receive a discount.

Comparing two amounts to decide if they are *not* equal to each other is the most confusing of all the comparisons. Using "not equal to" in decisions involves thinking in double negatives, which makes you prone to include logical errors in your programs. For example, consider the flowchart segment in Figure 5-5.

FIGURE 5-5: USING A NEGATIVE COMPARISON

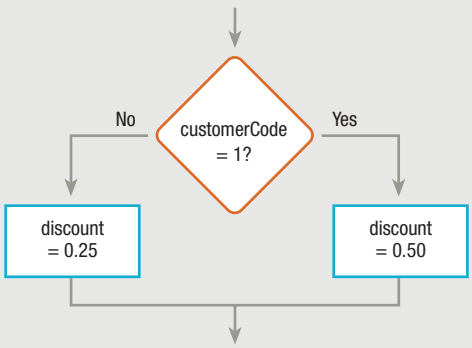



```
if customerCode not equal to 1 then
     discount = 0.25
else
     discount = 0.50
endif
```

In Figure 5-5, if the value of `customerCode` *is* equal to 1, the logical flow follows the false branch of the selection. If `customerCode not equal to 1` is true, the `discount` is 0.25; if `customerCode not equal to 1` is not true, it means the `customerCode` *is* 1, and the `discount` is 0.50. Even using the phrase "`customerCode not equal to 1 is not true`" is awkward.

Figure 5-6 shows the same decision, this time asked in the positive. Making the decision `if customerCode` *is* `1 then discount = 0.50` is clearer than trying to determine what `customerCode` is *not*.

FIGURE 5-6: USING THE POSITIVE EQUIVALENT OF THE NEGATIVE COMPARISON IN FIGURE 5-5




```
if customerCode = 1 then
     discount = 0.50
else
     discount = 0.25
endif
```

Besides being awkward to use, the "not equal to" comparison operator is the one most likely to be different in the various programming languages you may use. COBOL allows you to write "not equal to"; Visual Basic and Pascal use a less-than sign followed immediately by a greater-than sign (<>); C#, C++, C, and Java use an exclamation point followed by an equal sign (!=). In a flowchart or in pseudocode, you can use the symbol that mathematicians use to mean "not equal," an equal sign with a slash through it (≠). When you program, you will not be able to use this symbol, because no single key on the keyboard produces it.

TIP

Although NOT comparisons can be awkward to use, there are times when your meaning is clearest if you use one. Frequently, this occurs when you take action only when some comparison is expressed negatively—for example, when one value is not equal to another value. Examples of situations in which a negative comparison makes sense include the following:

```
if customerZipCode is not equal to localZipCode then
    add DELIVERY_CHARGE to total
endif

if creditCardBalance is not 0 then
     financeCharge = balance * INTEREST_RATE
endif
```

In these cases, action is taken when two values are not equal. The mainline logic of many programs, including those you have worked with in this book, includes a negative comparison that controls a loop. The pseudocode you have seen for almost every program includes a statement similar to: `while not eof, perform mainLoop()`.

Figure 5-7 summarizes the six comparison operators and contrasts trivial (both true and false) examples with typical examples of their use.

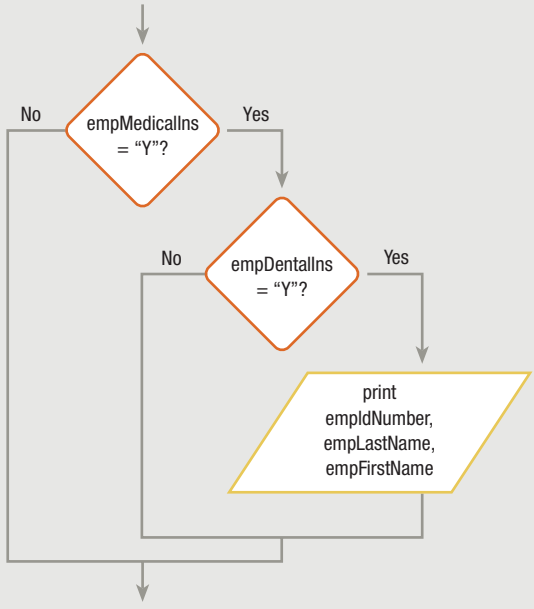
FIGURE 5-7: RELATIONAL COMPARISONS

Comparison	Trivial true example	Trivial false example	Typical example
Equal to	7 = 7?	7 = 4?	amtOrdered = 12?
Greater than	12 > 3?	4 > 9?	hoursWorked > 40?
Less than	1 < 8?	13 < 10?	hourlyWage < 5.65?
Greater than or equal to	5 >= 5?	3 >= 9?	customerAge >= 65?
Less than or equal to	4 <= 4?	8 <= 2?	daysOverdue <= 60?
Not equal to	16 <> 3?	18 <> 18?	customerBalance <> 0?

UNDERSTANDING AND LOGIC

Often, you need more than one selection structure to determine whether an action should take place. For example, suppose that your employer wants a report that lists workers who have registered for both insurance plans offered by the company: the medical plan and the dental plan. This type of situation is known as an **AND decision** because the employee's record must pass two tests—participation in the medical plan *and* participation in the dental plan—before you write that employee's information on the report. A compound, or AND, decision requires a **nested decision**, or a **nested if**. A nested decision is a decision "inside of" another decision. The logic looks like Figure 5-8.

FIGURE 5-8: FLOWCHART AND PSEUDOCODE OF AN AND DECISION




```
if empMedicalIns = "Y" then
   if empDentalIns = "Y" then
        print empIdNumber,
          empLastName,
          empFirstName
   endif
endif
```

TIP You first learned about nesting structures in Chapter 2.

TIP A series of nested `if` statements can also be called a **cascading if statement**.

The AND decision shown in Figure 5-8 is part of a much larger program. To help you develop this program, suppose your employer provides you with the employee data file description shown in Figure 5-9, and you learn that the medical and dental insurance fields contain a single character, "Y" or "N", indicating each employee's participation status. With your employer's approval, you develop the sample output shown in Figure 5-10.

FIGURE 5-9: EMPLOYEE FILE DESCRIPTION

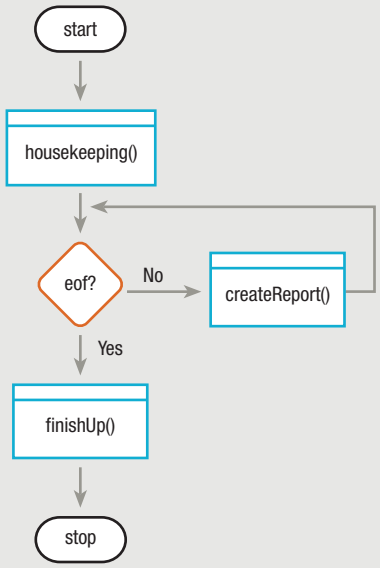
```
EMPLOYEE FILE DESCRIPTION
File Name: EMPFILE
FIELD DESCRIPTION       DATA TYPE      COMMENTS
ID Number               Numeric        4 digits, 0 decimal places
Last Name               Character      15 characters
First Name              Character      15 characters
Department              Numeric        1 digit
Hourly Rate             Numeric        2 decimal places
Medical Plan            Character      1 character, Y or N
Dental Plan             Character      1 character, Y or N
Number of Dependents    Numeric        0 decimal places
```

FIGURE 5-10: SAMPLE REPORT LISTING EMPLOYEES PARTICIPATING IN BOTH INSURANCE PLANS

```
Employees with Medical and Dental Insurance

ID Number          Last Name           First Name

1246               Kroening            Virginia
1419               Lewis               Kathleen
2765               Bowman              Bradley
3872               Daniels             James
```

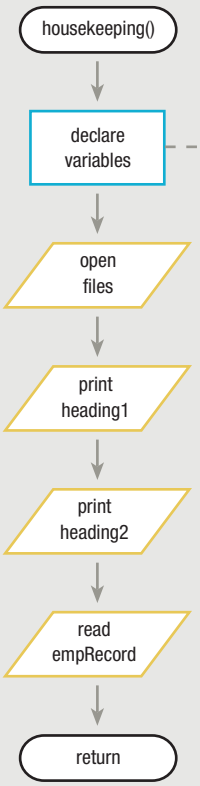
The mainline logic and `housekeeping()` routines for this program are diagrammed in Figures 5-11 and 5-12.

FIGURE 5-11: FLOWCHART AND PSEUDOCODE OF MAINLINE LOGIC FOR MEDICAL AND DENTAL PARTICIPANT REPORT




```
start
   perform housekeeping()
   while not eof
      perform createReport()
   endwhile
   perform finishUp()
stop
```

FIGURE 5-12: FLOWCHART AND PSEUDOCODE OF `housekeeping()` MODULE FOR MEDICAL AND DENTAL PARTICIPANT REPORT

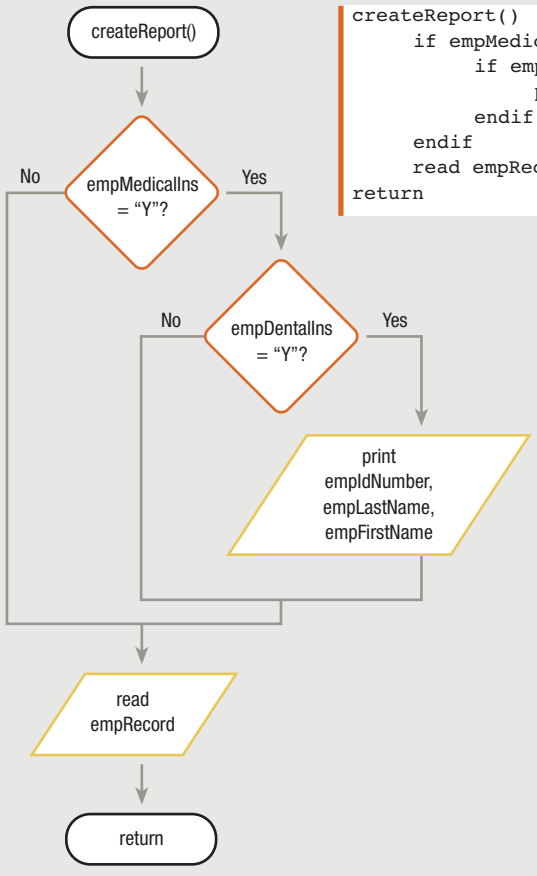



```
empRecord
     num empIdNumber
     char empLastName
     char empFirstName
     num empDept
     num empRate
     char empMedicalIns
     char empDentalIns
     num empDependents
char heading1 = "Employees with Medical
          and Dental Insurance"
char heading2 = "ID number   Last name   First name"
```

```
housekeeping()
   declare variables
   open files
   print heading1
   print heading2
   read empRecord
return
```

At the end of the `housekeeping()` module, the first employee record is read into computer memory. Assuming that the `eof` condition is not yet met, the logical flow proceeds to the `createReport()` method. If the program required data for all employees to be printed, this method would simply print the information from the current record and get the next record. However, in this case, the output should contain only the names of those employees who participate in both the medical and dental insurance plans. Therefore, within the `createReport()` module of this program, you ask the questions that determine whether the current employee's record will print; if the employee's data meet the medical and dental insurance requirements, then you print the record. Whether or not you take the path that prints the record, the last thing you do in the `createReport()` method is to read the next input record. Figure 5-13 shows the `createReport()` module.

FIGURE 5-13: THE `createReport()` MODULE OF A PROGRAM THAT LISTS EMPLOYEES WHO ARE BOTH MEDICAL AND DENTAL INSURANCE PROGRAM PARTICIPANTS




```
createReport()
     if empMedicalIns = "Y" then
          if empDentalIns = "Y" then
               print empIdNumber, empLastName, empFirstName
          endif
     endif
     read empRecord
return
```

TIP

At the end of the `housekeeping()` module in Figure 5-12, instead of the statement `read empRecord`, an interactive program might prompt the user for values for each of the eight data fields. Instead of the single read statement, you might choose to call a method containing eight pairs of statements, such as `print "Please enter employee ID number"` and `read empIdNumber`. The programs in this chapter read data from a file to keep them simpler.

The `createReport()` module works like this: If the employee has medical insurance, *then* and *only then* test to see if the employee has dental insurance. If so, *then* and *only then* print the employee's data. The dental insurance question is nested entirely within half of the medical insurance question structure. If an employee does not carry medical insurance, there is no need to ask about the dental insurance; the employee is already disqualified from the report. Pseudocode for the entire program is shown in Figure 5-14. Notice how the second (dental insurance) decision within the `createReport()` method is indented within the first (medical insurance) decision. This technique shows that the second question is asked only when the result of the first comparison is true.

FIGURE 5-14: PSEUDOCODE OF PROGRAM THAT PRINTS RECORDS OF EMPLOYEES WHO PARTICIPATE IN BOTH THE MEDICAL AND DENTAL INSURANCE PLANS

```
start
    perform housekeeping()
    while not eof
      perform createReport()
    endwhile
    perform finishUp()
stop

housekeeping()
    declare variables
    open files
    print heading1
    print heading2
    read empRecord
return

createReport()
    if empMedicalIns = "Y" then
         if empDentalIns = "Y" then
            print empIdNumber, empLastName, empFirstName
         endif
    endif
    read empRecord
return

finishUp()
    close files
return
```

```
empRecord
     num empIdNumber
     char empLastName
     char empFirstName
     num empDept
     num empRate
     char empMedicalIns
     char empDentalIns
     num empDependents
char heading1 = "Employees with Medical
          and Dental Insurance"
char heading2 = "ID number   Last name   First name"
```

WRITING NESTED AND DECISIONS FOR EFFICIENCY

When you nest decisions because the resulting action requires that two conditions be true, you must decide which of the two decisions to make first. Logically, either selection in an AND decision can come first. However, when there are two selections, you often can improve your program's performance by making an appropriate choice as to which selection to make first.

For example, Figure 5-15 shows the nested decision structure in the `createReport()` method logic of the program that produces a report of employees who participate in both the medical and dental insurance plans. Alternatively, you can write the decision as in Figure 5-16.

FIGURE 5-15: FINDING MEDICAL AND DENTAL PLAN PARTICIPANTS, CHECKING MEDICAL FIRST

```
if empMedicalIns = "Y" then
     if empDentalIns = "Y" then
          print empIdNumber, empLastName, empFirstName
     endif
endif
```

FIGURE 5-16: FINDING DENTAL AND MEDICAL PLAN PARTICIPANTS, CHECKING DENTAL FIRST

```
if empDentalIns = "Y" then
     if empMedicalIns = "Y" then
           print empIdNumber, empLastName, empFirstName
     endif
endif
```

Examine the decision statements in Figures 5-15 and 5-16. If you want to print employees who participate in the medical AND dental plans, you can ask about the medical plan first, eliminate those employees who do not participate, and ask about the dental plan only for those employees who "pass" the medical insurance test. Or, you could ask about the dental plan first, eliminate those who do not participate, and ask about the medical plan only for those employees who "pass" the dental insurance test. Either way, the final list contains only those employees who have both kinds of insurance.

Does it make a difference which question is asked first? As far as the output goes, no. Either way, the same employee names appear on the report—those with both types of insurance. As far as program efficiency goes, however, it *might* make a difference which question is asked first.

Assume you know that out of 1,000 employees in your company, about 90 percent, or 900, participate in the medical insurance plan. Assume you also know that out of 1,000 employees, only about half, or 500, participate in the dental plan.

The medical and dental insurance program will ask the first question in the `createReport()` method 1,000 times during its execution—once for each employee record contained in the input file. If the program uses the logic in Figure 5-15, it asks the first question `empMedicalIns = "Y"?` 1,000 times. For approximately 90 percent of the employees, or 900 of the records, the answer is true, meaning the `empMedicalIns` field contains the character "Y". So 100 employees are eliminated, and 900 proceed to the next question about dental insurance. Only about half of the employees participate in the dental plan, so 450 out of the 900 will appear on the printed report.

Using the alternate logic in Figure 5-16, the program asks the first question `empDentalIns = "Y"?` 1,000 times. Because only about half of the company's employees participate, only 500 will "pass" this test and proceed to the medical insurance question. Then about 90 percent of the 500, or 450 employees, will appear on the printed report. Whether you use the logic in Figure 5-15 or 5-16, the same 450 employees who have both types of insurance appear on the report.

The difference lies in the fact that when you use the logic in Figure 5-15, the program must ask 1,900 questions to produce the report—the medical insurance question tests all 1,000 employee records, and 900 continue to the dental insurance question. If you use the logic in Figure 5-16 to produce the report, the program asks only 1,500 questions—all 1,000 records are tested for dental insurance, but only 500 proceed to the medical insurance question. By asking about the dental insurance first, you "save" 400 decisions.

The 400-question difference between the first set of decisions and the second set really doesn't take much time on most computers. But it will take *some* time, and if there are hundreds of thousands of employees instead of only 1,000, or if many such decisions have to be made within a program, performance time can be significantly improved by asking questions in the proper order.

In many AND decisions, you have no idea which of two events is more likely to occur; in that case, you can legitimately ask either question first. In addition, even though you know the probability of each of two conditions, the two events might not be mutually exclusive; that is, one might depend on the other. For example, if employees with dental insurance are significantly more likely to carry medical insurance than those who don't carry dental insurance, the order in which to ask the questions might matter less or not matter at all. However, if you do know the probabilities of the conditions, or can make a reasonable guess, the general rule is: *In an AND decision, first ask the question that is less likely to be true.* This eliminates as many records as possible from having to go through the second decision, which speeds up processing time.

COMBINING DECISIONS IN AN AND SELECTION

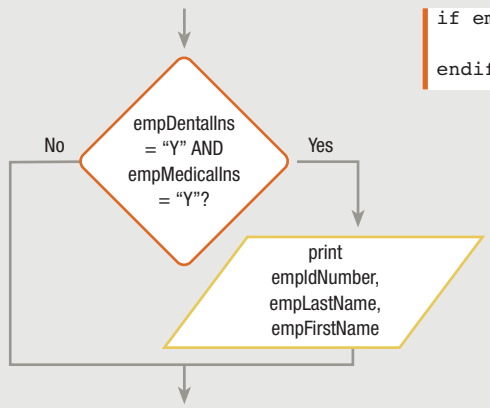
Most programming languages allow you to ask two or more questions in a single comparison by using a **logical AND operator**. For example, if you want to select employees who carry both medical and dental insurance, you can use nested `if`s, or you can include both decisions in a single statement by writing `empDentalIns = "Y" AND empMedicalIns = "Y"?`. When you use one or more AND operators to combine two or more Boolean expressions, each Boolean expression must be true in order for the entire expression to be evaluated as true. For example, if you ask, "Are you at least 18, and are you a registered voter, and did you vote in the last election?", the answer to all three parts of the question must be "yes" before the response can be a single, summarizing "yes". If any part of the question is false, then the entire question is false.

TIP

You can think of an AND expression in an algebraic way if you consider 0 to be false and any nonzero value to be true. The AND operator works like multiplication (not addition, as you might suspect). A true expression AND a true expression yields a true result because 1 * 1 is 1. Any other combination yields a false result because 1 * 0, 0 * 1, and 0 * 0 all result in 0.

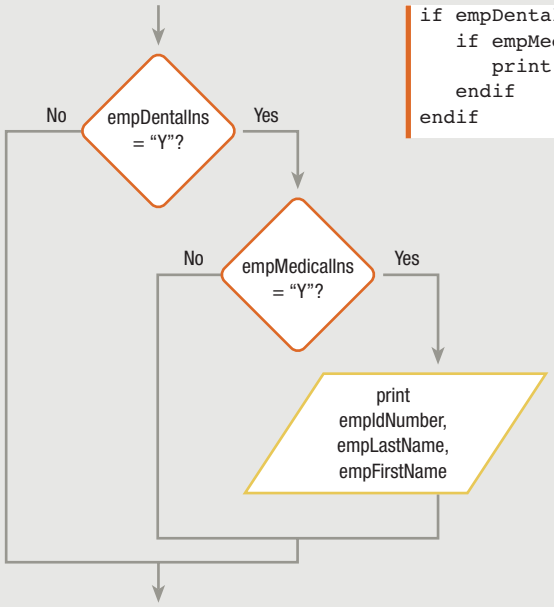
If the programming language you use allows an AND operator (and almost all do), you still must realize that the question you place first is the question that will be asked first, and cases that are eliminated based on the first question will not proceed to the second question. The computer can ask only one question at a time; even when your logic follows the flowchart segment in Figure 5-17, the computer will execute the logic in the flowchart in Figure 5-18.

FIGURE 5-17: FLOWCHART AND PSEUDOCODE OF AN AND DECISION USING AN AND OPERATOR




```
if empDentalIns = "Y" AND empMedicalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
endif
```

FIGURE 5-18: FLOWCHART AND PSEUDOCODE OF COMPUTER LOGIC OF PROGRAM CONTAINING AN AND OPERATOR IN THE DECISION (THE COMPUTER STILL MAKES TWO SEPARATE DECISIONS, EVEN THOUGH AN AND OPERATOR IS USED)




```
if empDentalIns = "Y" then
   if empMedicalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
   endif
endif
```

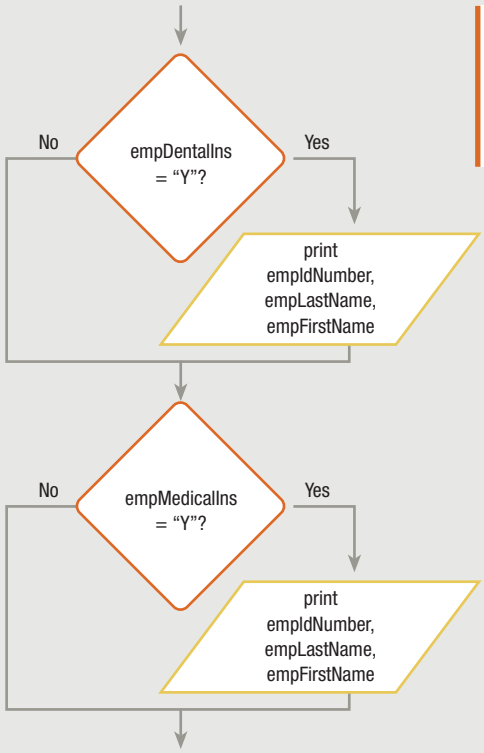
TIP The AND operator in Java, C++, and C# consists of two ampersands, with no spaces between them (&&).

TIP Using an AND operator in a decision that involves multiple conditions does not eliminate your responsibility for determining which of the conditions to test first. Even when you use an AND operator, the computer makes decisions one at a time, and makes them in the order you ask them. If the first question in an AND expression evaluates to false, then the entire expression is false, and the second question will not even be tested. Not bothering to test the second expression when it would make no difference in the ultimate result is called **short-circuiting**. (Some languages—for example, VB .NET—provide special non-short-circuiting operators. However, the standard AND operator is short-circuiting.)

AVOIDING COMMON ERRORS IN AN AND SELECTION

When you must satisfy two or more criteria to initiate an event in a program, you must make sure that the second decision is made entirely within the first decision. For example, if a program's objective is to print a report of those employees who carry both medical and dental insurance, then the program segment shown in Figure 5-19 contains three different types of logic errors.

FIGURE 5-19: INCORRECT LOGIC TO PRODUCE REPORT CONTAINING EMPLOYEES WHO PARTICIPATE IN BOTH MEDICAL AND DENTAL INSURANCE PLANS




```
if empDentalIns = "Y" then
   print empIdNumber, empLastName, empFirstName
endif
if empMedicalIns = "Y" then
   print empIdNumber, empLastName, empFirstName
endif
```

The diagram shows that the program asks the dental insurance question first. However, if an employee participates in the dental program, the employee's record prints immediately. The employee record should not print, because the employee might not have the medical insurance. In addition, the program should eliminate an employee without dental insurance from the next selection, but every employee's record proceeds to the medical insurance question, where it might print, whether the employee has dental insurance or not. Additionally, any employee who has both medical and dental insurance, having passed each test successfully, will appear twice on this report. For many reasons, the logic shown in Figure 5-19 is *not* correct for this problem.

Beginning programmers often make another type of error when they must make two comparisons on the same field when using a logical AND operator. For example, suppose you want to list employees who make between $10.00 and $11.99 per hour, inclusive. When you make this type of decision, you are basing it on a **range** of values—every value between low and high limits. For example, you want to select employees whose `empRate` is greater than or equal to

10.00 AND whose `empRate` is less than 12.00; therefore, you need to make two comparisons on the same field. Without the logical AND operator, the comparison is:

```
if empRate >= 10.00 then
     if empRate < 12.00 then
          print empIdNumber, empLastName, empFirstName
     endif
endif
```

TIP

To check for `empRate` values that are 10.00 or greater, you can use either `empRate > 9.99?` or `empRate >= 10.00?`. To check for `empRate` values under 12.00, you can write `empRate <= 11.99?` or `empRate < 12.00?`.

The correct way to make this comparison with the AND operator is as follows:

```
if empRate >= 10.00 AND empRate < 12.00 then
     print empIdNumber, empLastName, empFirstName
endif
```

You substitute the AND operator for the phrase `then if`. However, some programmers might try to make the comparison as follows:

```
if empRate >= 10.00 AND < 12.00 then
     print empIdNumber, empLastName, empFirstName
endif
```

In most languages, the phrase `empRate >= 10.00 AND < 12.00` is incorrect. The logical AND is usually a binary operator that requires a complete Boolean expression on each side. The expression to the right of the AND, `< 12.00`, is not a complete Boolean expression; you must indicate *what* is being compared to 12.00.

TIP

In some programming languages, such as COBOL and RPG, you can write the equivalent of `empRate >= 10.00 AND < 12.00?` and the `empRate` variable is implied for both comparisons. Still, it is clearer, and therefore preferable, to use the two full expressions, `empRate >= 10.00 AND empRate < 12.00?`.

UNDERSTANDING OR LOGIC

Sometimes, you want to take action when one *or* the other of two conditions is true. This is called an **OR decision** because either a first condition must be met *or* a second condition must be met for an event to take place. If someone asks you, "Are you free Friday or Saturday?", only one of the two conditions has to be true in order for the answer to the whole question to be "yes"; only if the answers to both halves of the question are false is the value of the entire expression false.

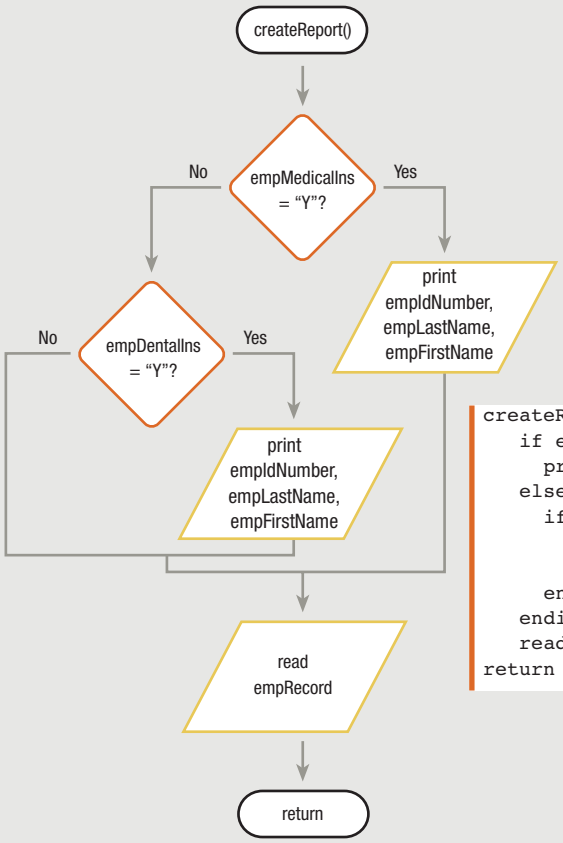
TIP

You can think of an OR expression in an algebraic way if you consider 0 to be false and any nonzero value to be true. The OR operator works like addition. A false expression OR a false expression yields a false result because 0 + 0 is 0. Any other combination yields a true result because 1 + 0, 0 + 1, and 1 + 1 all result in nonzero values.

For example, suppose your employer wants a list of all employees who participate in either the medical or dental plan. Assuming you are using the same input file described in Figure 5-9, the mainline logic and `housekeeping()` module for this program are identical to those used in Figures 5-11 and 5-12. You only need to change the heading on the sample output (Figure 5-10) and change the `heading1` variable in Figure 5-12 from `heading1 = "Employees with Medical and Dental Insurance"` to `heading1 = "Employees with Medical or Dental Insurance"`. The only substantial changes to the program occur in the `createReport()` module.

Figure 5-20 shows the possible logic for the `createReport()` method in this OR selection. As each record enters the `createReport()` method, you ask the question `empMedicalIns = "Y"?`, and if the result is true, you print the employee data. Because the employee needs to participate in only one of the two insurance plans to be selected for printing, there is no need for further questioning after you have determined that an employee has medical insurance. If the employee does not participate in the medical insurance plan, only then do you need to ask if `empDentalIns = "Y"?`. If the employee does not have medical insurance, but does have dental, you want this employee information to print on the report.

FIGURE 5-20: FLOWCHART AND PSEUDOCODE FOR `createReport()` MODULE OF PROGRAM THAT PRINTS RECORDS OF EMPLOYEES WHO PARTICIPATE IN EITHER THE MEDICAL OR DENTAL INSURANCE PLAN

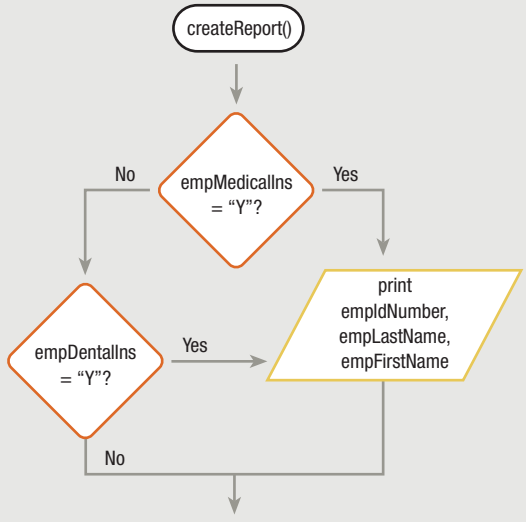



```
createReport()
   if empMedicalIns = "Y" then
     print empIdNumber, empLastName, empFirstName
   else
     if empDentalIns = "Y" then
         print empIdNumber, empLastName,
             empFirstName
     endif
   endif
   read empRecord
return
```

AVOIDING COMMON ERRORS IN AN OR SELECTION

You might have noticed that the statement `print empIdNumber, empLastName, empFirstName` appears twice in the flowchart and in the pseudocode shown in Figure 5-20. The temptation is to redraw the flowchart in Figure 5-20 to look like Figure 5-21. Logically, you can argue that the flowchart in Figure 5-21 is correct because the correct employee records print. However, this flowchart is not allowed because it is not structured.

FIGURE 5-21: INCORRECT FLOWCHART FOR `createReport()` MODULE



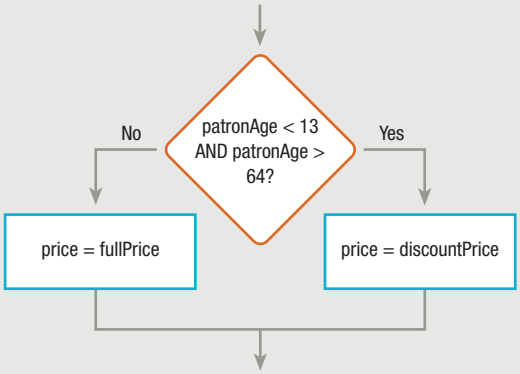
TIP If you do not see that Figure 5-21 is not structured, go back and review Chapter 2. In particular, review the example that begins at Figure 2-21.

TIP An additional source of error that is specific to the OR selection stems from a problem with language and the way people use it too casually. When your boss needs a report of all employees who carry medical or dental insurance, she is likely to say, "I need a report of all the people who have medical insurance and all those who have dental insurance." The request contains the word "and," and the report contains people who have one type of insurance "and" people who have another. However, the records you want to print are those from employees who have medical insurance OR dental insurance OR both. The logical situation requires an OR decision. Instead of saying "people who have medical insurance and people who have dental insurance," it would be clearer if your boss asked for "people who have medical or dental insurance." In other words, it would be more correct to put the question-joining "or" conjunction between the insurance types held by each person than between the people, but bosses and other human beings often do not speak like computers. As a programmer, you have the job of clarifying what really is being requested, and determining that often a request for A *and* B means a request for A *or* B.

The way we casually use English can cause another type of error when you require a decision based on a value falling within a range of values. For example, a movie theater manager might say, "Provide a discount to patrons who are

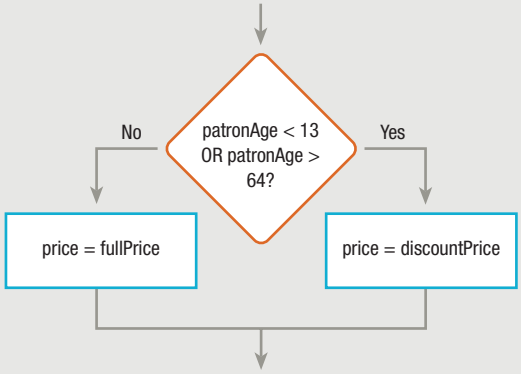
under 13 years old and those who are over 64 years old; otherwise, charge the full price." Because the manager has used the word "and" in the request, you might be tempted to create the decision shown in Figure 5-22; however, this logic will not provide a discounted price for any movie patron. You must remember that every time the decision in Figure 5-22 is made, it is made using a single data record. If the age field in that record contains an age lower than 13, then it cannot possibly contain an age over 64. Similarly, if it contains an age over 64, then there is no way it can contain an age under that. Therefore, there is no value that could be stored in the age field of a movie patron record for which both parts of the AND question are true—and the price will never be set to the `discountPrice` for any record. Figure 5-23 shows the correct logic.

FIGURE 5-22: INCORRECT LOGIC THAT ATTEMPTS TO PROVIDE A DISCOUNT FOR MOVIE PATRONS UNDER 13 AND FOR MOVIE PATRONS OVER 64




```
if patronAge < 13 AND patronAge > 64 then
   price = discountPrice
else
   price = fullPrice
endif
```

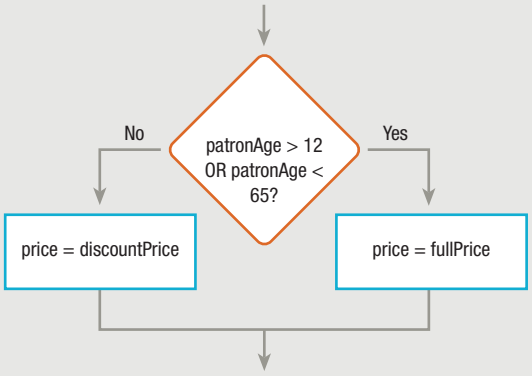
FIGURE 5-23: CORRECT LOGIC THAT PROVIDES A DISCOUNT FOR MOVIE PATRONS UNDER 13 AND FOR MOVIE PATRONS OVER 64




```
if patronAge < 13 OR patronAge > 64 then
   price = discountPrice
else
   price = fullPrice
endif
```

A similar error can occur in your logic if the theater manager says something like, "Don't give a discount—that is, charge full price—if a patron is over 12 or under 65." Because the word "or" appears in the request, you might plan your logic like that shown in Figure 5-24.

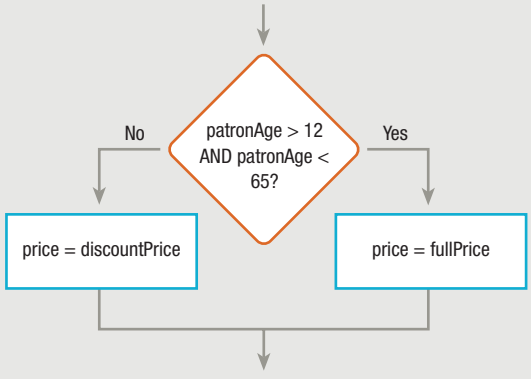
FIGURE 5-24: INCORRECT LOGIC THAT ATTEMPTS TO CHARGE FULL PRICE FOR MOVIE PATRONS OVER 12 AND UNDER 65




```
if patronAge > 12 OR patronAge < 65 then
   price = fullPrice
else
   price = discountPrice
endif
```

As in Figure 5-22, in Figure 5-24, no patron ever receives a discount, because every patron is either over 12 or under 65. Remember, in an OR decision, only one of the conditions needs to be true in order for the entire expression to be evaluated as true. So, for example, because a patron who is 10 is under 65, the full price is charged, and because a patron who is 70 is over 12, the full price also is charged. Figure 5-25 shows the correct logic for this decision.

FIGURE 5-25: CORRECT LOGIC THAT CHARGES FULL PRICE FOR MOVIE PATRONS OVER 12 AND UNDER 65




```
if patronAge > 12 AND patronAge < 65 then
   price = fullPrice
else
   price = discountPrice
endif
```

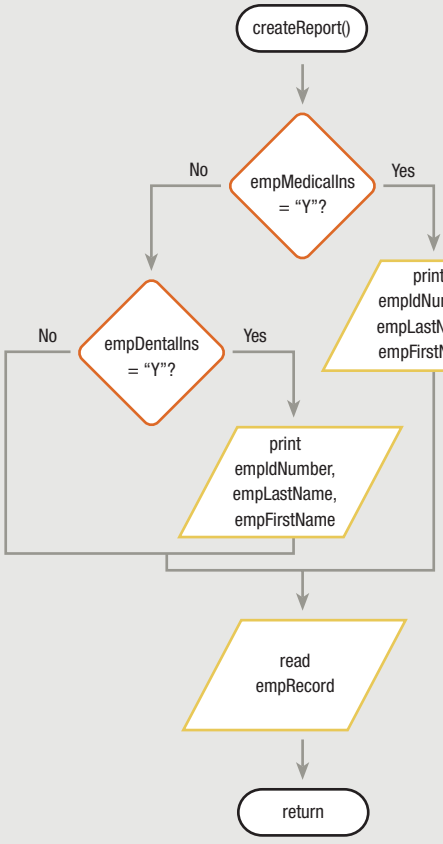
TIP

Using an OR operator in a decision that involves multiple conditions does not eliminate your responsibility for determining which of the conditions to test first. Even when you use an OR operator, the computer makes decisions one at a time, and makes them in the order you ask them. If the first question in an OR expression evaluates to true, then the entire expression is true, and the second question will not even be tested.

WRITING OR DECISIONS FOR EFFICIENCY

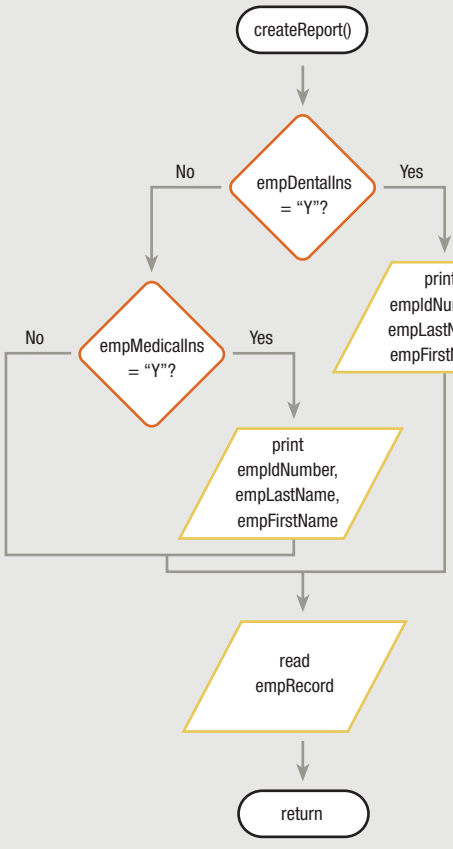
You can write a program that creates a report containing all employees who have either medical or dental insurance by using the `createReport()` method in either Figure 5-26 or Figure 5-27.

FIGURE 5-26: THE `createReport()` MODULE TO SELECT EMPLOYEES WITH MEDICAL OR DENTAL INSURANCE, USING MEDICAL DECISION FIRST




```
createReport()
   if empMedicalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
   else
      if empDentalIns = "Y" then
         print empIdNumber, empLastName,
               empFirstName
      endif
   endif
   read empRecord
return
```

FIGURE 5-27: ALTERNATE `createReport()` MODULE TO SELECT EMPLOYEES WITH MEDICAL OR DENTAL INSURANCE, USING DENTAL DECISION FIRST




```
createReport()
   if empDentalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
   else
      if empMedicalIns = "Y" then
         print empIdNumber, empLastName,
             empFirstName
      endif
   endif
   read empRecord
return
```

You might have guessed that one of these selections is superior to the other, if you have some background information about the relative likelihood of each condition you are testing. For example, once again assume you know that out of 1,000 employees in your company, about 90 percent, or 900, participate in the medical insurance plan, and about half, or 500, participate in the dental plan.

When you use the logic shown in Figure 5-26 to select employees who participate in either insurance plan, you first ask about medical insurance. For 900 employees, the answer is true; you print these employee records. Only about 100 records continue to the next question regarding dental insurance, where about half, or 50, fulfill the requirements to print. In the end, you print about 950 employees.

If you use Figure 5-27, you ask `empDentalIns = "Y"?` first. The result is true for 50 percent, or 500 employees, whose names then print. Five hundred employee records then progress to the medical insurance question, after which 90 percent, or 450, of them print.

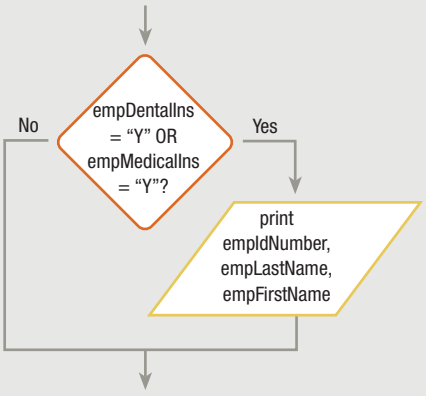
Using either scenario, 950 employee records appear on the list, but the logic used in Figure 5-26 requires 1,100 decisions, whereas the logic used in Figure 5-27 requires 1,500 decisions. The general rule is: *In an OR decision, first ask the question that is more likely to be true*. Because a record qualifies for printing as soon as it passes one test, asking the more likely question first eliminates as many records as possible from having to go through the second decision. The time it takes to execute the program is decreased.

COMBINING DECISIONS IN AN OR SELECTION

When you need to take action when either one or the other of two conditions is met, you can use two separate, nested selection structures, as in the previous examples. However, most programming languages allow you to ask two or more questions in a single comparison by using a **logical OR operator**—for example, `empDentalIns = "Y" OR empMedicalIns = "Y"`. When you use the logical OR operator, only one of the listed conditions must be met for the resulting action to take place. If the programming language you use allows this construct, you still must realize that the question you place first is the question that will be asked first, and cases eliminated by the first question will not proceed to the second question. The computer can ask only one question at a time; even when you draw the flowchart in Figure 5-28, the computer will execute the logic in the flowchart in Figure 5-29.

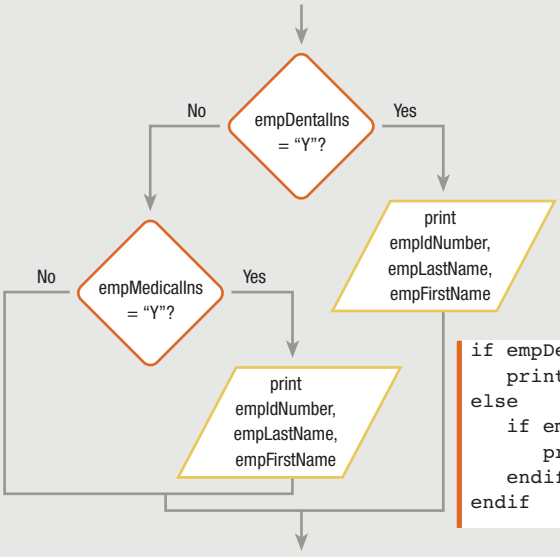
TIP C#, C++, C, and Java use the symbol || to represent the logical OR.

FIGURE 5-28: FLOWCHART AND PSEUDOCODE OF AN OR DECISION USING AN OR OPERATOR




```
if empDentalIns = "Y" OR empMedicalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
endif
```

FIGURE 5-29: FLOWCHART AND PSEUDOCODE OF COMPUTER LOGIC OF PROGRAM CONTAINING AN OR OPERATOR IN THE DECISION; THE COMPUTER STILL MAKES TWO SEPARATE DECISIONS EVEN THOUGH AN OR OPERATOR IS USED




```
if empDentalIns = "Y" then
   print empIdNumber, empLastName, empFirstName
else
   if empMedicalIns = "Y" then
      print empIdNumber, empLastName, empFirstName
   endif
endif
```

USING SELECTIONS WITHIN RANGES

Business programs often need to make selections based on a variable falling within a range of values. For example, suppose you want to print a list of all employees and the names of their supervisors. An employee's supervisor is assigned according to the employee's department number, as shown in Figure 5-30.

FIGURE 5-30: SUPERVISORS BY DEPARTMENT

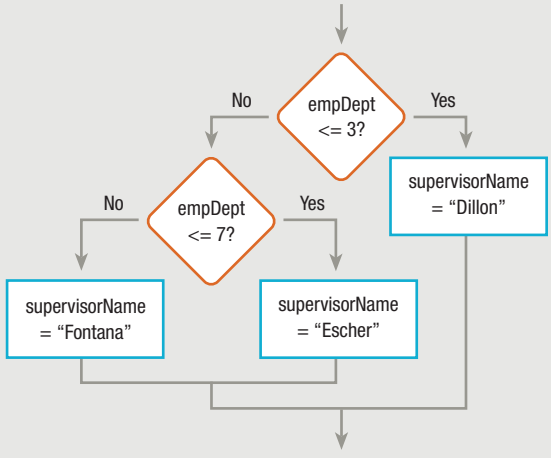
DEPARTMENT NUMBER	SUPERVISOR
1–3	Dillon
4–7	Escher
8–9	Fontana

When you write the program that reads each employee's record, you could make nine decisions before printing the supervisor's name, such as `empDept = 1?`, `empDept = 2?`, and so on. However, it is more convenient to find the supervisor by using a range check.

When you use a **range check**, you compare a variable to a series of values between limits. To perform a range check, make comparisons using either the lowest or highest value in each range of values you are using. For example, to find each employee's supervisor as listed in Figure 5-30, either use the values 1, 4, and 8, which represent the low ends of each supervisor's department range, or use the values 3, 7, and 9, which represent the high ends.

Figure 5-31 shows the flowchart and pseudocode that represent the logic for choosing a supervisor name by using the high-end range values. You test the `empDept` value for less than or equal to the high end of the lowest range group. If the comparison evaluates as true, you know the intended value of `supervisorName`. If not, you continue checking.

FIGURE 5-31: USING HIGH-END VALUES FOR A RANGE CHECK




```
if empDept <= 3 then
   supervisorName = "Dillon"
else
   if empDept <= 7 then
        supervisorName = "Escher"
   else
        supervisorName = "Fontana"
   endif
endif
```

TIP In Figure 5-31, notice how each `else` aligns vertically with its corresponding `if`.

For example, consider records containing three different values for `empDept`, and compare how they would be handled by the set of decisions in Figure 5-31.

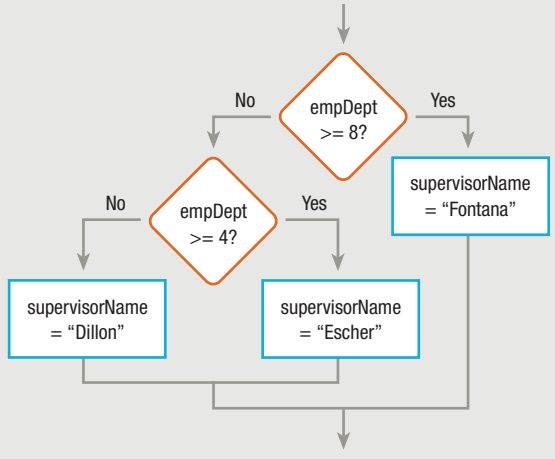
- First, assume that the value of `empDept` for a record is 2. Using the logic in Figure 5-31, the value of the Boolean expression `empDept <= 3` is true, `supervisorName` is set to “Dillon”, and the `if` structure ends. In this case, the second decision, `empDept <= 7`, is never made, because the `else` half of `empDept <= 3` never executes.
- Next, assume that for another record, the value of `empDept` is 7. Then, `empDept <= 3` evaluates as false, so the `else` clause of the decision executes. There, `empDept <= 7` is evaluated, and found to be true, so `supervisorName` becomes “Escher”.
- Finally, assume that the value of `empDept` is 9. In this case, the first decision, `empDept <= 3`, is false, so the `else` clause executes. Then, the second decision, `empDept <=7`, also evaluates as false, so the `else` clause of the second decision executes, and `supervisorName` is set to “Fontana”. In this example, “Fontana” can be called a **default value**, because if neither of the two decision expressions is true, `supervisorName` becomes “Fontana” by default. A default value is the value assigned after a series of selections are all false.

TIP

Using the logic in Figure 5-31, `supervisorName` becomes "Fontana" even if `empDept` is a high, invalid value such as 10, 12, or even 300. The example is intended to be simple, using only two decisions. However, in a business application, you might consider amending the logic so an additional, third decision is made that compares `empDept` less than or equal to 9. Then, you could assign "Fontana" as the supervisor name if `empDept` is less than or equal to 9, and issue an error message if `empDept` is not. You might also want to insert a similar decision at the beginning of the program segment to make sure `empDept` is not less than 1.

The flowchart and pseudocode for choosing a supervisor name using the reverse of this method, by comparing the employee department to the low end of the range values that represent each supervisor's area, appear in Figure 5-32. Using the technique shown in Figure 5-32, you compare `empDept` to the low end (8) of the highest range (8 to 9) first; if `empDept` falls in the range, `supervisorName` is known; otherwise, you check the next lower group. In this example, "Dillon" becomes the default value. That is, if the department number is not greater than or equal to 8, and it is also not greater than or equal to 4, then by default, `supervisorName` is set to "Dillon".

FIGURE 5-32: USING LOW-END VALUES OF RANGES TO DETERMINE EMPLOYEE'S SUPERVISOR

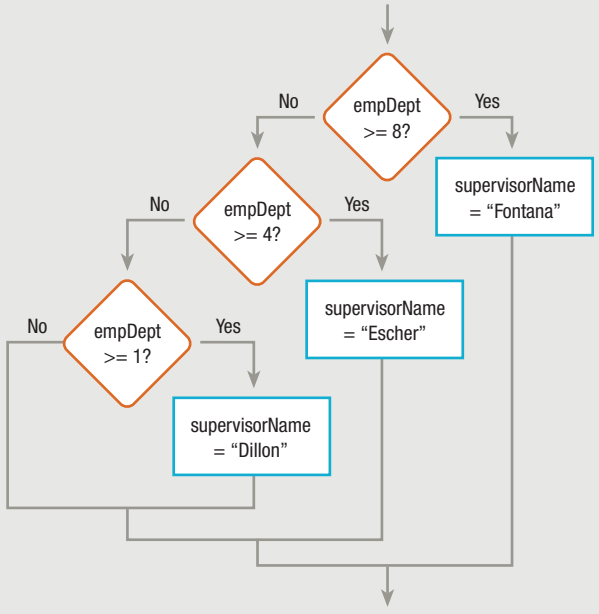



```
if empDept >= 8 then
   supervisorName = "Fontana"
else
   if empDept >= 4 then
      supervisorName = "Escher"
   else
      supervisorName = "Dillon"
   endif
endif
```

COMMON ERRORS USING RANGE CHECKS

Two common errors that occur when programmers perform range checks both entail doing more work than is necessary. Figure 5-33 shows a range check in which the programmer has asked one question too many. If you know that all `empDept` values are positive numbers, then if `empDept` is not greater than or equal to 8, and it is also not greater than or equal to 4, then by default it must be greater than or equal to 1. Asking whether `empDept` is greater than or equal to 1 is a waste of time; no employee record can ever travel the logical path on the far left. You might say that the path that can never be traveled is a **dead** or **unreachable path**, and that the statements written there constitute dead or unreachable code. Providing such a path is always a logical error.

FIGURE 5-33: INEFFICIENT RANGE SELECTION INCLUDING UNREACHABLE PATH



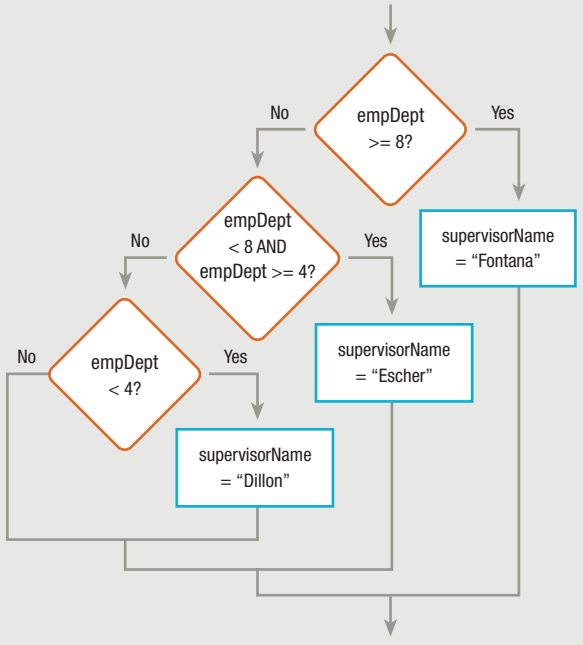

```
if empDept >=8 then
   supervisorName = "Fontana"
else
   if empDept >= 4 then
      supervisorName = "Escher"
   else
      if empDept >= 1 then
         supervisorName = "Dillon"
      endif
   endif
endif
```

TIP

When you ask questions of human beings, you sometimes ask a question to which you already know the answer. For example, in court, a good trial lawyer seldom asks a question if the answer will be a surprise. With computer logic, however, such questions are an inefficient waste of time.

Another error that programmers make when writing the logic to perform a range check also involves asking unnecessary questions. You should never ask a question if there is only one possible answer or outcome. Figure 5-34 shows an inefficient range selection that asks two unneeded questions. In the figure, if `empDept` is greater than or equal to 8, “Fontana” is the supervisor. If `empDept` is not greater than or equal to 8, then it must be less than 8, so the next question does not have to check for less than 8. The computer logic will never execute the second decision unless `empDept` is already less than 8—that is, unless it follows the false branch of the first selection. If you use the logic in Figure 5-34, you are wasting computer time asking a question that has previously been answered. Similarly, if `empDept` is not greater than or equal to 8 and it is also not greater than or equal to 4, then it must be less than 4. Therefore, there is no reason to compare `empDept` to 4 to determine whether “Dillon” is the supervisor. If the logic makes it past the first two `if` statements in Figure 5-34, then the supervisor must be “Dillon”.

FIGURE 5-34: INEFFICIENT RANGE SELECTION INCLUDING UNNECESSARY QUESTION




```
if empDept >= 8 then
   supervisorName = "Fontana"
else
   if empDept < 8 AND empDept >= 4 then
      supervisorName = "Escher"
   else
      if empDept < 4 then
         supervisorName = "Dillon"
      endif
   endif
endif
```

TIP Beginning programmers sometimes justify their use of unnecessary questions as “just making really sure.” Such caution is unnecessary when writing computer logic.

UNDERSTANDING PRECEDENCE WHEN COMBINING AND AND OR SELECTIONS

Most programming languages allow you to combine as many AND and OR operators in an expression as you need. For example, assume you need to achieve a score of at least 75 on each of three tests in order to pass a course. When multiple conditions must be true before performing an action, you can use an expression like the following:

```
if score1 >= 75 AND score2 >= 75 AND score3 >= 75 then
   classGrade = "Pass"
else
   classGrade = "Fail"
endif
```

On the other hand, if you need to pass only one test in order to pass the course, then the logic is as follows:

```
if score1 >= 75 OR score2 >= 75 OR score3 >= 75 then
   classGrade = "Pass"
else
   classGrade = "Fail"
endif
```

The logic becomes more complicated when you combine AND and OR operators within the same statement. When you combine AND and OR operators, the AND operators take **precedence**, meaning their Boolean values are evaluated first.

For example, consider a program that determines whether a movie theater patron can purchase a discounted ticket. Assume discounts are allowed for children (age 12 and under) and senior citizens (age 65 and older) who attend "G"-rated movies. The following code looks reasonable, but produces incorrect results, because the AND operator evaluates before the OR.

```
if age <= 12 OR age >= 65 AND rating = "G" then
  print "Discount applies"
```

For example, assume a movie patron is 10 years old and the movie rating is "R". The patron should not receive a discount—or be allowed to see the movie! However, within the previous `if` statement, the part of the expression containing the AND, `age >= 65 AND rating = "G"`, evaluates first. For a 10-year-old and an "R"-rated movie, the question is false (on both counts), so the entire `if` statement becomes the equivalent of the following:

```
if age <= 12 OR aFalseExpression
```

Because the patron is 10, `age <= 12` is true, so the original `if` statement becomes the equivalent of:

```
if aTrueExpression OR aFalseExpression
```

which evaluates as true. Therefore, the statement "Discount applies" prints when it should not.

Many programming languages allow you to use parentheses to correct the logic and force the expression `age <= 12 OR age >= 65` to evaluate first, as shown in the following pseudocode:

```
if (age <= 12 OR age >= 65) AND rating = "G" then
   print "Discount applies"
```

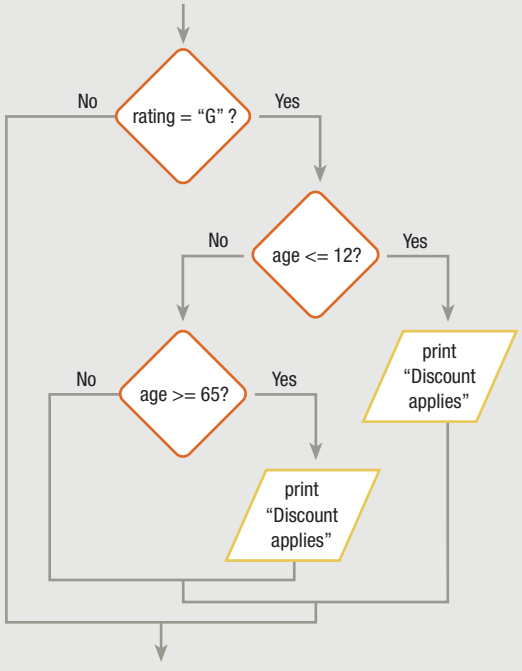
With the added parentheses, if the patron's age is 12 or under OR 65 or over, the expression is evaluated as:

```
if aTrueExpression AND rating = "G"
```

When the age value qualifies a patron for a discount, then the rating value must also be acceptable before the discount applies. This was the original intention of the statement.

You always can avoid the confusion of mixing AND and OR decisions by nesting `if` statements instead of using ANDs and ORs. With the flowchart and pseudocode shown in Figure 5-35, it is clear which movie patrons receive the discount. In the flowchart in the figure, you can see that the OR is nested entirely within the Yes branch of the `rating = "G"?` selection. Similarly, by examining the pseudocode in Figure 5-35, you can see by the alignment that if the rating is not "G", the logic proceeds directly to the last `endif` statement, bypassing any checking of the age at all.

FIGURE 5-35: NESTED `if` LOGIC THAT DETERMINES MOVIE PATRON DISCOUNTS




```
if rating = "G" then
   if age <= 12 then
      print "Discount applies"
   else
      if age >= 65 then
         print "Discount applies"
      endif
   endif
endif
```

TIP

In every programming language, multiplication has precedence over addition in an arithmetic statement. That is, the value of 2 + 3 * 4 is 14 because the multiplication occurs before the addition. Similarly, in every programming language, AND has precedence over OR. That's because computer circuitry treats the AND operator as multiplication and the OR operator as addition. In every programming language, 1 represents true and 0 represents false. So, for example, `aTrueExpression` AND `aTrueExpression` results in true, because 1 * 1 is 1, and `aTrueExpression` AND `aFalseExpression` is false, because 1 * 0 is 0. Similarly, `aFalseExpression` OR `aFalseExpression` AND `aTrueExpression` evaluates to `aFalseExpression` because 0 + 0 * 1 is 0, whereas `aFalseExpression` AND `aFalseExpression` OR `aTrueExpression` evaluates to `aTrueExpression` because 0 * 0 + 1 is 1.

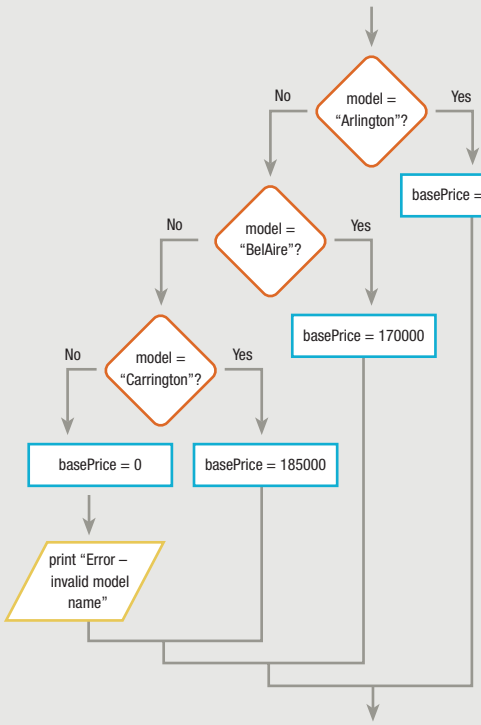
UNDERSTANDING THE CASE STRUCTURE

When you have a series of decisions based on the value stored in a single variable, most languages allow you to use a case structure. You first learned about the case structure in Chapter 2. There, you learned that you can solve any programming problem using only the three basic structures—sequence, selection, and loop. You are never required to use a case structure—you can always substitute a series of nested selections. The **case structure** simply provides a convenient alternative to using a series of decisions when you must make choices based on the value stored in a single variable.

TIP In some languages, the case structure is called the switch statement.

For example, suppose you work for a real estate developer who is selling houses that have one of three different floor plans. The logic segment of a program that determines the base price of the house might look like the logic shown in Figure 5-36.

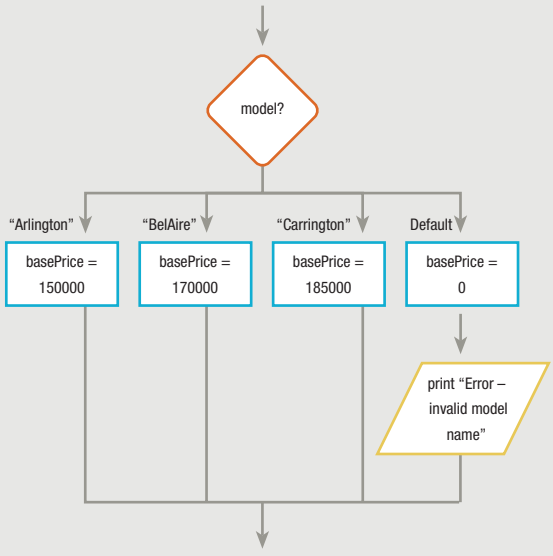
FIGURE 5-36: FLOWCHART AND PSEUDOCODE DETERMINING HOUSE MODEL PRICE USING `if`S




```
if model = "Arlington" then
     basePrice = 150000
else
     if model = "BelAire" then
          basePrice = 170000
     else
          if model = "Carrington" then
               basePrice = 185000
          else
               basePrice = 0
               print "Error - invalid model name"
          endif
     endif
endif
```

The logic shown in Figure 5-36 is completely structured. However, rewriting the logic using a case structure, as shown in Figure 5-37, might make it easier to understand. When using the case structure, you test a variable against a series of values, taking appropriate action based on the variable's value.

FIGURE 5-37: FLOWCHART AND PSEUDOCODE DETERMINING HOUSE MODEL PRICE USING THE CASE STRUCTURE




```
case based on model
     case "Arlington"
          basePrice = 150000
     case "BelAire"
          basePrice = 170000
     case "Carrington"
          basePrice = 185000
     default
          basePrice = 0
          print "Error – invalid model name"
endcase
```

In Figure 5-37, the `model` variable is compared in turn with "Arlington", "BelAire", and "Carrington", and an appropriate `basePrice` value is set. The default case is the case that executes in the event no other cases execute. The logic shown in Figure 5-36 is identical to that shown in Figure 5-37; your choice of method to set the housing model prices is entirely a matter of preference.

TIP

When you look at a nested if-else structure containing an outer and inner selection, if the inner nested `if` is within the `if` portion of the outer `if`, the program segment is a candidate for AND logic. On the other hand, if the inner `if` is within the `else` portion of the outer `if`, the program segment might be a candidate for the case structure.

TIP

Some languages require a break statement at the end of each case selection segment. In those languages, once a case is true, all the following cases execute until a break statement is encountered. When you study a specific programming language, you will learn how to use break statements if they are required in that language.

USING DECISION TABLES

Some programs require multiple decisions to produce the correct output. Managing all possible outcomes of multiple decisions can be a difficult task, so programmers sometimes use a tool called a decision table to help organize the possible decision outcome combinations.

A **decision table** is a problem-analysis tool that consists of four parts:

- Conditions
- Possible combinations of Boolean values for the conditions
- Possible actions based on the conditions
- The specific action that corresponds to each Boolean value of each condition

For example, suppose a college collects input data like that shown in Figure 5-38. Each student's data record includes the student's age and a variable that indicates whether the student has requested a residence hall that enforces quiet study hours.

FIGURE 5-38: STUDENT RESIDENCE FILE DESCRIPTION

```
STUDENT RESIDENCE FILE DESCRIPTION
File Name: STURESFILE
FIELD DESCRIPTION       DATA TYPE     COMMENTS
ID Number               Numeric       4 digits, 0 decimal places
Last Name               Character     15 characters
First Name              Character     15 characters
Age                     Numeric       0 decimal places
Request for Hall        Character     1 character, Y or N
  with Quiet Hours
```

Assume that the residence hall director makes residence hall assignments based on the following rules:

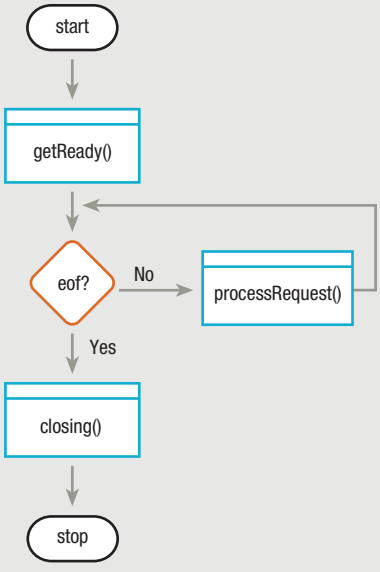
- Students who are under 21 years old and who request a residence hall with quiet study hours are assigned to Addams Hall.
- Students who are under 21 years old and who do not request a residence hall with quiet study hours are assigned to Grant Hall.
- Students who are 21 years old and over and who request a residence hall with quiet study hours are assigned to Lincoln Hall.
- Students who are 21 years old and over and who do not request a residence hall with quiet study hours are also assigned to Lincoln Hall.

You can create a program that assigns each student to the appropriate residence hall and prints a list of students along with each student's hall assignment. A sample report is shown in Figure 5-39. The mainline logic for this program appears in Figure 5-40. Most programs you write will contain the same basic mainline logic: Each performs start-up or housekeeping tasks, a main loop that acts repeatedly—once for each input record—and a finishing module that performs any necessary program-ending tasks, including closing the open files.

FIGURE 5-39: SAMPLE REPORT LISTING STUDENT RESIDENCE HALL ASSIGNMENTS

```
     Student Residence Hall Assignments

Student ID      Age     Request for Quiet     Assigned Hall

1288            21            Y               Lincoln
1567            20            Y               Addams
5612            24            N               Lincoln
7610            18            N               Grant
7723            20            N               Grant
8012            19            Y               Addams
```

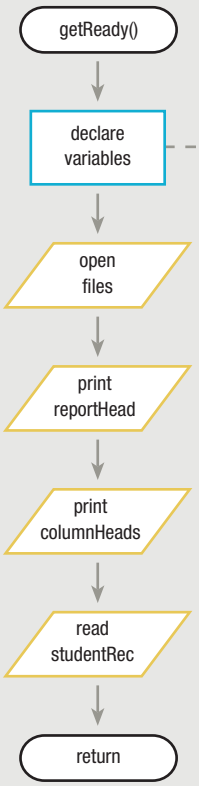
FIGURE 5-40: FLOWCHART AND PSEUDOCODE OF MAINLINE LOGIC FOR STUDENT RESIDENCE HALL ASSIGNMENTS REPORT




```
start
   perform getReady()
   while not eof
      perform processRequest()
   endwhile
   perform closing()
stop
```

The `getReady()` module for the program that produces the residence hall report is shown in Figure 5-41. It declares variables, opens the files, prints the report headings, and reads the first data record into memory.

FIGURE 5-41: FLOWCHART AND PSEUDOCODE OF `getReady()` MODULE FOR STUDENT RESIDENCE HALL ASSIGNMENTS REPORT




```
studentRec
   num stuId
   char stuLastName
   char stuFirstName
   num stuAge
   char stuQuietRequest
char reportHead =
    "Student Residence Hall Assignments"
char columnHeads = "Student ID   Age
   Request for Quiet  Assigned Hall"
char assignedHall
```

```
getReady()
   declare variables
   open files
   print reportHead
   print columnHeads
   read studentRec
return
```

Before you draw a flowchart or write the pseudocode for the `processRequest()` module, you can create a decision table to help you manage all the decisions. You can begin to create a decision table by listing all possible conditions. They are:

- `stuAge < 21`, or not
- `stuQuietRequest = "Y"`, or not

Next, determine how many possible Boolean value combinations exist for the conditions. In this case, there are four possible combinations, shown in Figure 5-42. A student can be under 21, request a residence hall with quiet hours, both, or neither. Because each condition has two outcomes and there are two conditions, there are 2 * 2, or four, possibilities. Three conditions would produce eight possible outcome combinations (2 * 2 * 2); four conditions would produce 16 possible outcome combinations (2 * 2 * 2 * 2), and so on.

FIGURE 5-42: POSSIBLE OUTCOMES OF RESIDENCE HALL REQUEST CONDITIONS

Condition	Outcome			
stuAge < 21	T	T	F	F
stuQuietRequest = "Y"	T	F	T	F

Next, add rows to the decision table to list the possible outcome actions. A student might be assigned to Addams, Grant, or Lincoln Hall. Figure 5-43 shows an expanded decision table that includes these three possible outcomes.

FIGURE 5-43: DECISION TABLE INCLUDING POSSIBLE OUTCOMES OF RESIDENCE HALL DECISIONS

Condition	Outcome			
stuAge < 21	T	T	F	F
stuQuietRequest = "Y"	T	F	T	F
assignedHall = "Addams"				
assignedHall = "Grant"				
assignedHall = "Lincoln"				

You choose one required outcome for each possible combination of conditions. As shown in Figure 5-44, you place an X in the Addams Hall row when **stuAge** is less than 21 and the student requests a residence hall with quiet study hours. You place an X in the Grant Hall row when a student is under 21 but does not request a residence hall with quiet hours. Finally, you place Xs in the Lincoln Hall row for both **stuQuietRequest** values when a student is not under 21 years old—only one residence hall is available for students 21 and over, whether they have requested a hall with quiet hours or not.

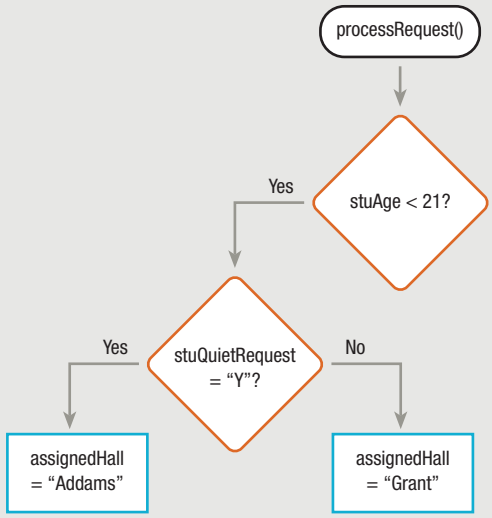
FIGURE 5-44: COMPLETED DECISION TABLE FOR RESIDENCE HALL SELECTION

Condition	Outcome			
stuAge < 21	T	T	F	F
stuQuietRequest = "Y"	T	F	T	F
assignedHall = "Addams"	X			
assignedHall = "Grant"		X		
assignedHall = "Lincoln"			X	X

The decision table is complete (count the Xs—there are four possible outcomes). Take a moment and confirm that each residence hall selection is the appropriate value based on the original specifications. Now that the decision table is complete, you can start to plan the logic.

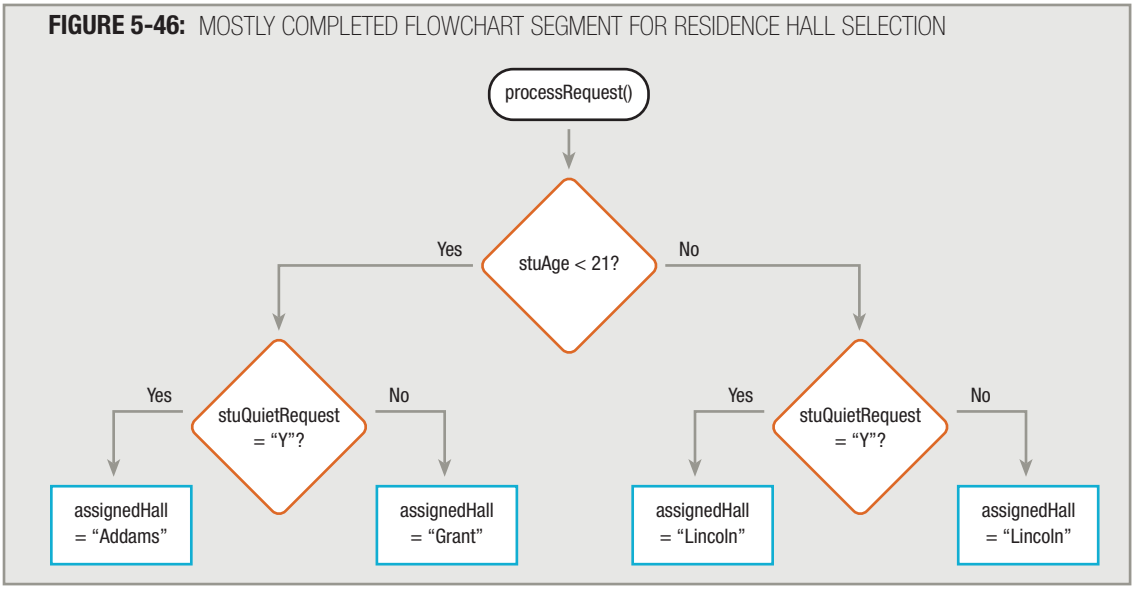
If you choose to use a flowchart to express the logic, you start by drawing a path to the outcome shown in the first column. This result (which occurs when `stuAge < 21` and `stuQuietRequest = "Y"`) sets the residence hall to "Addams". Next, add the resulting action shown in the second column of the decision table, which occurs when `stuAge < 21` is true and `stuQuietRequest = "Y"` is false. In those cases, the residence hall becomes "Grant". See Figure 5-45.

FIGURE 5-45: PARTIALLY COMPLETED FLOWCHART SEGMENT FOR RESIDENCE HALL SELECTION



Next, on the false outcome side of the `stuAge < 21` question, you add the resulting action shown in the third column of the decision table—set the residence hall to "Lincoln". This action occurs when `stuAge < 21` is false and `stuQuietRequest = "Y"` is true. Finally, add the resulting action shown in the fourth column of the decision table, which occurs when both conditions are false. When a student is not under 21 and does not request a hall with quiet study hours, then the assigned hall is "Lincoln". See Figure 5-46.

FIGURE 5-46: MOSTLY COMPLETED FLOWCHART SEGMENT FOR RESIDENCE HALL SELECTION

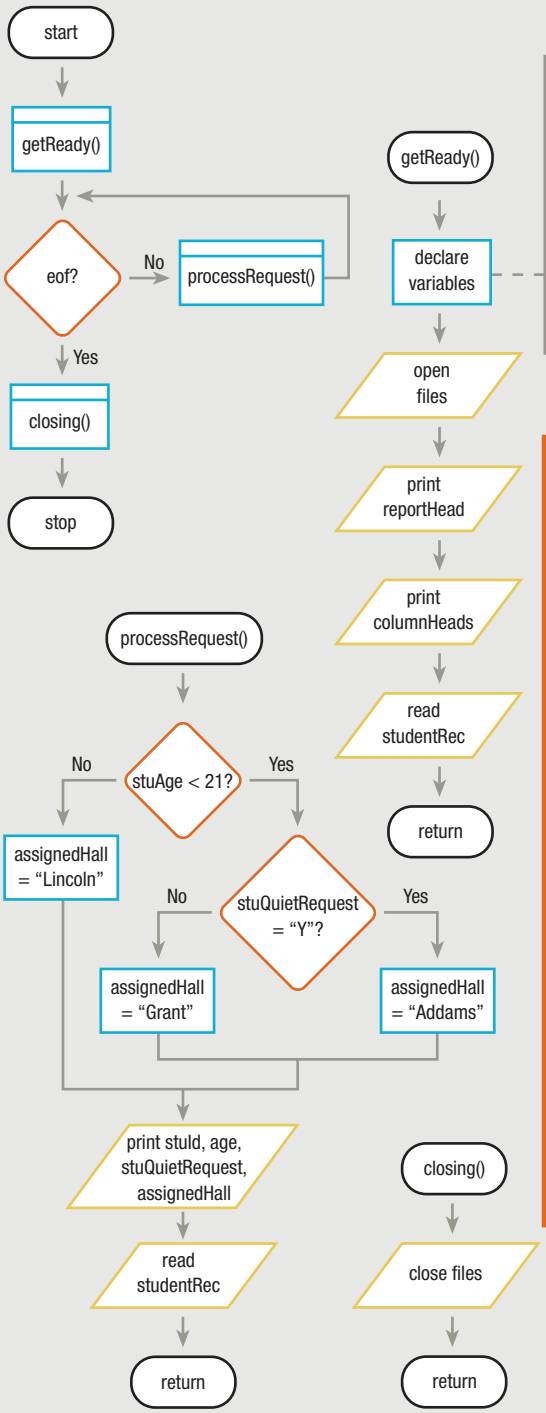


The decision making in the flowchart segment is now complete and accurately assigns each student to the correct residence hall. To finish it, all you need to do is tie up the loose ends of the decision structure, print a student's ID number and residence hall assignment, and read the next record. However, if you examine the two result boxes on the far right in Figure 5-46, you see that the assigned residence hall is identical—"Lincoln" in both cases. When a student is not under 21, whether the `stuQuietRequest` equals "Y" or not, the residence hall assignment is the same; therefore, there is no point in asking the `stuQuietRequest` question. Additionally, many programmers prefer that the True or Yes side of a flowchart decision always appears on the right side of a flowchart. Figure 5-47 shows the complete residence hall assignment program, including the redrawn `processRequest()` module, which has only one "Lincoln" assignment statement and True results to the right of each selection. Figure 5-47 also shows the pseudocode for the same problem.

Perhaps you could have created the final decision-making `processRequest()` module without creating the decision table first. If so, you need not use the table. Decision tables are more useful to the programmer when the decision-making process becomes more complicated. Additionally, they serve as a useful graphic tool when you want to explain the decision-making process of a program to a user who is not familiar with flowcharting symbols.

TIP In Appendix C, you can walk through the process used to create a larger decision table.

FIGURE 5-47: COMPLETE FLOWCHART AND PSEUDOCODE FOR RESIDENCE HALL SELECTION PROBLEM




```
studentRec
  num stuId
  char stuLastName
  char stuFirstName
  num stuAge
  char stuQuietRequest
char reportHead =
  "Student Residence Hall Assignments"
char columnHeads = "Student ID   Age
   Request for Quiet  Assigned Hall"
char assignedHall
```

```
start
     perform getReady()
     while not eof
          perform processRequest()
     endwhile
     perform closing()
stop
getReady()
      declare variables
      open files
      print reportHead
      print columnHeads
      read studentRec
return
processRequest()
      if stuAge < 21 then
           if stuQuietRequest = "Y" then
                assignedHall = "Addams"
           else
                assignedHall = "Grant"
           endif
      else
           assignedHall = "Lincoln"
      endif
      print stuId, age, stuQuietRequest,
        assignedHall
      read studentRec
return
closing()
      close files
return
```

CHAPTER SUMMARY

- Every decision you make in a computer program involves evaluating a Boolean expression. You can use dual-alternative, or binary, selections or if-then-else structures to choose between two possible outcomes. You also can use single-alternative, or unary, selections or if-then structures when there is only one outcome for the question where an action is required.
- For any two values that are the same type, you can use relational comparison operators to decide whether the two values are equal, the first value is greater than the second value, or the first value is less than the second value. The two values used in a Boolean expression can be either variables or constants.
- An AND decision occurs when two conditions must be true in order for a resulting action to take place. An AND decision requires a nested decision, or a nested `if`.
- In an AND decision, first ask the question that is less likely to be true. This eliminates as many records as possible from having to go through the second decision, which speeds up processing time.
- Most programming languages allow you to ask two or more questions in a single comparison by using a logical AND operator.
- When you must satisfy two or more criteria to initiate an event in a program, you must make sure that the second decision is made entirely within the first decision, and that you use a complete Boolean expression on both sides of the AND.
- An OR decision occurs when you want to take action when one or the other of two conditions is true.
- Errors occur in OR decisions when programmers do not maintain structure. An additional source of errors that are particular to the OR selection stems from people using the word AND to express OR requirements.
- In an OR decision, first ask the question that is more likely to be true.
- Most programming languages allow you to ask two or more questions in a single comparison by using a logical OR operator.
- To perform a range check, make comparisons with either the lowest or highest value in each range of values you are using.
- Common errors that occur when programmers perform range checks include asking unnecessary and previously answered questions.
- The case structure provides a convenient alternative to using a series of decisions when you must make choices based on the value stored in a single variable.
- A decision table is a problem-analysis tool that consists of conditions, possible combinations of Boolean values for the conditions, possible actions based on the conditions, and the action that corresponds to each Boolean value of each condition.

KEY TERMS

A **dual-alternative**, or **binary**, selection structure offers two actions, each associated with one of two possible outcomes. It is also called an **if-then-else** structure.

In a **single-alternative**, or **unary**, selection structure, an action is required for only one outcome of the question. You call this form of the selection structure an **if-then**, because no "else" action is necessary.

The **if clause** of a decision holds the action or actions that execute when a Boolean expression in a decision is true.

The **else clause** of a decision holds the action or actions that execute when the Boolean expression in a decision is false.

A **Boolean expression** is one that represents only one of two states, usually expressed as true or false.

A **trivial** Boolean expression is one that always evaluates to the same result.

Relational comparison operators are the symbols that express Boolean comparisons. Examples include =, >, <, >=, <=, and <>.

A **logical operator** (as the term is most often used) compares single bits. However, some programmers use the term synonymously with "relational comparison operator."

With an **AND decision**, two conditions must both be true for an action to take place. An AND decision requires a **nested decision**, or a **nested if**—that is, a decision "inside of" another decision. A series of nested `if` statements can also be called a **cascading if statement**.

A **logical AND operator** is a symbol that you use to combine decisions so that two (or more) conditions must be true for an action to occur.

Short-circuiting is the compiler technique of not evaluating an expression when the outcome makes no difference.

A **range** of values encompasses every value between a high and low limit.

An **OR decision** contains two (or more) decisions; if at least one condition is met, the resulting action takes place.

A **logical OR operator** is a symbol that you use to combine decisions when any one condition can be true for an action to occur.

When you use a **range check**, you compare a variable to a series of values between limits.

A **default value** is one that is assigned after all test conditions are found to be false.

A **dead** or **unreachable path** is a logical path that can never be traveled.

When an operator has **precedence**, it is evaluated before others.

The **case structure** provides a convenient alternative to using a series of decisions when you must make choices based on the value stored in a single variable.

A **decision table** is a problem-analysis tool that consists of four parts: conditions, possible combinations of Boolean values for the conditions, possible actions based on the conditions, and the specific action that corresponds to each Boolean value of each condition.

REVIEW QUESTIONS

1. **The selection statement** `if quantity > 100 then discountRate = 0.20` **is an example of a _____.**
   a. single-alternative selection
   b. dual-alternative selection
   c. binary selection
   d. all of the above

2. **The selection statement** `if dayOfWeek = "S" then price = 5.00 else price = 6.00` **is an example of a _____.**
   a. unary selection
   b. single-alternative selection
   c. binary selection
   d. all of the above

3. **All selection statements must have _____.**
   a. an `if` clause
   b. an `else` clause
   c. both of these
   d. neither a nor b

4. **An expression like** `amount < 10` **is a _____ expression.**
   a. Gregorian
   b. Boolean
   c. unary
   d. binary

5. **Usually, you compare only variables that have the same _____.**
   a. value
   b. size
   c. name
   d. type

6. **Symbols like > and < are known as _____ operators.**
   a. arithmetic
   b. relational comparison
   c. sequential
   d. scripting accuracy

7. **If you could use only three relational comparison operators, you could get by with _____.**
   a. greater than, less than, and greater than or equal to
   b. less than, less than or equal to, and not equal to
   c. equal to, less than, and greater than
   d. equal to, not equal to, and less than

8. If `a > b` is false, then which of the following is always true?

a. `a < b`
b. `a <= b`
c. `a = b`
d. `a >= b`

9. Usually, the most difficult comparison operator to work with is _____.

a. equal to
b. greater than
c. less than
d. not equal to

10. Which of the lettered choices is equivalent to the following decision?

```
if x > 10 then
   if y > 10 then
      print "X"
   endif
endif
```

a. `if x > 10 AND y > 10 then print "X"`
b. `if x > 10 OR y > 10 then print "X"`
c. `if x > 10 AND x > y then print "X"`
d. `if y > x then print "X"`

11. The Midwest Sales region of Acme Computer Company consists of five states—Illinois, Indiana, Iowa, Missouri, and Wisconsin. Suppose you have input records containing Acme customer data, including state of residence. To most efficiently select and display all customers who live in the Midwest Sales region, you would use _____.

a. five completely separate unnested `if` statements
b. nested `if` statements using AND logic
c. nested `if` statements using OR logic
d. Not enough information is given.

12. The Midwest Sales region of Acme Computer Company consists of five states—Illinois, Indiana, Iowa, Missouri, and Wisconsin. About 50 percent of the regional customers reside in Illinois, 20 percent in Indiana, and 10 percent in each of the other three states. Suppose you have input records containing Acme customer data, including state of residence. To most efficiently select and display all customers who live in the Midwest Sales region, you would ask first about residency in _____.

a. Illinois
b. Indiana
c. Wisconsin
d. either Iowa, Missouri, or Wisconsin—it does not matter which one is first

13. The Boffo Balloon Company makes helium balloons. Large balloons cost $13 a dozen, medium-sized balloons cost $11 a dozen, and small balloons cost $8.60 a dozen. About 60 percent of the company's sales are the smallest balloons, 30 percent are the medium, and large balloons constitute only 10 percent of sales. Customer order records include customer information, quantity ordered, and size. When you write a program to determine price based on size, for the most efficient decision, you should ask first whether the size is _____.

a. large
b. medium
c. small
d. It does not matter.

14. The Boffo Balloon Company makes helium balloons in three sizes, 12 colors, and with a choice of 40 imprinted sayings. As a promotion, the company is offering a 25 percent discount on orders of large, red "Happy Valentine's Day" balloons. To most efficiently select the orders to which a discount applies, you would use _____.

a. three completely separate unnested `if` statements
b. nested `if` statements using AND logic
c. nested `if` statements using OR logic
d. Not enough information is given.

15. Radio station FM-99 keeps a record of every song played on the air in a week. Each record contains the day, hour, and minute the song started, and the title and artist of the song. The station manager wants a list of every title played during the important 8 a.m. commute hour on the two busiest traffic days, Monday and Friday. Which logic would select the correct titles?

a.
```
if day = "Monday" OR day = "Friday" OR hour = 8 then
   print title
endif
```
b.
```
if day = "Monday" then
   if hour = 8 then
      print title
   else
      if day = "Friday" then
         print title
      endif
   endif
endif
```
c.
```
if hour = 8 AND day = "Monday" OR day = "Friday" then
   print title
endif
```
d.
```
if hour = 8 then
   if day = "Monday" OR day = "Friday" then
      print title
   endif
endif
```

16. In the following pseudocode, what percentage raise will an employee in Department 5 receive?

```
if department < 3 then
   raise = 25
else
   if department < 5 then
     raise = 50
   else
     raise = 75
   endif
endif
```

a. 25
b. 50
c. 75
d. impossible to tell

17. In the following pseudocode, what percentage raise will an employee in Department 8 receive?

```
if department < 5 then
   raise = 100
else
   if department < 9 then
     raise = 250
   else
      if department < 14 then
        raise = 375
      endif
   endif
endif
```

a. 100
b. 250
c. 375
d. impossible to tell

18. In the following pseudocode, what percentage raise will an employee in Department 10 receive?

```
if department < 2 then
   raise = 1000
else
   if department < 6 then
     raise = 2500
   else
      if department < 10 then
        raise = 3000
      endif
   endif
endif
```

a. 1000
b. 2500
c. 3000
d. impossible to tell

19. When you use a range check, you compare a variable to the _____ value in the range.

a. lowest
b. middle
c. highest
d. lowest or highest

20. Which of the following is not a part of a decision table?

a. conditions
b. declarations
c. possible actions
d. specific actions that will take place under given conditions

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. This pseudocode should create a report containing annual profit statistics for a retail store. Input records contain a department name (for example, "Cosmetics") and profits for each quarter for the last two years. For each quarter, the program should determine whether the profit is higher, lower, or the same as in the same quarter of the previous year. Additionally, the program should determine whether the annual profit is higher, lower, or the same as in the previous year. For example, the line that displays the Cosmetics Department statistics might read "Cosmetics Same Lower Lower Higher Higher" if profits were the same in the first quarter as last year, lower in the second and third quarters, but higher in the fourth quarter and for the year as a whole.

```
start
   perform housekeeping()
   while not eof
      perform detrmineProfitStatistics()
   perform finalTasks()
stop

housekeeping()
   declare variables
        profitRec
             char department
             num salesQuarter1ThisYear
             num salesQuarter2ThisYear
             num salesQuarter2ThisYear
             num salesQuarter4ThisYear
             num salesQuarter1LastYear
             num salesQuarter2LastYear
             num salesQuarter3ThisYear
             num salesQuarter4LastYear
             char mainHead = "Profit Report"
             char columnHeaders = "Department     Quarter 1
Quarter 2     Quarter 3     Quarter 4     Over All"
        num totalThisYear
        num totalLastYear
        char word1
        char word2
        char word3
        char word4
        char word5
   open files
   perform printHeadings()
   read profitRec
return

printHeadings()
   print mainHeader
   print columnHeaders
return
```

```
determineProfitStatistics()
   if salesQuarter1ThisYear > salesQuarter1LastYear then
      word1 = "Higher"
   else
      if salesQuarter1ThisYear < salesQuarter2LastYear then
            word1 = "Lower"
      else
            word1 = "Same"
      endif
   endif
   if salesQuarter2ThisYear > salesQuarter3LastYear then
      word2 = "Higher"
   else
      if salesQuarter2LastYear < salesQuarter2LastYear then
            word2 = "Lower"
      else
            word2 = "Equal"
      endif
   endif
   if salesQuarter3ThisYear > salesQuarter3LastYear then
      word3 = "Higher"
   else
      if salesQuarter3ThisYear < salesQuarter3LastYear then
            word2 = "Lower"
      else
            word3 = "Same"
      endif
   endif
   if salesQuarter4ThisYear > salesQuarter4LastYear then
      word4 = "Higher"
   else
      if salesQuarter4LastYear < salesQuarter4LastYear then
            word4 = "Lower"
      else
            word4 = "Same"
      endif
   endif
```

```
   totalThisYear = salesQuarter1ThisYear + salesQuarter1ThisYear +
       salesQuarter3LastYear + salesQuarter4ThisYear
   totalLastYear = salesQuarter1LastYear + salesQuarter1LastYear +
       salesQuarter3LastYear + salesQuarter4LastYear
   if totalThisYear > totalLastYear then
      word5 = "Higher"
   else
      if totalThisYear > totalLastYear then
            word5 = "Lower"
      else
            word5 = "Same"
     endif
   endif
   print department, word1, word2, word3, word4, word5
   read profitRec
return

finalTasks()
   close files
return
```

2. **This pseudocode should create a report containing rental agents' commissions at an apartment complex. Input records contain an apartment number, the ID number and name of the agent who rented the apartment, and the number of bedrooms in the apartment. The commission is $100 for renting a three-bedroom apartment, $75 for renting a two-bedroom apartment, $55 for renting a one-bedroom apartment, and $30 for renting a studio (zero-bedroom) apartment. Each report line should list the apartment number, the salesperson's name and ID number, and the commission earned on the rental.**

```
start
   perform housekeeping()
   while not eof
      perform calculateCommission()
   perform finishUp()
stop
```

```
housekeeping()
   declare variables
        rentalRecord
            num apartmentNum
            num salesPersonID
            char salesPersonName
            num numBedrooms
       char mainHeader = "Commission Report"
       char columnHeaders = "Apartment number     Salesperson ID
          Name     Commission Earned"
       num comm3Bedroom = 100.00
       num comm2Bedroom = 75.00
       num comm1Bedroom = 55.00
       num commStudio = 30.00
   open files
   perform displayHeaders()
   read rentalRecord
stop

displayHeader()
   print mainHeader
   print columnHeaders
return

calculateCommission()
   if numBedrooms = 3 then
      commissionEarned = comm3Bedroom
   else
      if numBedrooms = 3 then
         commissionEarned = comm3Bedroom
      else
         if numBedrooms = 3 then
              commission = comm3Bedroom
         else
             commissionEarned = comStudio
         endif
   endif
   print apartmentNum, salesPersonID, salesPersonName,
      commissionEarned
   read rentalRecord
return

finishUp()
   close files
return
```

EXERCISES

1. Assume that the following variables contain the values shown:

```
numberRed = 100    numberBlue = 200    numberGreen = 300
wordRed = "Wagon"  wordBlue = "Sky"    wordGreen = "Grass"
```

For each of the following Boolean expressions, decide whether the statement is true, false, or illegal.

a. `numberRed = numberBlue?`
b. `numberBlue > numberGreen?`
c. `numberGreen < numberRed?`
d. `numberBlue = wordBlue?`
e. `numberGreen = "Green"?`
f. `wordRed = "Red"?`
g. `wordBlue = "Blue"?`
h. `numberRed <= numberGreen?`
i. `numberBlue >= 200?`
j. `numberGreen >= numberRed + numberBlue?`

2. A candy company wants a list of its best-selling items, including the item number and the name of candy. Best-selling items are those that sell over 2,000 pounds per month. Input records contain fields for the item number (three digits), the name of the candy (20 characters), the price per pound (four digits, two assumed decimal places), and the quantity in pounds sold last month (four digits, no decimals).

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

3. The same candy company described in Exercise 2 wants a list of its high-priced, best-selling items. Best-selling items are those that sell over 2,000 pounds per month. High-priced items are those that sell for $10 per pound or more.

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

4. The Literary Honor Society needs a list of English majors who have a grade point average of 3.5 or higher. The student record file includes students' last names and first names, major (for example, "History" or "English"), and grade point average (for example, 3.9 or 2.0).

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Draw the flowchart for this program.
d. Write the pseudocode for this program.

5. **A telephone company charges 10 cents per minute for all calls outside the customer's area code that last over 20 minutes. All other calls are 13 cents per minute. The phone company has a file with one record for every call made in one day. (In other words, a single customer might have many such records on file.) Fields for each call include customer area code (three digits), customer phone number (seven digits), called area code (three digits), called number (seven digits), and call time in minutes (never more than four digits). The company wants a report listing one detail line for each call, including the customer area code and number, the called area code and number, the minutes, and the total charge.**

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Create a decision table to use while planning the logic for this program.
   d. Draw the flowchart for this program.
   e. Write the pseudocode for this program.

6. **A nursery maintains a file of all plants in stock. Each record contains the name of a plant, its price, and fields that indicate the plant's light and soil requirements. The light field contains either "sunny", "partial sun", or "shady". The soil field contains either "clay" or "sandy". Only 20 percent of the nursery stock does well in shade, and 50 percent does well in sandy soil. Customers have requested a report that lists the name and price of each plant that would be appropriate in a shady, sandy yard. Consider program efficiency when designing your solution.**

   a. Design the output for this program; create either sample output or a print chart.
   b. Draw the hierarchy chart for this program.
   c. Create a decision table to use while planning the logic for this program.
   d. Draw the flowchart for this program.
   e. Write the pseudocode for this program.

7. **You have declared variables for an insurance company program as follows:**

```
FIELD                          EXAMPLE
num custPolicyNumber           223356
char custLastName              Salvatore
num custAge                    25
num custDueMonth               06
num custDueDay                 24
num custDueYear                2007
num custAccidents              2
```

   Draw the flowchart or write the pseudocode for the selection structures that print the `custPolicyNumber` **and** `custLastName` **for customers whose data satisfy the following requests for lists of policyholders:**

   a. over 35 years old
   b. at least 21 years old
   c. no more than 30 years old
   d. due no later than March 15 any year

e. due up to and including January 1, 2007
f. due by April 27, 2010
g. due as early as December 1, 2006
h. fewer than 11 accidents
i. no more than five accidents
j. no accidents

8. Student files contain an ID number (four digits), last and first names (15 characters each), and major field of study (10 characters). Plan a program that lists ID numbers and names for all French or Spanish majors.

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

9. A florist wants to send coupons to her best customers, so she needs a list of names and addresses for customers who placed orders more than three times last year or spent more than $200 last year. Consider program efficiency when designing your solution. The input file description follows:

```
File name: FLORISTCUSTS
FIELD DESCRIPTION      DATA TYPE          COMMENTS
Customer ID            Numeric            4 digits, 0 decimals
First Name             Character          15 characters
Last Name              Character          15 characters
Street Address         Character          20 characters
Orders Last Year       Numeric            0 decimals
Amount Spent           Numeric            2 decimals
  Last Year
```

(Note: To save room, the record does not include a city or state. Assume that all the florist's best customers are in town.)

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

10. A carpenter needs a program that computes the price of any desk a customer orders, based on the following input fields: order number, desk length and width in inches (three digits each, no decimals), type of wood (20 characters), and number of drawers (two digits). The price is computed as follows:

- ☐ The charge for all desks is a minimum $200.
- ☐ If the surface (length * width) is over 750 square inches, add $50.
- ☐ If the wood is "mahogany", add $150; for "oak", add $125. No charge is added for "pine".
- ☐ For every drawer in the desk, there is an additional $30 charge.

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

11. A company is attempting to organize carpools to save energy. Each input record contains an employee's name and town of residence. Ten percent of the company's employees live in Wonder Lake. Thirty percent of the employees live in Woodstock. Because these towns are both north of the company, the company wants a list of employees who live in either town, so it can recommend that these employees drive to work together.

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

12. A supervisor in a manufacturing company wants to produce a report showing which employees have increased their production this year over last year, so that she can issue them a certificate of commendation. She wants to have a report with three columns: last name, first name, and either the word "UP" or blanks printed under the column heading PRODUCTION. "UP" is printed when this year's production is a greater number than last year's production. Input exists as follows:

```
PRODUCTION FILE DESCRIPTION
File name: PRODUCTION
FIELD DESCRIPTION         DATA TYPE     COMMENTS
Last Name                 Character     15 characters
First Name                Character     15 characters
Last Year's Production    Numeric       0 decimals
This Year's Production    Numeric       0 decimals
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

13. A supervisor in the same manufacturing company as described in Exercise 12 wants to produce a report from the PRODUCTION input file showing bonuses she is planning to give based on this year's production. She wants to have a report with three columns: last name, first name, and bonus. The bonuses will be distributed as follows.

If this year's production is:

- 1,000 units or fewer, the bonus is $25
- 1,001 to 3,000 units, the bonus is $50
- 3,001 to 6,000 units, the bonus is $100
- 6,001 units and up, the bonus is $200

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

14. Modify Exercise 13 to reflect the following new facts, and have the program execute as efficiently as possible:

- Only employees whose production this year is higher than it was last year will receive bonuses. This is true for approximately 30 percent of the employees.
- Sixty percent of employees produce over 6,000 units per year; 20 percent produce 3,001 to 6,000; 15 percent produce 1,001 to 3,000 units; and only 5 percent produce fewer than 1,001.

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

15. The Richmond Riding Club wants to assign the title of Master or Novice to each of its members. A member earns the title of Master by accomplishing two or more of the following:

- Participating in at least eight horse shows
- Winning a first-place or second-place ribbon in at least two horse shows, no matter how many shows the member has participated in
- Winning a first-place, second-place, third-place, or fourth-place ribbon in at least four horse shows, no matter how many shows the member has participated in

Create a report that prints each club member's name along with the designation "Master" or "Novice". Input exists as follows:

```
RIDING FILE DESCRIPTION
File name: RIDING
FIELD DESCRIPTION       DATA TYPE     COMMENTS
Last Name               Character     15 characters
First Name              Character     15 characters
Number of Shows         Numeric       0 decimals
First-Place Ribbons     Numeric       0 decimals
Second-Place Ribbons    Numeric       0 decimals
Third-Place Ribbons     Numeric       0 decimals
Fourth-Place Ribbons    Numeric       0 decimals
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

16. Freeport Financial Services manages clients' investment portfolios. The company charges for its services based on each client's annual income, net worth, and length of time as a client, as follows:

- Clients with an annual income over $100,000 and a net worth over $1 million are charged 1.5 percent of their net worth.
- Clients with an annual income over $100,000 and a net worth between $500,000 and $1 million inclusive are charged $8,000.
- Clients with an annual income over $100,000 and a net worth of less than $500,000 are charged $6,000.
- Clients with an annual income from $75,000 up to and including $100,000 are charged 1 percent of their net worth.
- Clients with an income of $75,000 or less are charged $4,000, unless their net worth is over $1 million, in which case they are charged $4,500.
- Any client for over four years gets a 10 percent discount; any client for over seven years gets a 15 percent discount.

Create a report that prints each client's name and the client's annual fee. Input records contain the following data:

```
FINANCIAL SERVICE CLIENTS' FILE DESCRIPTION
File name: CLIENTS
FIELD DESCRIPTION       DATA TYPE     COMMENTS
Last Name               Character     15 characters
First Name              Character     15 characters
Annual Income           Numeric       0 decimals
Portfolio Value         Numeric       0 decimals
Years as Client         Numeric       0 decimals
```

a. Design the output for this program; create either sample output or a print chart.
b. Draw the hierarchy chart for this program.
c. Create a decision table to use while planning the logic for this program.
d. Draw the flowchart for this program.
e. Write the pseudocode for this program.

DETECTIVE WORK

1. **Computers are expert chess players because they can make many good decisions very rapidly. Explore the history of computer chess playing.**

2. **George Boole is considered the father of symbolic logic. Find out about his life.**

UP FOR DISCUSSION

1. **Computer programs can be used to make decisions about your insurability as well as the rates you will be charged for health and life insurance policies. For example, certain preexisting conditions may raise your insurance premiums considerably. Is it ethical for insurance companies to access your health records and then make insurance decisions about you?**

2. **Job applications are sometimes screened by software that makes decisions about a candidate's suitability based on keywords in the applications. Is such screening fair to applicants?**

3. **Medical facilities often have more patients waiting for organ transplants than there are available organs. Suppose you have been asked to write a computer program that selects which of several candidates should receive an available organ. What data would you want on file to be able to use in your program, and what decisions would you make based on the data? What data do you think others might use that you would choose not to use?**

6 LOOPING

After studying Chapter 6, you should be able to:

- Understand the advantages of looping
- Control a `while` loop using a loop control variable
- Increment a counter to control a loop
- Loop with a variable sentinel value
- Control a loop by decrementing a loop control variable
- Avoid common loop mistakes
- Use a `for` statement
- Use `do while` and `do until` loops
- Recognize the characteristics shared by all loops
- Nest loops
- Use a loop to accumulate totals

UNDERSTANDING THE ADVANTAGES OF LOOPING

If making decisions is what makes computers seem intelligent, it's looping that makes computer programming worthwhile. When you use a loop within a computer program, you can write one set of instructions that operates on multiple, unique sets of data. Consider the following set of tasks required for each employee in a typical payroll program:

- Determine regular pay.
- Determine overtime pay, if any.
- Determine federal withholding tax based on gross wages and number of dependents.
- Determine state withholding tax based on gross wages, number of dependents, and state of residence.
- Determine insurance deduction based on insurance code.
- Determine Social Security deduction based on gross pay.
- Subtract federal tax, state tax, Social Security, and insurance from gross pay.

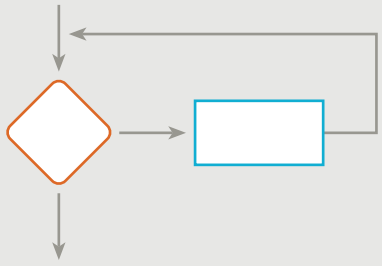
In reality, this list is too short—companies deduct stock option plans, charitable contributions, union dues, and other items from checks in addition to the items mentioned in this list. Also, they might pay bonuses and commissions and provide sick days and vacation days that must be taken into account and handled appropriately. As you can see, payroll programs are complicated.

The advantage of having a computer perform payroll calculations is that all of the deduction instructions need to be written *only once* and can be repeated over and over again for each paycheck using a **loop**, the structure that repeats actions while some condition continues.

USING A WHILE LOOP WITH A LOOP CONTROL VARIABLE

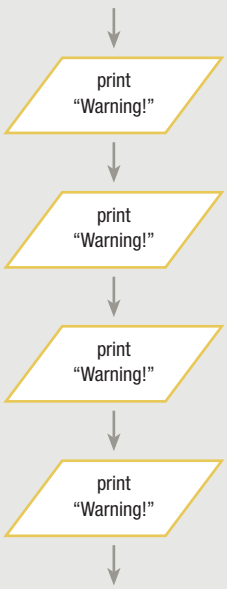
Recall the loop, or `while` structure, that you learned about in Chapter 2. (See Figure 6-1.) In Chapter 4, you learned that almost every program has a **main loop**, or a basic set of instructions that is repeated for every record. The main loop is a typical loop—within it, you write one set of instructions that executes repeatedly while records continue to be read from an input file. Several housekeeping tasks execute at the start of most programs, and a few cleanup tasks execute at the end. However, most of a program's tasks are located in a main loop; these tasks repeat over and over for many records (sometimes hundreds, thousands, or millions).

FIGURE 6-1: THE `while` LOOP



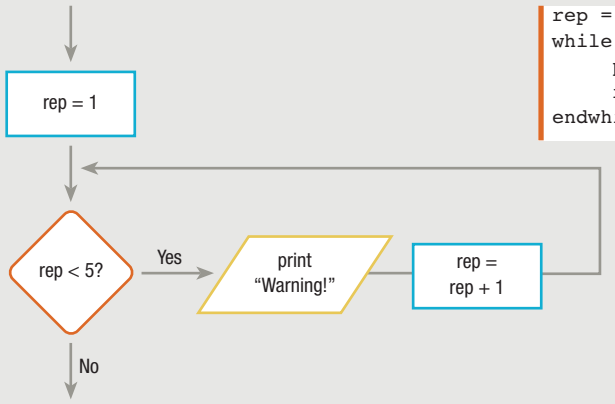
In addition to this main loop, loops also appear within a program's modules. They are used any time you need to perform a task several times and don't want to write identical or similar instructions over and over. Suppose, for example, as part of a much larger program, you want to print a warning message on the computer screen when the user has made a potentially dangerous menu selection (for example, "Delete all files"). To get the user's attention, you want to print the message four times. You can write this program segment as a sequence of four steps, as shown in Figure 6-2, but you can also use a loop, as shown in Figure 6-3.

FIGURE 6-2: PRINTING FOUR WARNING MESSAGES IN SEQUENCE




```
print "Warning!"
print "Warning!"
print "Warning!"
print "Warning!"
```

FIGURE 6-3: PRINTING FOUR WARNING MESSAGES IN A LOOP




```
rep = 1
while rep < 5
     print "Warning!"
     rep = rep + 1
endwhile
```

The flowchart and pseudocode segments in Figure 6-3 show three steps that should occur in every loop:

1. You initialize a variable that will control the loop. The variable in this case is named `rep`.
2. You compare the variable to some value that controls whether the loop continues or stops. In this case, you compare `rep` to the value 5.
3. Within the loop, you alter the variable that controls the loop. In this case, you alter `rep` by adding 1 to it.

On each pass through the loop, the value in the `rep` variable determines whether the loop will continue. Therefore, variables like `rep` are known as **loop control variables**. Any variable that determines whether a loop will continue to execute is a loop control variable. To stop a loop's execution, you compare the loop control value to a **sentinel value** (also known as a limit or ending value), in this case the value 5. The decision that controls every loop is always based on a Boolean comparison. You can use any of the six comparison operators that you learned about in Chapter 5 to control a loop—equal to, greater than, less than, greater than or equal to, less than or equal to, and not equal to.

TIP Just as with a selection, the Boolean comparison that controls a `while` loop must compare same-type values: numeric values are compared to other numeric values, and character values to other character values.

The statements that execute within a loop are known as the **loop body**. The body of a loop might contain any number of statements, including method calls, sequences, decisions, and other loops. Once your program enters the body of a structured loop, the entire loop body must execute. Your program can leave a structured loop only at the comparison that tests the loop control variable.

USING A COUNTER TO CONTROL LOOPING

Suppose you own a factory and have decided to place a label on every product you manufacture. The label contains the words "Made for you personally by " followed by the first name of one of your employees. For one week's production, suppose you need 100 personalized labels for each employee.

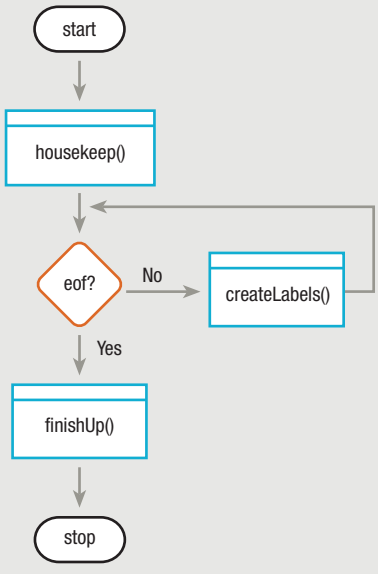
Assume you already have a personnel file that can be used for input. This file has more information than you'll need for this program: an employee last name, first name, Social Security number, address, date hired, and salary. The important feature of the file is that it does contain each employee's name stored in a separate record. The input file description appears in Figure 6-4.

FIGURE 6-4: EMPLOYEE FILE DESCRIPTION

```
File Name: EMPFILE
FIELD DESCRIPTION          DATA TYPE      COMMENTS
Employee Last Name         Character      20 characters
Employee First Name        Character      15 characters
Social Security Number     Numeric        0 decimal places
Address                    Character      15 characters
Date Hired                 Numeric        8 digits, YYYYMMDD
Hourly Salary              Numeric        2 decimal places
```

In the mainline logic of this program, you call three modules: a housekeeping module (`housekeep()`), a main loop module (`createLabels()`), and a finish routine (`finishUp()`). See Figure 6-5.

FIGURE 6-5: MAINLINE LOGIC FOR LABEL-MAKING PROGRAM




```
start
     perform housekeep()
     while not eof
          perform createLabels()
     endwhile
     perform finishUp()
stop
```

The first task for the label-making program is to name the fields in the input record so you can refer to them within the program. As a programmer, you can choose any variable names you like, for example: `inLastName`, `inFirstName`, `inSSN`, `inAddress`, `inDate`, and `inSalary`.

TIP

In Chapter 4 you learned that starting all field names in the input record with the same prefix, such as `in`, is a common programming technique to help identify these fields in a large program and differentiate them from work areas and output areas that will have other names. Another benefit to using a prefix like `in` is that some language compilers produce a dictionary of variable names when you compile your program. These dictionaries show at which lines in the program each data name is referenced. If all your input field names start with the same prefix, they will be together alphabetically in the dictionary, and perhaps be easier to find and work with.

You also can set up a variable to hold the characters "Made for you personally by " and name it `labelLine`. You eventually will print this `labelLine` variable followed by the employee's first name (`inFirstName`).

You will need one more variable: a location to be used as a counter. A **counter** is any numeric variable you use to count the number of times an event has occurred; in this example, you need a counter to keep track of how many labels have been printed at any point. Each time you read an employee record, the counter variable is set to 0. Then every time a label is printed, you add 1 to the counter. Adding to a variable is called **incrementing** the variable; programmers often use the term "incrementing" specifically to mean "increasing by one." Before the next employee label is printed, the program checks the variable to see if it has reached 100 yet. When it has, that means 100 labels have been printed, and the job is done for that employee. While the counter remains below 100, you continue to print labels. As with all variables, the programmer can choose any name for a counter; this program uses `labelCounter`. In this example, `labelCounter` is the loop control variable.

The `housekeep()` module for the label program, shown in Figure 6-6, includes a step to open the files: the employee file and the printer. Unlike a program that produces a report, this program produces no headings, so the next and last task performed in `housekeep()` is to read the first input record.

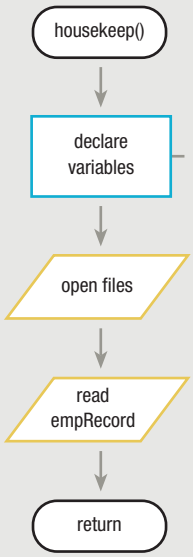
TIP

Remember, you can give any name to modules within your programs. This program uses `housekeep()` for its first routine, but `housekeeping()`, `startUp()`, `prep()`, or any other name with the same general meaning could be used.

TIP

If you don't know why the first record is read in the `housekeep()` module, go back and review the concept of the priming read, presented in Chapter 2.

FIGURE 6-6: THE `housekeep()` MODULE FOR THE LABEL PROGRAM




```
empRecord
     char inLastName
     char inFirstName
     num inSSN
     char inAddress
     num inDate
     num inSalary
char labelLine = "Made for you
          personally by "
num labelCounter
```

```
housekeep()
     declare variables
     open files
     read empRecord
return
```

TIP

The label-making program could be interactive instead of reading data from a file. An easy way to make the program interactive would be to replace the `read empRecord` statement with a series of statements or a call to a module that provides a prompt and a read statement for each of the six data fields needed for each employee. A user could then enter these values from the keyboard. (If this were an interactive program, the programmer would likely require the user to enter data only in the field that is necessary for output—the employee's name.) Also, if this were an interactive program, the user might be asked to type a sentinel value, such as "XXX", when finished. This program is discussed as one that reads from a file to reduce the number of statements you must view to understand the logical process.

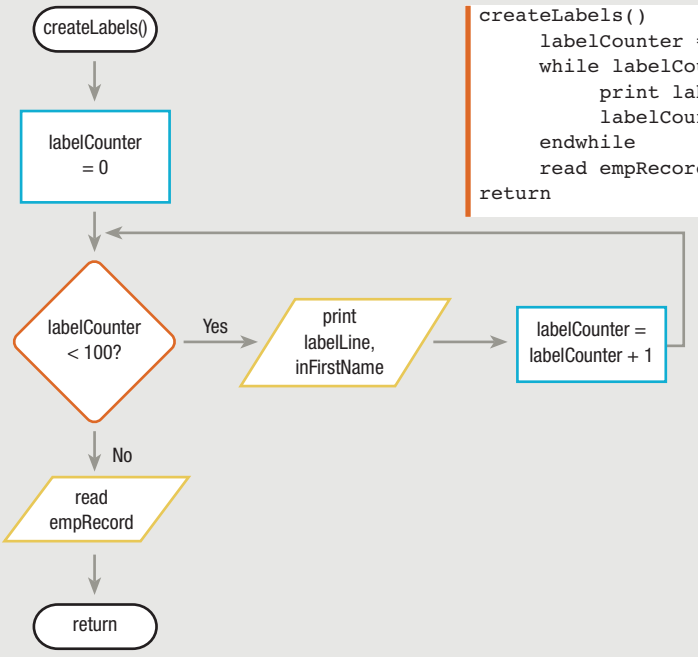
TIP

In previous chapters, the list of declared variables was shown with both the flowchart and the pseudocode. To save space in the rest of the chapters in this book, the variable list will be shown only with the flowchart.

When the `housekeep()` module is done, the logical flow returns to the `eof` question in the mainline logic. If you attempt to read the first record at the end of `housekeep()` and for some reason there is no record, the answer to `eof?` is Yes, so the `createLabels()` module is never entered; instead, the logic of the program flows directly to the `finishUp()` module.

Usually, however, employee records will exist and the program will enter the `createLabels()` module, which is shown in Figure 6-7. When this happens, the first employee record is sitting in memory waiting to be processed. During one execution of the `createLabels()` module, 100 labels will be printed for one employee. As the last event within the `createLabels()` module, the program reads the next employee record. Control of the program then returns to the `eof` question. If the new read process has not resulted in the `eof` condition, control reenters the `createLabels()` module, where 100 more labels print for the new employee.

FIGURE 6-7: THE `createLabels()` MODULE FOR THE LABEL PROGRAM




```
createLabels()
     labelCounter = 0
     while labelCounter < 100
          print labelLine, inFirstName
          labelCounter = labelCounter + 1
     endwhile
     read empRecord
return
```

The `createLabels()` method of this label-making program contains three parts:

- Set `labelCounter` to 0.
- Compare `labelCounter` to 100.
- While `labelCounter` is less than 100, print `labelLine` and `inFirstName`, and add 1 to `labelCounter`.

When the first employee record enters the `createLabels()` module, `labelCounter` is set to 0. The `labelCounter` value is less than 100, so the record enters the label-making loop. One label prints for the first employee, `labelCounter` increases by one, and the logical flow returns to the question `labelCounter < 100?`. After the first label is printed, `labelCounter` holds a value of only 1. It is nowhere near 100 yet, so the value of the Boolean expression is true, and the loop is entered for a second time, thus printing a second label.

After the second printing, `labelCounter` holds a value of 2. After the third printing, it holds a value of 3. Finally, after the 100th label prints, `labelCounter` has a value of 100. When the question `labelCounter < 100?` is asked, the answer will finally be No, and the loop will exit.

Before leaving the `createLabels()` method, and after the program prints 100 labels for an employee, there is one final step: the next input record is read from the EMPLOYEES file. When the `createLabels()` method is over, control returns to the `eof` question in the main line of the logic. If it is not `eof` (if another employee record is present), the program enters the `createLabels()` method again, resets `labelCounter` to 0, and prints 100 new labels with the next employee's name.

TIP

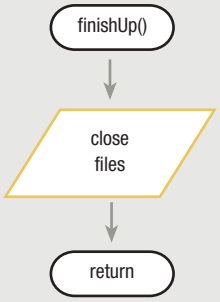
Setting `labelCounter` to 0 when the `createLabels()` module is entered is important. With each new record, `labelCounter` must begin at 0 if 100 labels are to print. When the first employee's set of labels is complete, `labelCounter` holds the value 100. If it is not reset to 0 for the second employee, then no labels will ever print for that employee.

TIP

In this example, the label-making loop executes as `labelCounter` varies from 0 to 100. The program would work just as well if you decided to vary the counter from 1 to 101 or use any other pair of values that differs by 100.

At some point while attempting to read a new record, the program encounters the end of the file, the `createLabels()` module is not entered again, and control passes to the `finishUp()` module. In this program, the `finishUp()` module simply closes the files. See Figure 6-8.

FIGURE 6-8: THE `finishUp()` MODULE FOR THE LABEL PROGRAM




```
finishUp()
     close files
return
```

LOOPING WITH A VARIABLE SENTINEL VALUE

Sometimes you don't want to be forced to repeat every pass through a loop the same number of times. For example, instead of printing 100 labels for each employee, you might want to vary the number of labels based on how many items a worker actually produces. That way, high-achieving workers won't run out of labels, and less productive workers won't have too many. Instead of printing the same number of labels for every employee, a more sophisticated program prints a different number for each employee, depending on that employee's production the previous week. For example, you might decide to print enough labels to cover 110 percent of each employee's production rate from the previous week; this ensures that the employee will have enough labels for the week, even if his or her production level improves.

For example, assume that employee production data exists in an input file called EMPPRODUCTION in the format shown in Figure 6-9.

A real-life production file would undoubtedly have more fields in each record, but these fields supply more than enough information to produce the labels. You need the first name to print on the label, and you need the field that holds production for the last week in order to calculate the number of labels to print for each employee. Assume this field can contain any number from 0 through 999.

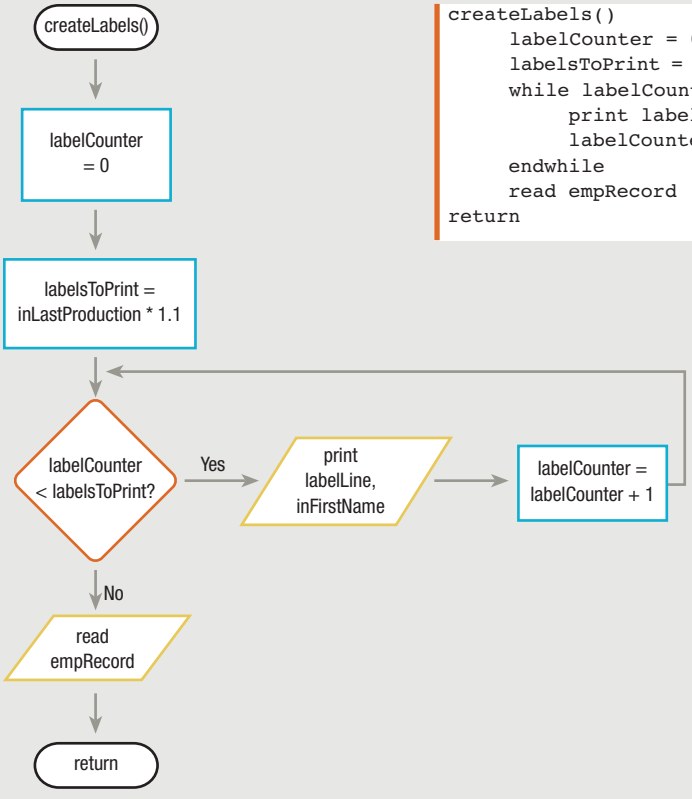
FIGURE 6-9: EMPLOYEE PRODUCTION FILE DESCRIPTION

```
File Name: EMPPRODUCTION
FIELD DESCRIPTION          DATA TYPE      COMMENTS
Last Name                  Character      20 characters
First Name                 Character      15 characters
Production Last Week       Numeric        0 decimal places
```

To write a program that produces an appropriate number of labels for each employee, you can make some minor modifications to the original label-making program. For example, the input file variables have changed; you must declare a variable for an `inLastProduction` field. Additionally, you might want to create a numeric field named `labelsToPrint` that can hold a value equal to 110 percent of a worker's `inLastProduction`.

The major modification to the original label-making program is in the question that controls the label-producing loop. Instead of asking if `labelCounter < 100`, you now can ask if `labelCounter < labelsToPrint`. The sentinel, or limit, value can be a variable like `labelsToPrint` just as easily as it can be a constant like 100. See Figure 6-10 for the flowchart as well as the pseudocode.

FIGURE 6-10: FLOWCHART AND PSEUDOCODE FOR LABEL-MAKING `createLabels()` MODULE




```
createLabels()
     labelCounter = 0
     labelsToPrint = inLastProduction * 1.1
     while labelCounter < labelsToPrint
          print labelLine, inFirstName
          labelCounter = labelCounter + 1
     endwhile
     read empRecord
return
```

TIP

The statement `labelsToPrint = inLastProduction * 1.1` calculates `labelsToPrint` as 110 percent of `inLastProduction`. Alternatively, you can perform the calculation as `labelsToPrint = inLastProduction + 0.10 * inLastProduction`. The mathematical result is the same.

LOOPING BY DECREMENTING

Rather than increasing a loop control variable until it passes some sentinel value, sometimes it is more convenient to reduce a loop control variable on every cycle through a loop. For example, again assume you want to print enough labels for every worker to cover 110 percent production. As an alternative to setting a `labelCounter` variable to 0 and increasing it after each label prints, you initially can set `labelCounter` equal to the number of labels to print (`inLastProduction * 1.1`), and subsequently reduce the `labelCounter` value every time a label prints. You continue printing labels and reducing `labelCounter` until you have counted down to zero. Decreasing a variable is called **decrementing** the variable; programmers most often use the term to mean a decrease by one.

For example, when you write the following, you produce enough labels to equal 110 percent of `inLastProduction`:

```
labelCounter = inLastProduction * 1.1
while labelCounter > 0
     print labelLine, inFirstName
     labelCounter = labelCounter - 1
endwhile
```

TIP

Many languages provide separate numeric data types for whole number (integer) values and floating-point values (those with decimal places). Depending on the data type you choose for `labelCounter`, you might end up calculating a fraction of a label to print. For example, if `inLastProduction` is 5, then the number of labels to produce is 5.5. The logic shown here would print the additional label.

When you decrement, you can avoid declaring a special variable for `labelsToPrint`. The `labelCounter` variable starts with a value that represents the labels to print, and works its way down to zero.

Yet another alternative allows you to eliminate the `labelCounter` variable. You could use the `inLastProduction` variable itself to keep track of the labels. For example, the following pseudocode segment also produces a number of labels equal to 110 percent of each worker's `inLastProduction` value:

```
inLastProduction = inLastProduction * 1.1
while inLastProduction > 0
     print labelLine, inFirstName
     inLastProduction = inLastProduction - 1
endwhile
```

In this example, `inLastProduction` is first increased by 10 percent. Then, while it remains above 0, there are more labels to print; when it is eventually reduced to hold the value 0, all the needed labels will have been printed. With this method, you do not need to create any new counter variables such as `labelCounter`, because `inLastProduction` itself acts as a counter. However, you can't use this method if you need to use the value of `inLastProduction` for this record later in the program. By decrementing the variable, you are changing its value on every cycle through the loop; when you have finished, the original value in `inLastProduction` has been lost.

TIP Do not think the value of `inLastProduction` is gone forever when you alter it. If the data is being read from a file, then the original value still exists within the data file. It is the main memory location called `inLastProduction` that is being reduced.

AVOIDING COMMON LOOP MISTAKES

The mistakes that programmers make most often with loops are:

- Neglecting to initialize the loop control variable
- Neglecting to alter the loop control variable
- Using the wrong comparison with the loop control variable
- Including statements inside the loop that belong outside the loop
- Initializing a variable that does not require initialization

NEGLECTING TO INITIALIZE THE LOOP CONTROL VARIABLE

It is always a mistake to fail to initialize a loop's control variable. For example, assume you remove the statement `labelCounter = 0` from the program illustrated in Figure 6-10. When `labelCounter` is compared to `labelsToPrint` at the start of the `while` loop, it is impossible to predict whether any labels will print. Because uninitialized values contain unknown, unpredictable garbage, comparing such a variable to another value is meaningless. Even if you initialize `labelCounter` to 0 in the `housekeep()` module of the program, you must reset `labelCounter` to 0 for each new record that is processed within the `while` loop. If you fail to reset `labelCounter`, it never surpasses 100 because after it reaches 100, the answer to the question `labelCounter < 100` is always No, and the logic never enters the loop where a label can be printed.

NEGLECTING TO ALTER THE LOOP CONTROL VARIABLE

A different sort of error occurs if you remove the statement that adds 1 to `labelCounter` from the program in Figure 6-10. This error results in the following code:

```
while labelCounter < labelsToPrint
     print labelLine, inFirstName
endwhile
```

Following this logic, if `labelCounter` is 0 and `labelsToPrint` is, for example, 110, then `labelCounter` will be less than `labelsToPrint` forever. Nothing in the loop changes either variable, so when `labelCounter` is less than `labelsToPrint` once, then `labelCounter` is less than `labelsToPrint` forever, and labels will continue to print. A loop that never stops executing is called an **infinite loop**. It is unstructured and incorrect to create a loop that cannot terminate on its own.

TIP Although most programmers advise that infinite loops must be avoided, some programmers argue that there are legitimate uses for them. Intentional uses for infinite loops include programs that are supposed to run continuously, such as product demonstrations, or in programming for embedded systems.

USING THE WRONG COMPARISON WITH THE LOOP CONTROL VARIABLE

Programmers must be careful to use the correct comparison in the statement that controls a loop. Although there is only a one-keystroke difference between the following two code segments, one performs the loop 10 times and the other performs the loop 11 times.

```
counter = 0
while counter < 10
     perform someModule()
     counter = counter + 1
endwhile
```

and

```
counter = 0
while counter <= 10
     perform someModule()
     counter = counter + 1
endwhile
```

The seriousness of the error of using <= or >= when only < or > is needed depends on the actions performed within the loop. For example, if such an error occurred in a loan company program, each customer might be charged a month's additional interest; if the error occurred in an airline's program, it might overbook a flight; and if it occurred in a pharmacy's drug-dispensing program, each patient might receive one extra (and possibly harmful) unit of medication.

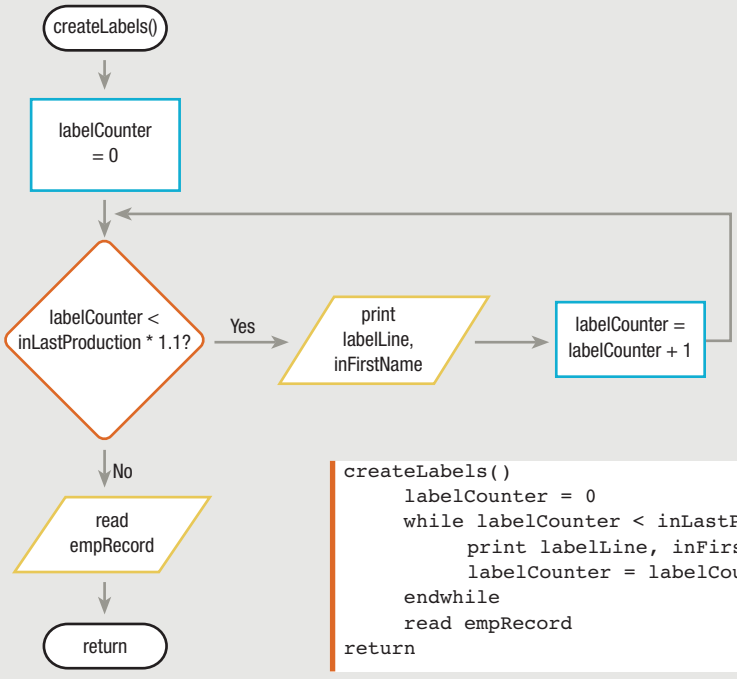
INCLUDING STATEMENTS INSIDE THE LOOP THAT BELONG OUTSIDE THE LOOP

When you run a computer program that uses the loop in Figure 6-10, hundreds or thousands of employee records might pass through the `createLabels()` method. If there are 100 employee records, then `labelCounter` is set to 0 exactly 100 times; it must be reset to 0 once for each employee, in order to count each employee's labels correctly. Similarly, `labelsToPrint` is reset (to 1.1 times the current `inLastProduction` value) once for each employee.

If the average employee produces 100 items during a week, then the loop within the `createLabels()` method, the one controlled by the statement `while labelCounter < labelsToPrint`, executes 11,000 times—110 times each for 100 employees. This number of repetitions is necessary in order to print the correct number of labels.

A repetition that is *not* necessary would be to execute 11,000 separate multiplication statements to recalculate the value to compare to `labelCounter`. See Figure 6-11.

FIGURE 6-11: INEFFICIENT PSEUDOCODE FOR LABEL-MAKING `createLabels()` MODULE




```
createLabels()
     labelCounter = 0
     while labelCounter < inLastProduction * 1.1
          print labelLine, inFirstName
          labelCounter = labelCounter + 1
     endwhile
     read empRecord
return
```

Although the logic shown in Figure 6-11 will produce the correct number of labels for every employee, the statement `while labelCounter < inLastProduction * 1.1` executes an average of 110 times for each employee. That means the arithmetic operation that is part of the question—multiplying `inLastProduction` by 1.1—occurs 110 separate times for each employee. Performing the same calculation that results in the same mathematical answer 110 times in a row is inefficient. Instead, it is superior to perform the multiplication just once for each employee and use the result 110 times, as shown in the original version of the program in Figure 6-10. In the pseudocode in Figure 6-10, you still must recalculate `labelsToPrint` once for each record, but not once for each label, so you have improved the program's efficiency.

The modules illustrated in Figures 6-10 and 6-11 do the same thing: print enough labels for every employee to cover 110 percent of production. As you become more proficient at programming, you will recognize many opportunities to perform the same tasks in alternative, more elegant, and more efficient ways.

INITIALIZING A VARIABLE THAT DOES NOT REQUIRE INITIALIZATION

Another common error made by beginning programmers involves initializing a variable that does not require initialization. When declaring variables for the label-making program, you might be tempted to declare `num labelsToPrint = inLastProduction * 1.1`. It seems as though this declaration statement indicates that the value of `labelsToPrint` will always be 110 percent of the `inLastProduction` figure. However, this approach is incorrect for two reasons. First, at the time `labelsToPrint` is declared, the first employee record has not yet been read into memory, so the value of `inLastProduction` is garbage; therefore, the result in `labelsToPrint` after multiplication will also be garbage. Second, even if you read the first `empRecord` into memory before declaring the `labelsToPrint` variable, the mathematical calculation of `labelsToPrint` within the `housekeep()` module would be valid for the first record only. The value of `labelsToPrint` must be recalculated for each employee record in the input file. Therefore, calculation of `labelsToPrint` correctly belongs within the `createLabels()` module, as shown in Figure 6-10.

USING THE FOR STATEMENT

The label-making programs discussed in this chapter each contain two loops. For example, Figures 6-12 and 6-13 show the loop within the mainline program as well as the loop within the `createLabels()` module for a program that produces exactly 100 labels for each employee. (These flowcharts were shown earlier in this chapter.)

FIGURE 6-12: MAINLINE LOGIC FOR LABEL-MAKING PROGRAM

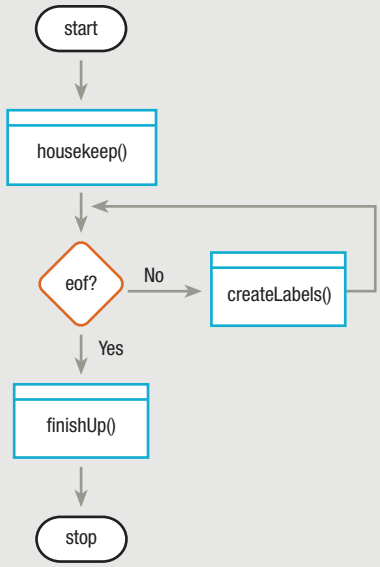
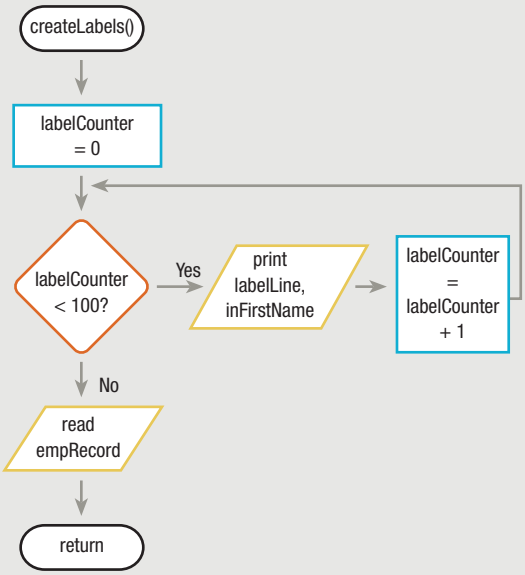


FIGURE 6-13: THE `createLabels()` LOGIC FOR LABEL-MAKING PROGRAM



Entry to the `createLabels()` module in the mainline logic of the label-making program is controlled by the `eof` decision. Within the `createLabels()` method, the loop that produces labels is controlled by the `labelCounter` decision. When you execute the mainline logic, you cannot predict how many times the `createLabels()` module will execute. Depending on the size of the input file (that is, depending on the number of employees who require labels), any number of records might be processed; while the program runs, you don't know what the total number of records finally will be. Until you attempt to read a record and encounter the end of the file, you don't know if more records are going to become available. Of course, not being able to predict the number of input records is valuable—it allows the program to function correctly no matter how many employees exist from week to week or year to year. Because you can't determine ahead of time how many records there might be and, therefore, how many times the loop might execute, the mainline loop in the label-making program is called an **indeterminate**, or **indefinite**, **loop**.

With some loops, you know exactly how many times they will execute. If every employee needs 100 printed labels, then the loop within the `createLabels()` module executes exactly 100 times for each employee. This kind of loop, in which you definitely know the repetition factor, is a **definite loop**.

Every high-level computer programming language contains a `while` **statement** that you can use to code any loop, including indefinite loops (like the mainline loop) and definite loops (like the label-printing loop). You can write statements like the following:

```
while not eof
     perform createLabels()
endwhile
```

and

```
while labelCounter < 100
     print labelLine, inFirstName
     labelCounter = labelCounter + 1
endwhile
```

In addition to the `while` statement, most computer languages also support a `for` statement. You can use the `for` **statement** with definite loops—those for which you know how many times the loop will repeat. The `for` statement provides you with three actions in one compact statement. The `for` statement:

- initializes the loop control variable
- evaluates the loop control variable
- alters the loop control variable (typically by incrementing it)

The `for` statement usually takes the form:

```
for initialValue to finalValue
     do something
endfor
```

For example, to print 100 labels you can write:

```
for labelCounter = 0 to 99
     print labelLine, inFirstName
endfor
```

This `for` statement accomplishes several tasks at once in a compact form:

- The `for` statement initializes `labelCounter` to 0.
- The `for` statement checks `labelCounter` against the limit value 99 and makes sure that `labelCounter` is less than or equal to that value.
- If the evaluation is true, the `for` statement body that prints the label executes.
- After the `for` statement body executes, `labelCounter` increases by 1 and the comparison to the limit value is made again.

TIP As an alternative to using the loop `for labelCounter = 0 to 99`, you can use `for labelCounter = 1 to 100`. You can use any combination of values, as long as there are 100 whole number values between (and including) the two limits.

The `for` statement does not represent a new structure; it simply provides a compact way to write a pretest loop. You are never required to use a `for` statement; the label loop executes correctly using a `while` statement with `labelCounter` as a loop control variable. However, when a loop is based on a loop control variable progressing from a known starting value to a known ending value in equal increments, the `for` statement presents you with a convenient shorthand.

TIP The programmer needs to know neither the starting nor the ending value for the loop control variable; only the program must know those values. For example, you don't know the value of a worker's `inLastProduction`, but when you tell the program to read a record, the program knows. To use this value as a limit value, you can write a `for` statement that begins `for labelCounter = 1 to inLastProduction`.

TIP In most programming languages, you can provide a `for` statement with a step value. A step value is a number you use to increase (or decrease) a loop control variable on each pass through a loop. In most programming languages, the default loop step value is 1. You specify a step value when you want each pass through the loop to change the loop control variable by a value other than 1.

TIP In Java, C++, C#, and other modern languages, the `for` statement is written using the keyword `for` followed by parentheses that contain the increment test, which alters portions of the loop. For example, the following `for` statement could be used in several languages:

```
for(labelCounter = 0; labelCounter < 100; labelCounter = labelCounter + 1)
   print labelLine, inFirstName
```

In this example, the first section within the parentheses initializes the loop control variable, the middle section tests it, and the last section alters it. In languages that use this format, you can use the `for` statement for indefinite loops as well as definite loops.

USING THE DO WHILE AND DO UNTIL LOOPS

When you use either a `while` loop or a `for` statement, the body of the loop may never execute. For example, in the mainline logic in Figure 6-5, the last action in the `housekeep()` module is to read an input record. If the input file contains no records, the result of the `eof` decision is true, and the program executes the `finishUp()` module without ever entering the `createLabels()` module.

Similarly, when you produce labels within the `createLabels()` module shown in Figure 6-10, labels are produced `while labelCounter < labelsToPrint`. Suppose an employee record contains a 0 in the `inLastProduction` field—for example, in the case of a new employee or an employee who was on vacation during the previous week. In such a case, the value of `labelsToPrint` would be 0, and the label-producing body of the loop would never execute. With a `while` loop, you evaluate the loop control variable prior to executing the loop body, and the evaluation might indicate that you can't enter the loop.

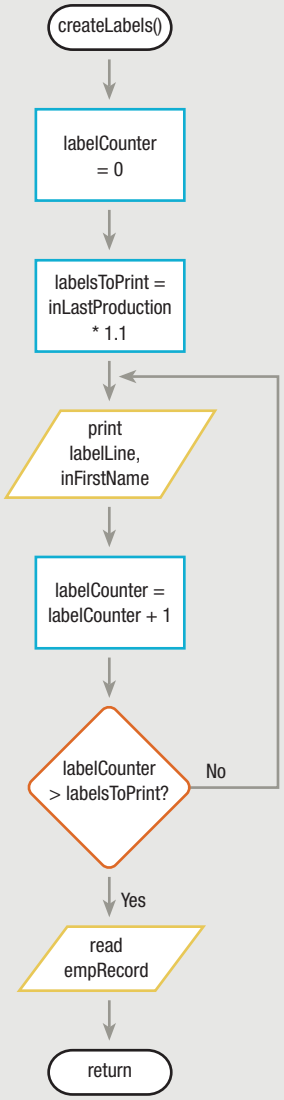
With a `while` loop, the loop body might not execute. When you want to ensure that a loop's body executes at least one time, you can use either a `do while` or a `do until` loop. In both types of loops, the loop control variable is evaluated after the loop body executes, instead of before. Therefore, the body always executes at least one time. Although the loops have similarities, as explained above, they are different in that the `do while` loop continues when the result of the test of the loop control variable is true, but the `do until` loop continues when the result of the test of the loop control variable is false. In other words, the difference between the two loops is simply in how the question at the bottom of the loop is phrased.

TIP You first learned about the `do while` and `do until` loops in Chapter 2. Review Chapter 2 to reinforce your understanding of the differences between a `while` loop and the `do while` and `do until` loops.

TIP Because the question that controls a `while` loop is asked before you enter the loop body, programmers say a `while` loop is a pretest loop. Because the question that controls `do while` and `do until` loops occurs after the loop body executes, programmers say these loops are posttest loops.

For example, suppose you want to produce one label for each employee to wear as identification, before you produce enough labels to cover 110 percent of last week's production. You can write the `do until` loop that appears in Figure 6-14.

FIGURE 6-14: USING A `do until` LOOP TO PRINT ONE IDENTIFICATION LABEL, THEN PRINT ENOUGH TO COVER PRODUCTION REQUIREMENTS



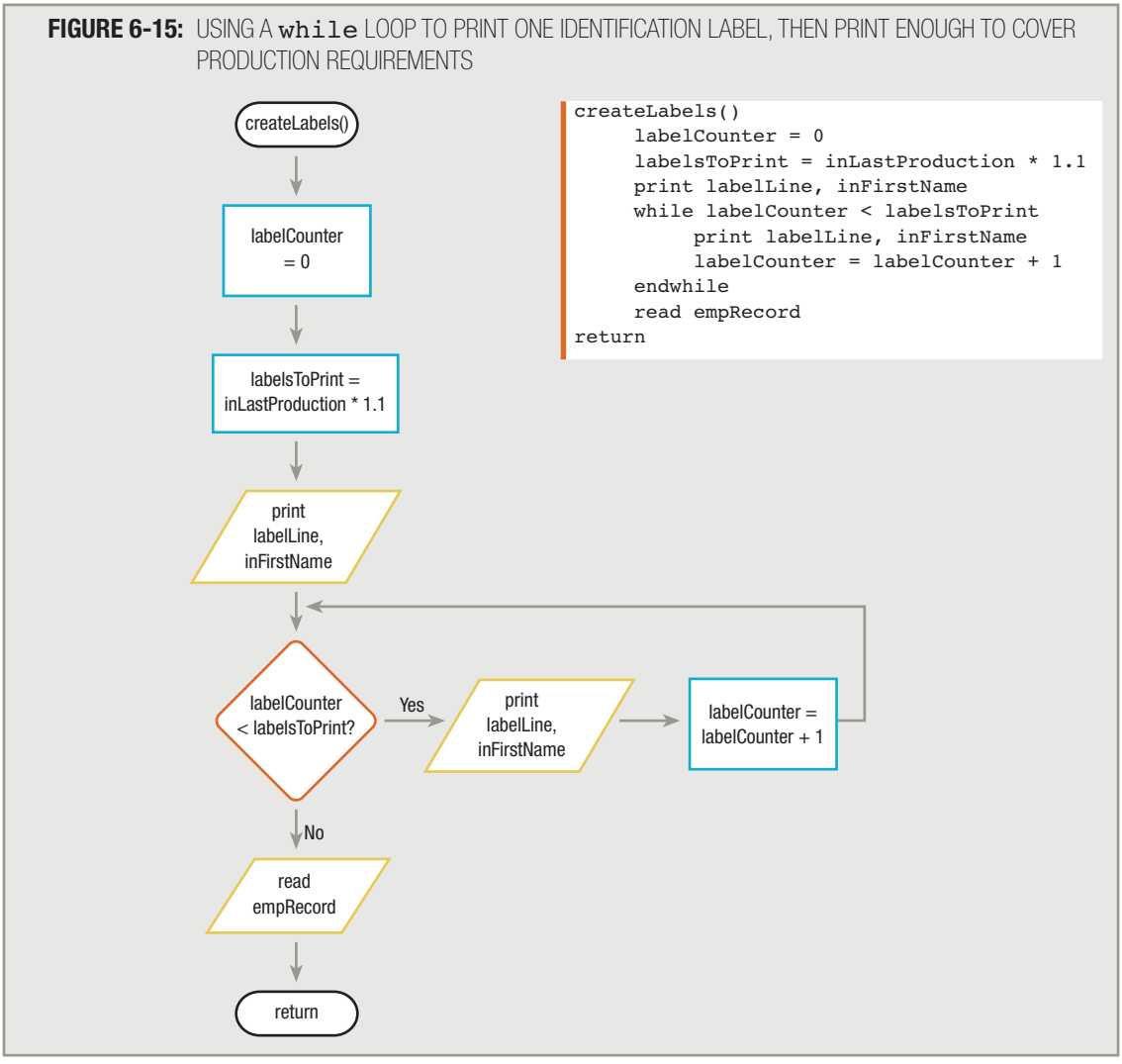

```
createLabels()
      labelCounter = 0
      labelsToPrint = inLastProduction * 1.1
      do
        print labelLine, inFirstName
        labelCounter = labelCounter + 1
      until labelCounter > labelsToPrint
      read empRecord
return
```

In Figure 6-14, the `labelCounter` variable is set to 0 and `labelsToPrint` is calculated. Suppose `labelsToPrint` is computed to be 0. The `do until` loop will be entered, a label will print, 1 will be added to `labelCounter`, and then and only then will `labelCounter` be compared to `labelsToPrint`. Because `labelCounter` is now 1 and `labelsToPrint` is only 0, the loop is exited, having printed a single identification label and no product labels.

As a different example using the logic in Figure 6-14, suppose that for a worker `labelsToPrint` is calculated to be 1. In this case, the loop is entered, a label prints, and 1 is added to `labelCounter`. Now, the value of `labelCounter` is not yet greater than the value of `labelsToPrint`, so the loop repeats, a second label prints, and `labelCounter` is incremented again. This time `labelCounter` (with a value of 2) does exceed `labelsToPrint` (with a value of 1), so the loop ends. This employee gets an identification label as well as one product label.

Of course, you could achieve the same results by printing one label, then entering a `while` loop, as in Figure 6-15. In this example, one label prints before `labelCounter` is compared to `labelsToPrint`. No matter what the value of `labelsToPrint` is, one identification label is produced.

FIGURE 6-15: USING A `while` LOOP TO PRINT ONE IDENTIFICATION LABEL, THEN PRINT ENOUGH TO COVER PRODUCTION REQUIREMENTS



TIP

The logic in Figure 6-15, in which you print one label and then test a value to determine whether you will print more, takes the same form as the mainline logic in most of the programs you have worked with so far. When you read records from a file, you read one record (the priming read) and then test for `eof` before continuing. In effect, the first label printed in Figure 6-15 is a "priming label."

The results of the programs shown in Figures 6-14 and 6-15 are the same. Using either, every employee will receive an identification label and enough labels to cover production. Each module works correctly, and neither is logically superior to the other. There is almost always more than one way to solve the same programming problem. As you learned in Chapter 2, a posttest loop (`do while` or `do until`) can always be replaced by pairing a sequence and a pretest `while` loop. Which method you choose depends on your (or your instructor's or supervisor's) preference.

TIP

There are several additional ways to approach the logic shown in the programs in Figures 6-14 and 6-15. For example, after calculating `labelsToPrint`, you could immediately add 1 to the value. Then, you could use the logic in Figure 6-14, as long as you change the loop-ending question to `labelCounter >= labelsToPrint` (instead of only >). Alternatively, using the logic in Figure 6-15, after adding 1 to `labelsToPrint`, you could remove the lone first label-printing instruction; that way, one identification label would always be printed, even if the last production figure was 0.

RECOGNIZING THE CHARACTERISTICS SHARED BY ALL LOOPS

You can see from Figure 6-15 that you are never required to use posttest loops (either a `do while` loop or a `do until` loop). The same results always can be achieved by performing the loop body steps once before entering a `while` loop. If you follow the logic of either of the loops shown in Figures 6-14 and 6-15, you will discover that when an employee has an `inLastProduction` value of 3, then exactly four labels print. Likewise, when an employee has an `inLastProduction` value of 0, then exactly one label prints. You can accomplish the same results with either type of loop; the posttest `do while` and `do until` loops simply are a convenience when you need a loop's statements to execute at least one time.

TIP

In some languages, the `do until` loop is called a `repeat until` loop.

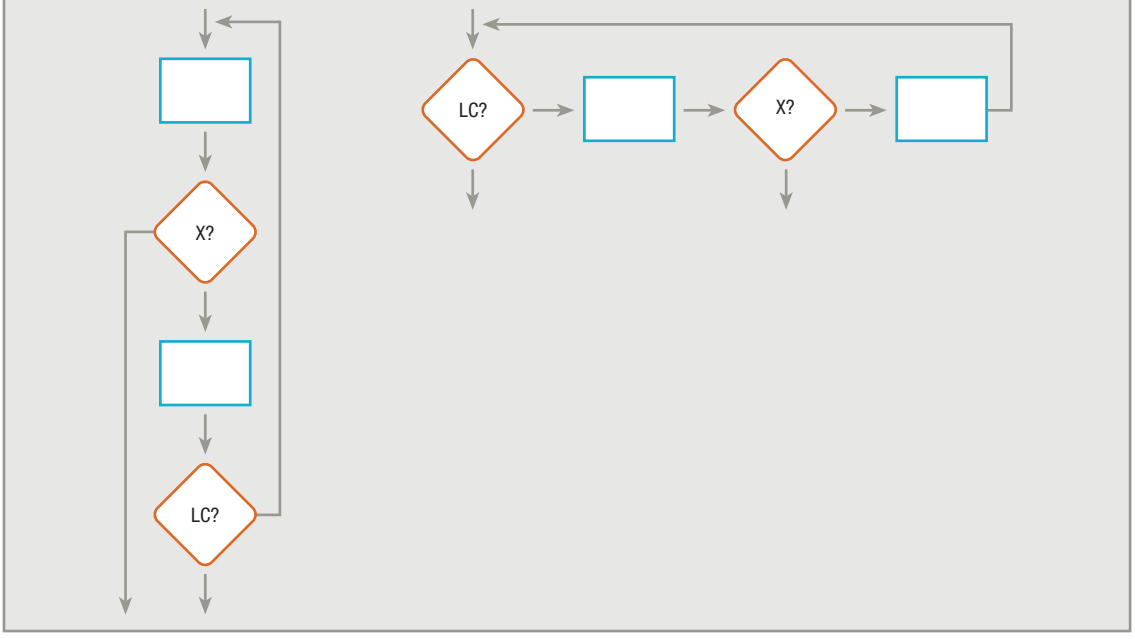
If you can express the logic you want to perform by saying "while a is true, keep doing b," you probably want to use a `while` loop. If what you want to accomplish seems to fit the statement "do a until b is true," you can probably use a `do until` loop. If the statement "do a while b is true" makes more sense, then you might choose to use a `do while` loop.

As you examine Figures 6-14 and 6-15, notice that with the `do until` loop in Figure 6-14, the loop-controlling question is placed at the *end* of the sequence of the steps that repeat. With the `while` loop, the loop-controlling question is placed at the *beginning* of the steps that repeat. All structured loops (whether they are `while` loops, `do while` loops, or `do until` loops) share these characteristics:

- The loop-controlling question provides either entry to or exit from the repeating structure.
- The loop-controlling question provides the *only* entry to or exit from the repeating structure.

You should also notice the difference between *unstructured* loops and the structured `do until` and `while` loops. Figure 6-16 diagrams the outline of two unstructured loops. In each case, the decision labeled X breaks out of the loop prematurely. In each case, the loop control variable (labeled `LC`) does not provide the only entry to or exit from the loop.

FIGURE 6-16: EXAMPLES OF UNSTRUCTURED LOOPS



NESTING LOOPS

Program logic gets more complicated when you must use loops within loops, or **nesting loops**. When one loop appears inside another, the loop that contains the other loop is called the **outer loop**, and the loop that is contained is called the **inner loop**. For example, suppose you work for a company that pays workers twice per month. The company has decided on an incentive plan to provide each employee with a one-fourth of one percent raise for each pay period during the coming year, and it wants a report for each employee like that shown in Figure 6-17. A list will be printed for each employee showing the exact paycheck amounts for each of the next 24 pay periods—two per month for 12 months. A description of the employee input record is shown in Figure 6-18.

FIGURE 6-17: SAMPLE PROJECTED PAYROLL REPORT FOR ONE EMPLOYEE

Projected Payroll for
Roberto Martinez

Month	Check	Amount
1	1	501.25
1	2	502.50
2	1	503.76
2	2	505.02
3	1	506.28

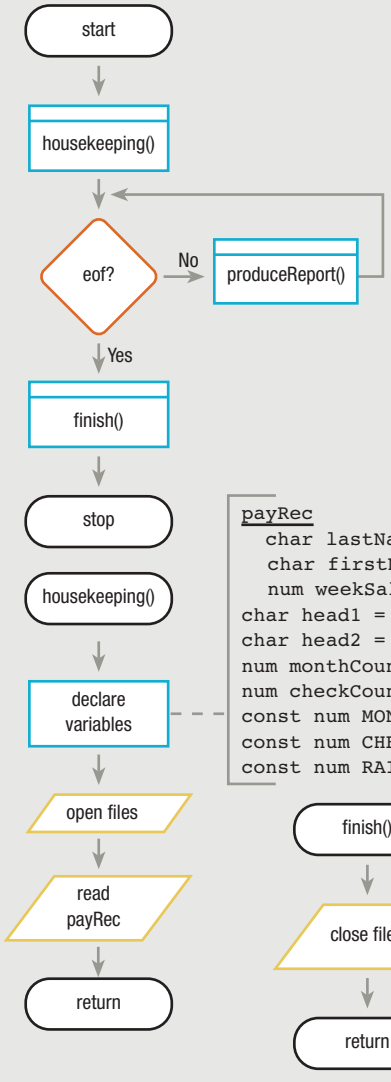
FIGURE 6-18: EMPLOYEE PAYROLL RECORD DATA FILE DESCRIPTION

```
File Name: EMPPAY
FIELD DESCRIPTION       DATA TYPE       COMMENTS
Employee Last Name      Character       12 characters
Employee First Name     Character       8 characters
Weekly salary at        Numeric         2 decimal places
   start of year
```

To produce the Projected Payroll report, you need to maintain two separate counters to control two separate loops. One counter will keep track of the month (1 through 12), and another will keep track of the pay period within the month (1 through 2). When nesting loops, you must maintain individual loop control variables—one for each loop—and alter each at the appropriate time.

Figure 6-19 shows the mainline, `housekeeping()`, and `finish()` logic for the program. These modules are standard. Besides the input file variables and the headers that print for each employee, the list of declared variables includes two counters. One, named `monthCounter`, keeps track of the month that is currently printing. The other, named `checkCounter`, keeps track of which check within the month is currently printing. Three additional declarations hold the number of months in a year (12), the number of checks in a month (2), and the rate of increase (0.0025). Declaring these constants is not required; the program could just use the numeric constants 12, 2, and 0.0025 within its statements, but providing those values with names serves two purposes. First, the program becomes more self-documenting—that is, it describes itself to the reader because the choice of variable names is clear. When other programmers read a program and encounter a number like 2, they might wonder about the meaning. Instead, if the value is named `CHECKS_IN_A_MONTH`, the meaning of the value is much clearer. Second, after the program is in production, the company might choose to change one of the values—for example, by going to an 11-month year, producing more or fewer paychecks in a month, or changing the raise rate. In those cases, the person who modifies the program would not have to search for appropriate spots to make those changes, but would simply redefine the values assigned to the appropriate named constants.

FIGURE 6-19: MAINLINE LOGIC, `housekeeping()`, AND `finish()` MODULES FOR PROJECTED PAYROLL REPORT PROGRAM




```
start
     perform housekeeping()
     while not eof
          perform produceReport()
     endwhile
     perform finish()
stop

housekeeping()
     declare variables
     open files
     read payRec
return

finish()
     close files
return
```

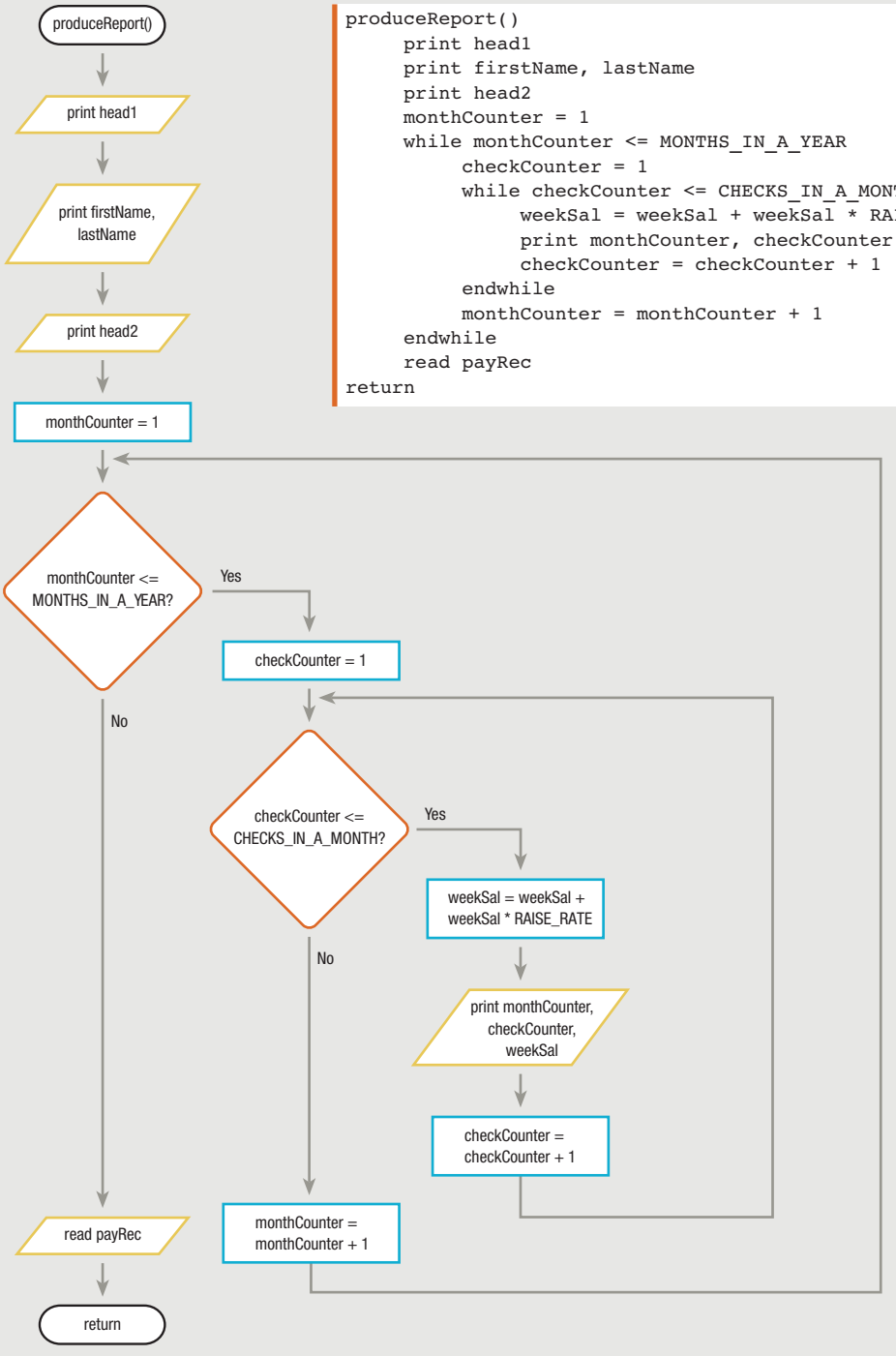
```
payRec
  char lastName
  char firstName
  num weekSal
char head1 = "Projected Payroll for"
char head2 = "Month Check Amount"
num monthCounter
num checkCounter
const num MONTH_IN_A_YEAR = 12
const num CHECKS_IN_A_MONTH = 2
const num RAISE-RATE = 0.0025
```

TIP In Chapter 1 you learned that by convention, many programmers use all uppercase letters when naming constants.

At the end of the `housekeeping()` module in Figure 6-19, the first employee record is read into main memory. Figure 6-20 shows how the record is processed in the `produceReport()` module. The program proceeds as follows:

1. The first heading prints, followed by the employee name and the column headings.
2. The `monthCounter` variable is set to 1; `monthCounter` is the loop control variable for the outer loop, and this step provides it with its initial value.
3. The `monthCounter` variable is compared to the number of months in a year, and because the comparison evaluates as true, the outer loop is entered. Within this loop, the `checkCounter` variable is used as a loop control variable for an inner loop.
4. The `checkCounter` variable is initialized to 1, and then compared to the number of checks in a month. Because this comparison evaluates as true, the inner loop is entered.
5. Within this inner loop, the employee's weekly salary is increased by one-fourth of one percent (the old salary plus 0.0025 of the old salary).
6. The month number (currently 1), check number (also currently 1), and newly calculated salary are printed.
7. The check number is increased (to 2), and the inner loop reaches its end; this causes the logical control to return to the top of the inner loop, where the `while` condition is tested again. Because the check number (2) is still less than or equal to the number of checks in a month, the inner loop is entered again.
8. The pay amount increases, and the month (still 1), check number (2), and new salary are printed.
9. Then, the check number becomes 3. Now, when the loop condition is tested for the third time, the check number is no longer less than or equal to the number of checks in a month, so the inner loop ends.
10. As the last step in the outer loop, `monthCounter` becomes 2.
11. After `monthCounter` increases to 2, control returns to the entry point of the outer loop.
12. The `while` condition is tested, and because 2 is not greater than the number of months in a year, the outer loop is entered for a second time.
13. The `checkCounter` variable is reset to 1 so that it will correctly count two checks for this month.
14. Because the newly reset `checkCounter` is not more than the number of checks in a month, the salary is increased, and the amount prints for month 2, check 1.
15. The `checkCounter` variable increases to 2 and another value is printed for month 2, check 2 before the inner loop ends and `monthCounter` is increased to 3.
16. Then, month 3, check 1 prints, followed by month 3, check 2. The inner loop is evaluated again. The `checkCounter` value is 3, so the evaluation result is false.
17. The `produceReport()` module continues printing two check amounts for each of 12 months before the outer loop is finished, when `monthCounter` eventually exceeds 12. Only then is the next employee record read into memory, and control leaves the `produceReport()` module and returns to the mainline logic, where the end of file is tested. If a new record exists, control returns to the `produceReport()` module for the new employee, for whom headings are printed, and `monthCounter` is set to 1 to start the set of 24 calculations for this employee.

FIGURE 6-20: THE `produceReport()` MODULE FOR THE PROJECTED PAYROLL REPORT PROGRAM




```
produceReport()
     print head1
     print firstName, lastName
     print head2
     monthCounter = 1
     while monthCounter <= MONTHS_IN_A_YEAR
          checkCounter = 1
          while checkCounter <= CHECKS_IN_A_MONTH
               weekSal = weekSal + weekSal * RAISE_RATE
               print monthCounter, checkCounter, weekSal
               checkCounter = checkCounter + 1
          endwhile
          monthCounter = monthCounter + 1
     endwhile
     read payRec
return
```

TIP If you have trouble seeing that the flowchart in Figure 6-20 is structured, consider moving the `checkCounter` loop and its three resulting actions to its own module. Then you should see that the `monthCounter` loop contains a sequence of three steps and that the middle step is a loop.

There is no limit to the number of loop-nesting levels a program can contain. For instance, suppose that in the projected payroll example, the company wanted to provide a slight raise each hour or each day of each pay period in each month for each of several years. No matter how many levels deep the nesting goes, each loop must still contain a loop control variable that is initialized, tested, and altered.

USING A LOOP TO ACCUMULATE TOTALS

Business reports often include totals. The supervisor requesting a list of employees who participate in the company dental plan is often as much interested in *how many* such employees there are as in *who* they are. When you receive your telephone bill at the end of the month, you are usually more interested in the total than in the charges for the individual calls. Some business reports list no individual detail records, just totals or other overall statistics such as averages. Such reports are called **summary reports**. Many business reports list both the details of individual records and totals at the end.

For example, a real estate broker might maintain a file of company real estate listings. Each record in the file contains the street address and the asking price of a property for sale. The broker wants a listing of all the properties for sale; she also wants a total value for all the company's listings. A typical report appears in Figure 6-21.

FIGURE 6-21: TYPICAL REAL ESTATE REPORT

PROPERTIES FOR SALE

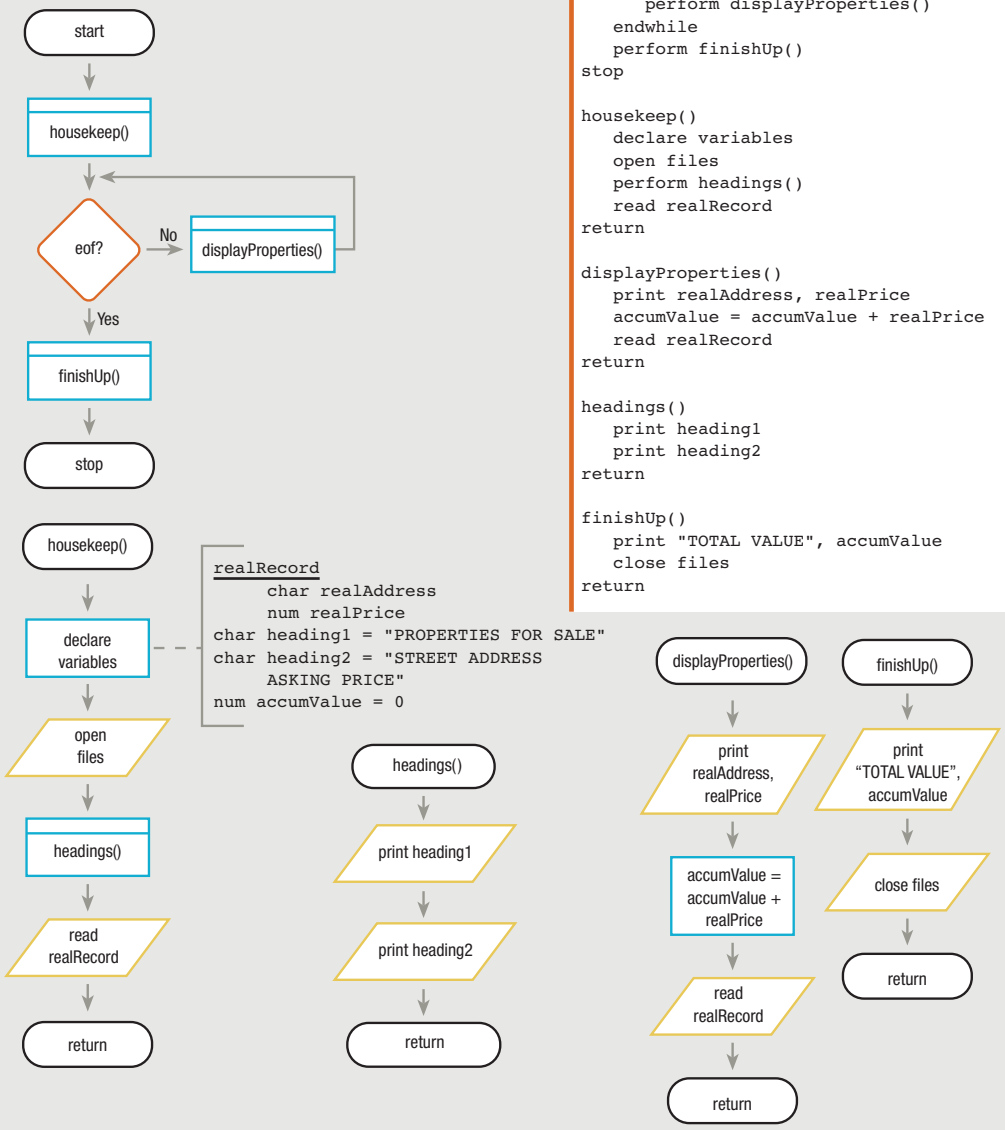
STREET ADDRESS	ASKING PRICE
12 Carpenter Road	218,000
312 Howard Street	119,900
416 Mockingbird Lane	349,900
58 Flowerwood Path	249,900
5914 Wisteria Lane	499,999
TOTAL VALUE	1,437,699

When you read a real estate listing record, besides printing it you must add its value to an accumulator. An **accumulator** is a variable that you use to gather, or accumulate, values. An accumulator is very similar to a counter. The difference lies in the value that you add to the variable; usually, you add just 1 to a counter, whereas you add some other value to an accumulator. If the real estate broker wants to know how many listings the company holds, you count them. When she wants to know total real estate value, you accumulate it.

In order to accumulate total real estate prices, you declare a numeric variable at the beginning of the program, as shown in the `housekeep()` module in Figure 6-22. You must initialize the accumulator, `accumValue`, to 0. In

Chapter 4, you learned that when using most programming languages, declared variables do not automatically assume any particular value; the unknown value is called garbage. When you read the first real estate record, you will add its value to the accumulator. If the accumulator contains garbage, the addition will not work. Some programming languages issue an error message if you don't initialize a variable you use for accumulating; others let you accumulate, but the results are worthless because you start with garbage.

FIGURE 6-22: THE REAL ESTATE PROGRAM



If you name the input record fields `realAddress` and `realPrice`, then the `displayProperties()` module of the real estate listing program can be written as shown in Figure 6-22. For each real estate record, you print it and add its value to the accumulator `accumValue`. Then you can read the next record.

After the program reaches the end of the file, the accumulator will hold the grand total of all the real estate values. When you reach the end of the file, the `finishUp()` module executes, and it is within the `finishUp()` module that you print the accumulated value, `accumValue`. After printing the total, you can close both the input and the output files and return to the mainline logic, where the program ends.

New programmers often want to reset the `accumValue` to 0 after printing it. Although you *can* take this step without harming the execution of the program, it does not serve any useful purpose. You cannot set `accumValue` to 0 in anticipation of having it ready for the next program, or even for the next time you execute this program. Program variables exist only for the life of the program, and even if a future program happens to contain a variable named `accumValue`, the variable will not necessarily occupy the same memory location as this one. Even if you run the program a second time, the variables might occupy physical memory locations different from those they occupied during the first run. At the beginning of the program, it is the programmer's responsibility to initialize all variables that must start with a specific value. There is no benefit to changing a variable's value when it will never be used again during the current execution of the program.

TIP It is especially important to avoid changing the value of a variable unnecessarily when the change occurs within a loop. One extra, unnecessary statement in a loop that executes hundreds of thousands of times can significantly slow a program's performance speed.

CHAPTER SUMMARY

- When you use a loop within a computer program, you can write one set of instructions that operates on multiple, separate sets of data.
- Three steps must occur in every loop: You must initialize a loop control variable, compare the variable to some value that controls whether the loop continues or stops, and alter the variable that controls the loop.
- A counter is a numeric variable you use to count the number of times an event has occurred. You can count occurrences by incrementing or decrementing a variable.
- You can use a variable sentinel value to control a loop.
- Sometimes it is convenient to reduce, or decrement, a loop control variable on every cycle through a loop.
- Mistakes that programmers often make with loops include neglecting to initialize the loop control variable and neglecting to alter the loop control variable. Other mistakes include using the wrong comparison with the loop control variable, including statements inside the loop that belong outside the loop, and initializing a variable that does not require initialization.
- Most computer languages support a **`for`** statement that you can use with definite loops when you know how many times a loop will repeat. The **`for`** statement uses a loop control variable that it automatically initializes, evaluates, and increments.
- When you want to ensure that a loop's body executes at least one time, you can use a **`do while`** loop or a **`do until`** loop, in which the loop control variable is evaluated after the loop body executes.
- All structured loops share these characteristics: The loop-controlling question provides either entry to or exit from the repeating structure, and the loop-controlling question provides the *only* entry to or exit from the repeating structure.
- When you must use loops within loops, you are using nested loops. When you create nested loops, you must maintain two individual loop control variables and alter each at the appropriate time.
- Business reports often include totals. Summary reports list no detail records—only totals. An accumulator is a variable that you use to gather or accumulate values.

KEY TERMS

A **loop** is a structure that repeats actions while some condition continues.

A **main loop** is a basic set of instructions that is repeated for every record.

A **loop control variable** is a variable that determines whether a loop will continue.

A **sentinel value** is a limit or ending value.

A **loop body** is the set of statements that executes within a loop.

A **counter** is any numeric variable you use to count the number of times an event has occurred.

Adding to a variable (often, adding one) is called **incrementing** the variable.

Decreasing a variable (often by one) is called **decrementing** the variable.

A loop that never stops executing is called an **infinite loop**.

An **indeterminate**, or **indefinite**, **loop** is one for which you cannot predetermine the number of executions.

A loop for which you definitely know the repetition factor is a **definite loop**.

A **`while` statement** can be used to code any loop.

A **`for` statement** frequently is used to code a definite loop. Most often, it contains a loop control variable that it initializes, evaluates, and increments.

Nesting loops are loops within loops.

When one loop appears inside another, the loop that contains the other loop is called the **outer loop**, and the loop that is contained is called the **inner loop**.

A **summary report** lists only totals and other statistics, without individual detail records.

An **accumulator** is a variable that you use to gather, or accumulate, values.

REVIEW QUESTIONS

1. **The structure that allows you to write one set of instructions that operates on multiple, separate sets of data is the _____.**
   a. sequence
   b. selection
   c. loop
   d. case

2. **Which of the following is not a step that must occur in every loop?**
   a. Initialize a loop control variable.
   b. Compare the loop control value to a sentinel.
   c. Set the loop control value equal to a sentinel.
   d. Alter the loop control variable.

3. The statements executed within a loop are known collectively as the _____.

a. sentinels
b. loop controls
c. sequences
d. loop body

4. A counter keeps track of _____.

a. the number of times an event has occurred
b. the number of modules in a program
c. the number of loop structures within a program
d. a total that prints at the end of a summary report

5. Adding 1 to a variable is also called _____.

a. digesting
b. incrementing
c. decrementing
d. resetting

6. In the following pseudocode, what is printed?

```
a = 1
b = 2
c = 5
while a < c
     a = a + 1
     b = b + c
endwhile
print a, b, c
```

a. 1 2 5
b. 5 22 5
c. 5 6 5
d. 6 22 9

7. In the following pseudocode, what is printed?

```
d = 4
e = 6
f = 7
while d > f
     d = d + 1
     e = e - 1
endwhile
print d, e, f
```

a. 7 3 7
b. 8 2 8
c. 4 6 7
d. 5 5 7

8. When you decrement a variable, most frequently you _____.

a. set it to 0
b. reduce it by one-tenth
c. subtract 1 from it
d. remove it from a program

9. In the following pseudocode, what is printed?

```
g = 4
h = 6
while g < h
     g = g + 1
endwhile
print g, h
```

a. nothing
b. 4 6
c. 5 6
d. 6 6

10. Most programmers use a `for` statement _____.

a. for every loop they write
b. as a compact version of the `while` statement
c. when they do not know the exact number of times a loop will repeat
d. when a loop will not repeat

11. Unlike a `while` loop, you use a `do until` loop when _____.

a. you can predict the exact number of loop repetitions
b. the loop body might never execute
c. the loop body must execute exactly one time
d. the loop body must execute at least one time

12. Which of the following is a characteristic shared by all loops—`while`, `do while`, and `do until` loops?

a. They all have one entry and one exit.
b. They all have a body that executes at least once.
c. They all compare a loop control variable at the top of the loop.
d. All of these are true.

13. A comparison with a loop control variable provides _____.

a. the only entry to a `while` loop
b. the only exit from a `do until` loop
c. both of the above
d. none of the above

14. When two loops are nested, the loop that is contained by the other is the _____ loop.

a. inner
b. outer
c. unstructured
d. captive

15. In the following pseudocode, how many times is "Hello" printed?

```
j = 2
k = 5
m = 6
n = 9
while j < k
     while m < n
          print "Hello"
          m = m + 1
     endwhile
     j = j + 1
endwhile
```

a. zero
b. three
c. six
d. nine

16. In the following pseudocode, how many times is "Hello" printed?

```
j = 2
k = 5
n = 9
while j < k
     m = 6
     while m < n
          print "Hello"
          m = m + 1
     endwhile
     j = j + 1
endwhile
```

a. zero
b. three
c. six
d. nine

17. In the following pseudocode, how many times is "Hello" printed?

```
p = 2
q = 4
while p < q
     print "Hello"
     r = 1
     while r < q
          print "Hello"
          r = r + 1
     endwhile
     p = p + 1
endwhile
```

a. zero
b. four
c. six
d. eight

18. A report that lists no details about individual records, but totals only, is a(n) _____ report.

a. accumulator
b. final
c. summary
d. detailless

19. Typically, the value added to a counter variable is _____.

a. 0
b. 1
c. 10
d. 100

20. Typically, the value added to an accumulator variable is _____.

a. 0
b. 1
c. at least 1000
d. Any value might be added to an accumulator variable.

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **This method is supposed to print every fifth year starting with 2005; that is, 2005, 2010, 2015, and so on, for 30 years.**

```
printEveryFifthYear()
   const num YEAR = 2005
   num factor = 5
   const num END_YEAR = 2035
   while year > END_YEAR
      print year
      year = year + 1
   endwhile
return
```

2. **A standard mortgage is paid monthly over 30 years. This method is intended to print 360 payment coupons for a new borrower. Each coupon lists the month number, year number, and a friendly reminder.**

```
printCoupons()
   const num MONTHS = 12
   const num YEARS = 30
   num monthCounter
   num yearCounter
   while yearCounter <= YEARS
      while monthCounter <= 12
         print month, year, "Remember to send your payment by the 10th"
         yearCounter = yearCounter + 1
      endwhile
   endwhile
return
```

3. **This application is intended to print estimated monthly payment amounts for customers of the EZ Credit Loan Company. The application reads customer records, each containing an account number, name and address, requested original loan amount, term in months, and annual interest rate. The interest rate per month is calculated by dividing the annual interest rate by 12. The customer's total payback amount is calculated by charging the monthly interest rate on the original balance every month for the term of the loan. The customer's monthly payment is then calculated by dividing the total payback amount by the number of months in the loan. The application produces a notice containing the customer's name, address, and estimated monthly payment amount.**

```
start
   perform getReady()
   while not eof
      perform produceEstimate()
   perform ending()
stop
startUp()
   declare variables
   custRecord
      num acctNumber
      char name
      char address
      num originalLoanAmount
      num termInMonths
      num annualRate
   const num MONTHS_IN_YEAR = 12
   const num totalPayback
   num monthlyRate
   num count
   open files
   read custRecord
return

produceEstimate()
   count = 1
   monthlyRate = annualRate / monthsInYear
   while count = termInMonths
      totalPayback = totalPayback + monthlyRate * originalLoanAmount
      count = count + 1
   endwhile
   monthlyPayment = totalPayback / MONTHS_IN_YEAR
   print "Loan Payment Estimate for:"
   print name
   print address
   print "$", monthPayment
return

ending()
   close files
return
```

EXERCISES

1. **Design the logic for a module that would print every number from 1 through 10.**
   a. Draw the flowchart.
   b. Design the pseudocode.

2. **Design the logic for a module that would print every number from 1 through 10 along with its square and cube.**
   a. Draw the flowchart.
   b. Design the pseudocode.

3. **Design a program that reads credit card account records and prints payoff schedules for customers. Input records contain an account number, customer name, and balance due. For each customer, print the account number and name; then print the customer's projected balance each month for the next 10 months. Assume that there is no finance charge on this account, that the customer makes no new purchases, and that the customer pays off the balance with equal monthly payments, which are 10 percent of the original bill.**
   a. Design the output for this program; create either sample output or a print chart.
   b. Design the hierarchy chart for this program.
   c. Design the flowchart for this program.
   d. Write pseudocode for this program.

4. **Design a program that reads credit card account records and prints payoff schedules for customers. Input records contain an account number, customer name, and balance due. For each customer, print the account number and name; then print the customer's payment amount and new balance each month until the card is paid off. Assume that when the balance reaches $10 or less, the customer can pay off the account. At the beginning of every month, 1.5 percent interest is added to the balance, and then the customer makes a payment equal to 5 percent of the current balance. Assume the customer makes no new purchases.**
   a. Design the output for this program; create either sample output or a print chart.
   b. Design the hierarchy chart for this program.
   c. Design the flowchart for this program.
   d. Write pseudocode for this program.

5. **Assume you have a bank account that compounds interest on a yearly basis. In other words, if you deposit $100 for two years at 4 percent interest, at the end of one year you will have $104. At the end of two years, you will have the $104 plus 4 percent of that, or $108.16. Create the logic for a program that would (1) read in records containing a deposit amount, a term in years, and an interest rate, and (2) for each record, print the running total balance for each year of the term.**
   a. Design the output for this program; create either sample output or a print chart.
   b. Design the hierarchy chart for this program.
   c. Design the flowchart for this program.
   d. Write pseudocode for this program.

6. A school maintains class records in the following format:

```
CLASS FILE DESCRIPTION
File name: CLASS
FIELD DESCRIPTION     DATA TYPE       EXAMPLE
Class Code            Character       CIS111
Section No.           Numeric         101
Teacher Name          Character       Gable
Enrollment            Numeric         24
Room                  Character       A213
```

There is one record for each class section offered in the college. Design the program that would print as many stickers as a class needs to provide one for each enrolled student, plus one for the teacher. Each sticker would leave a blank for the student's (or teacher's) name, like this:

The border is preprinted, but you must design the program to print all the text you see on the sticker. (You do not need to worry about the differing font sizes of the sticker text. You do not need to design a print chart or sample output—the image of the sticker serves as a print chart.)

a. Design the hierarchy chart for this program.
b. Design the flowchart for this program.
c. Write pseudocode for this program.

7. A mail-order company often sends multiple packages per order. For each customer order, print enough mailing labels to use on each of the separate boxes that will be mailed. The mailing labels contain the customer's complete name and address, along with a box number in the form "Box 9 of 9". For example, an order that requires three boxes produces three labels: Box 1 of 3, Box 2 of 3, and Box 3 of 3. The file description is as follows:

```
SHIPPING FILE DESCRIPTION
File name: ORDERS
FIELD DESCRIPTION     DATA TYPE     EXAMPLE
Title                 Character     Ms
First Name            Character     Kathy
Last Name             Character     Lewis
Street                Character     847 Pine
```

```
City                Character     Aurora
State               Character     IL
Boxes               Numeric       3
Balance Due         Numeric       129.95
```

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

8. A secondhand store is having a seven-day sale during which the price of any unsold item drops 10 percent each day. The inventory file includes an item number, description, and original price on day one. For example, an item that costs $10.00 on the first day costs 10 percent less, or $9.00, on the second day. On the third day, the same item is 10 percent less than $9.00, or $8.10. Produce a report that shows the price of the item on each day, one through seven.

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

9. The state of Florida maintains a census file in which each record contains the name of a county, the current population, and a number representing the rate at which the population is increasing per year. The governor wants a report listing each county and the number of years it will take for the population of the county to double, assuming the present rate of growth remains constant.

```
CENSUS FILE DESCRIPTION
File name: CENSUS
FIELD DESCRIPTION        DATA TYPE          EXAMPLE
County Name              Character          Dade
Current Population       Numeric            525000
Rate of Growth           Numeric            0.07
```

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

10. A Human Resources Department wants a report that shows its employees the benefits of saving for retirement. Produce a report that shows 12 predicted retirement account values for each employee—the values if the employee saves 5, 10, or 15 percent of his or her annual salary for 10, 20, 30, or 40 years. The department maintains a file in which each record contains the name of an employee and the employee's current annual salary. Assume that savings grow at a rate of 8 percent per year.

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

11. Randy's Recreational Vehicles pays its salespeople once every three months. Salespeople receive one-quarter of their annual base salary plus 7 percent of all sales made in the last three-month period. Randy creates an input file with four records for each salesperson. The first of the four records contains the salesperson's name and annual base salary, while each of the three records that follow contains the name of a month and the monthly sales figure. For example, the first eight records in the file might contain the following data:

Kimball	**20000**
April	**30000**
May	**40000**
June	**60000**
Johnson	**15000**
April	**65000**
May	**78000**
June	**135500**

Because the two types of records contain data in the same format—a character field followed by a numeric field—you can define one input record format containing two variables that you use with either type of record. Design the logic for the program that reads a salesperson's record, and if not at `eof`, reads the next three records in a loop, accumulating sales and computing commissions. For each salesperson, print the quarterly base salary, the three commission amounts, and the total salary, which is the quarterly base plus the three commission amounts.

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

12. Mr. Furly owns 20 apartment buildings. Each building contains 15 units that he rents for $800 per month each. Design the logic for the program that would print 12 payment coupons for each of the 15 apartments in each of the 20 buildings. Each coupon should contain the building number (1 through 20), the apartment number (1 through 15), the month (1 through 12), and the amount of rent due.

a. Design the output for this program; create either sample output or a print chart.
b. Design the hierarchy chart for this program.
c. Design the flowchart for this program.
d. Write pseudocode for this program.

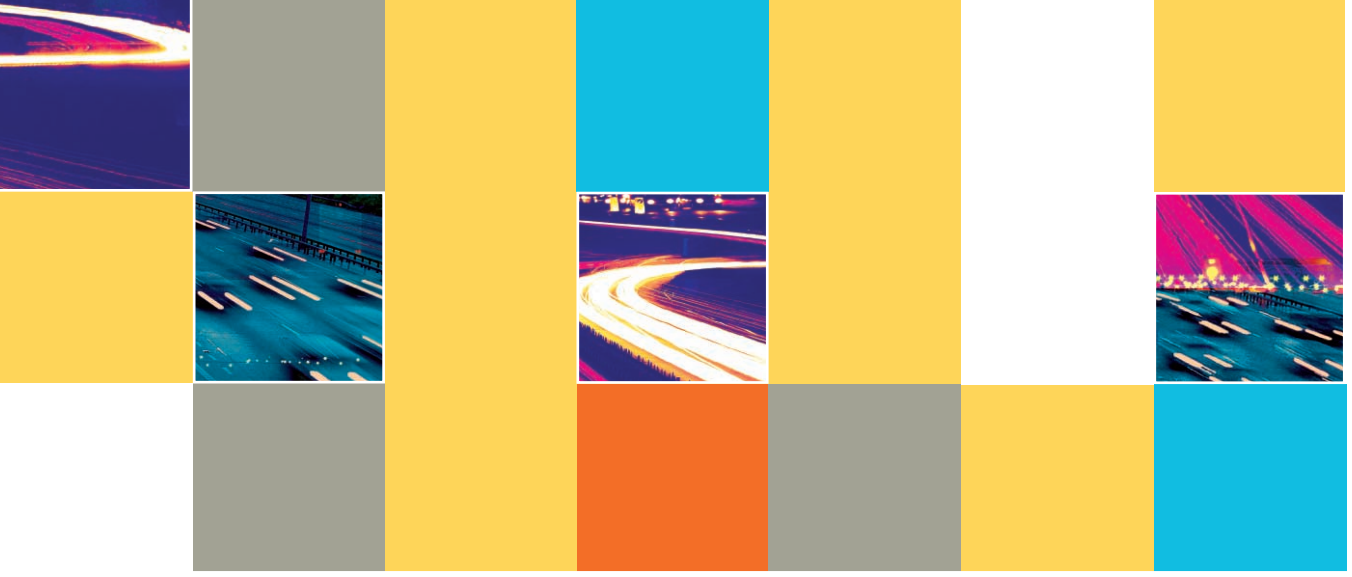
13. **Mr. Furly owns 20 apartment buildings. Each building contains 15 units that he rents. The usual monthly rent for apartments numbered 1 through 9 in each building is $700; the monthly rent is $850 for apartments numbered 10 through 15. The usual rent is due every month except July and December; in those months Mr. Furly gives his renters a 50 percent credit, so they owe only half the usual amount. Design the logic for the program that would print 12 payment coupons for each of the 15 apartments in each of the 20 buildings. Each coupon should contain the building number (1 through 20), the apartment number (1 through 15), the month (1 through 12), and the amount of rent due.**
    a. Design the output for this program; create either sample output or a print chart.
    b. Design the hierarchy chart for this program.
    c. Design the flowchart for this program.
    d. Write pseudocode for this program.

DETECTIVE WORK

1. **What company's address is at One Infinite Loop, Cupertino, California?**
2. **What are fractals? How do they use loops? Find some examples of fractal art on the Web.**

UP FOR DISCUSSION

1. **If programs could only make decisions or loops, but not both, which structure would you prefer to retain?**
2. **Suppose you wrote a program that you suspect is in an infinite loop because it just keeps running for several minutes with no output and without ending. What would you add to your program to help you discover the origin of the problem?**
3. **Suppose you know that every employee in your organization has a seven-digit ID number used for logging on to the computer system to retrieve sensitive information about their own customers. A loop would be useful to guess every combination of seven digits in an ID. Are there any circumstances in which you should try to guess another employee's ID number?**



7 CONTROL BREAKS

After studying Chapter 7, you should be able to:

- Understand control break logic
- Perform single-level control breaks
- Use control data within a heading in a control break module
- Use control data within a footer in a control break module
- Perform control breaks with totals
- Perform multiple-level control breaks
- Perform page breaks

UNDERSTANDING CONTROL BREAK LOGIC

A **control break** is a temporary detour in the logic of a program. In particular, programmers refer to a program as a **control break program** when a change in the value of a variable initiates special actions or causes special or unusual processing to occur. You usually write control break programs to organize output for programs that handle data records that are organized logically in groups based on the value in a field. As you read records, you examine the same field in each record, and when you encounter a record that contains a different value from the ones that preceded it, you perform a special action. If you have ever read a report that lists items in groups, with each group followed by a subtotal, then you have read a type of **control break report**. For example, you might generate a report that lists all company clients in order by state of residence, with a count of clients after each state's client list. See Figure 7-1 for an example of a report that breaks after each change in state.

FIGURE 7-1: A CONTROL BREAK REPORT WITH TOTALS AFTER EACH STATE

```
Company Clients by State of Residence

Name                    City                    State

Albertson               Birmingham              Alabama
Davis                   Birmingham              Alabama
Lawrence                Montgomery              Alabama
                                                Count for Alabama    3

Smith                   Anchorage               Alaska
Young                   Anchorage               Alaska
Davis                   Fairbanks               Alaska
Mitchell                Juneau                  Alaska
Zimmer                  Juneau                  Alaska
                                                Count for Alaska     5

Edwards                 Phoenix                 Arizona
                                                Count for Arizona    1
```

Some other examples of control break reports produced by control break programs include:

- All employees listed in order by department number, with a new page started for each department
- All books for sale in a bookstore in order by category (such as reference or self-help), with a count following each category of book
- All items sold in order by date of sale, with a different ink color for each new month

Each of these reports shares two traits:

- The records used in each report are listed in order by a specific variable: department, state, category, or date.
- When that variable changes, the program takes special action: starts a new page, prints a count or total, or switches ink color.

To generate a control break report, your input records must be organized in sequential order based on the field that will cause the breaks. In other words, if you are going to write a program that produces a report that lists customers by state, like the one in Figure 7-1, then the records must be grouped by state before you begin processing. Frequently, grouping by state will mean placing the records in alphabetical order by state, although they could just as easily be placed in order by population, governor's last name, or any other factor as long as all of one state's records are together. As you grow more proficient in programming logic, you will learn techniques for writing programs that sort records before you proceed with creating a program that contains control break logic. Programs that **sort** records take records that are not in order and rearrange them to be in order, according to the data in some field. For now, assume that a sorting program has already been used to presort your records before you begin the part of a program that determines control breaks.

TIP To use control break logic, either the records must arrive already in order in the input file or you must sort the records yourself. You will learn techniques for processing unsorted records in Chapter 8. In Chapter 9, you will learn to sort records. It is easier to work with sorted records than unsorted ones, so you are learning the easier techniques first.

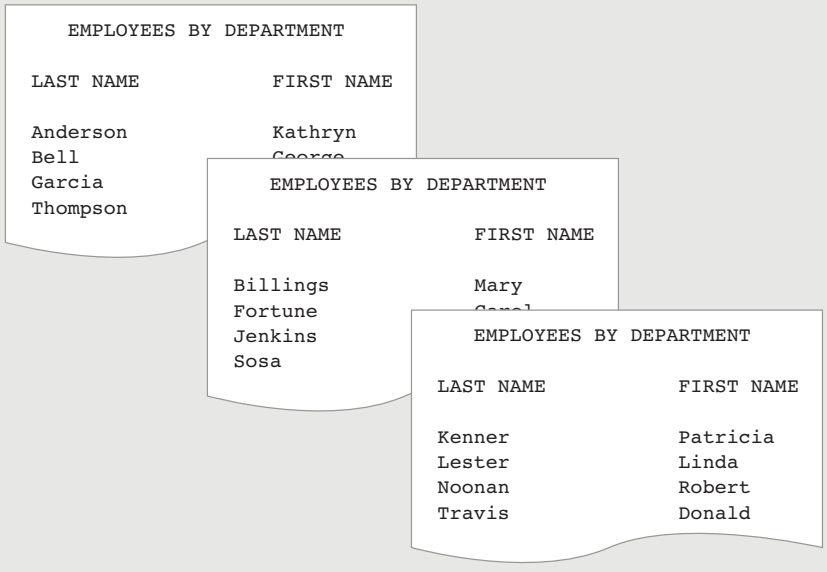
PERFORMING A SINGLE-LEVEL CONTROL BREAK TO START A NEW PAGE

Suppose you want to print a list of employees, advancing to a new page for each department. Figure 7-2 shows the input file description, from which you can see that the employee department is a numeric field, and that the file has been presorted so that the records will arrive in a program in department-number order. Figure 7-3 shows a sample report with the desired output—a simple list of employee names, with one department per page.

FIGURE 7-2: EMPLOYEE FILE DESCRIPTION

```
File name: EMPSBYDEPT
Sorted by: Department
FIELD DESCRIPTION        DATA TYPE     COMMENTS
Department               Numeric       0 decimals
Last Name                Character     15 characters
First Name               Character     15 characters
```

FIGURE 7-3: SAMPLE CONTROL BREAK REPORT LISTING EMPLOYEES, WITH EACH DEPARTMENT ON A NEW PAGE



TIP In the report in Figure 7-3, each new page contains employees from a new department. Later in this chapter, department numbers will be added to the headings, making this point clearer to those who read the report.

The basic logic of the program works like this: Each time you read an employee record from the input file, you will determine whether the employee belongs to the same department as the previous employee. If so, you simply print the employee record and read another record, without any special processing. If there are 20 employees in a department, these steps are repeated 20 times in a row—read an employee record and print the employee record. However, eventually you will read an employee record that does not belong to the same department. At that point, before you print the employee record from the new department, you must print headings at the top of a new page. Then, you can proceed to read and print employee records that belong to the new department, and you continue to do so until the next time you encounter an employee in a different department. This type of program contains a **single-level control break**, a break in the logic of the program (pausing or detouring to print new headings) that is based on the value of a single variable (the department number).

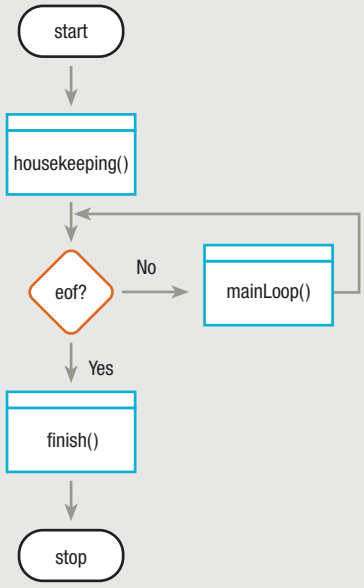
However, there is a slight problem you must solve before you can determine whether a new input record contains the same department number as the previous input record. When you read a record from an input file, you copy the data from storage locations (for example, from a disk) to temporary computer memory locations. After they are read, the data items that represent department, last name, and first name occupy specific physical locations in computer memory. For each new record that is read from storage, new data must occupy the same positions in memory as the previous record occupied, and the previous set of data is lost. For example, if you read a record containing data for Donald Travis in Department 1, when you read the next record for Mary Billings in Department 2, “Mary” replaces “Donald”, “Billings” replaces “Travis”, and 2 replaces 1. After you read a new record into memory, there is no way to look back at the

previous record to determine whether that record had a different department number. The previous record's data has been replaced in memory by the new record's data.

The technique you must use to "remember" the old department number is to create a special variable, called a **control break field**, to hold the previous department number. With a control break field, every time you read a record and print it, you also can save the crucial part of the record that will signal the change or control the program break. In this case, you want to store the department number in this specially created variable. Comparing the new and old department-number values will determine when it is time to print headings at the top of a new page.

The mainline logic for the Employees by Department report is the same as the mainline logic for all the other programs you've analyzed so far. It performs a `housekeeping()` module, after which an `eof` question controls execution of a `mainLoop()` module. At `eof`, a `finish()` module executes. See Figure 7-4.

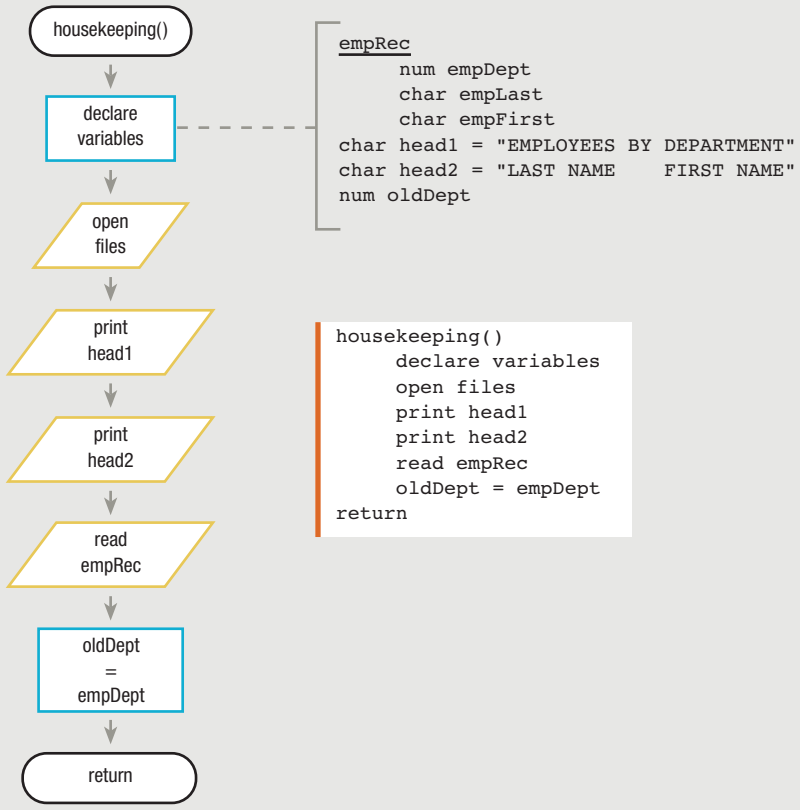
FIGURE 7-4: MAINLINE LOGIC FOR EMPLOYEES BY DEPARTMENT REPORT PROGRAM




```
start
     perform housekeeping()
     while not eof
          perform mainLoop()
     endwhile
     perform finish()
stop
```

The `housekeeping()` module for this program begins like others you have seen. You declare variables as shown in Figure 7-5, including those you will use for the input data: `empDept`, `empLast`, and `empFirst`. You can also declare variables to hold the headings, and an additional variable that is named `oldDept` in this example. The purpose of `oldDept` is to serve as the control break field. Every time you read a record from a new department, you can save its department number in `oldDept` before you read the next record. The `oldDept` field provides you with a comparison for each new department so you can determine whether there has been a change in value.

FIGURE 7-5: THE `housekeeping()` MODULE FOR EMPLOYEES BY DEPARTMENT REPORT PROGRAM



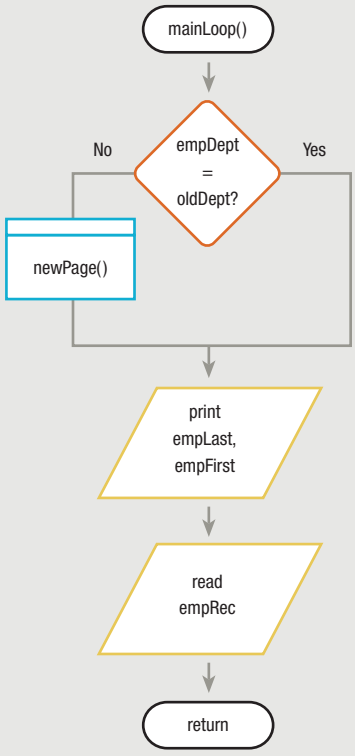
Note that it would be incorrect to initialize `oldDept` to the value of `empDept` when you declare `oldDept` in the `housekeeping()` module. When you declare variables at the beginning of the `housekeeping()` module, you have not yet read the first record; therefore, `empDept` does not yet have any usable value. You use the value of the first `empDept` variable at the end of the module, only after you read the first input record.

In the `housekeeping()` module, after declaring variables, you also open files, print headings, and read the first input record. Before you leave the `housekeeping()` module, you can set the `oldDept` variable to equal the `empDept` value in the first input record. You will write the `mainLoop()` module of the program to check for any change in department number; that's the signal to print headings at the top of a new page. Because you just printed headings and read the first record, you do not want to print headings again for this first record, so you want to ensure that `empDept` and `oldDept` are equal when you enter `mainLoop()`.

TIP As an alternative to the `housekeeping()` logic shown here, you can remove printing headings from the `housekeeping()` module and set `oldDept` to any impossible value—for example, –1. Then, in `mainLoop()`, the first record will force the control break, and the headings will print in the `newPage()` control break routine.

The first task within the `mainLoop()` module is to check whether `empDept` holds the same value as `oldDept`. For the first record, on the first pass through `mainLoop()`, the values are equal; you set them to be equal in the `housekeeping()` module. Therefore, you proceed without performing the `newPage()` module, printing the first employee's record and reading a second record. At the end of the `mainLoop()` module, shown in Figure 7-6, the logical flow returns to the mainline logic, shown in Figure 7-4. If it is not `eof`, the flow travels back into the `mainLoop()` module. There, you compare the second record's `empDept` to `oldDept`. If the second record holds an employee from the same department as the first employee, then you simply print that second employee's record and read a third record into memory. As long as each new record holds the same `empDept` value, you continue reading and printing, never pausing to perform the `newPage()` module.

FIGURE 7-6: THE `mainLoop()` MODULE FOR EMPLOYEES BY DEPARTMENT REPORT PROGRAM




```
mainLoop()
     if empDept not = oldDept then
          perform newPage()
     endif
     print empLast, empFirst
     read empRec
return
```

TIP

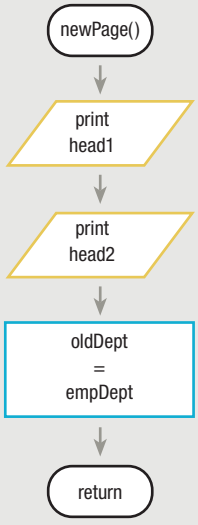
In the flowchart in Figure 7-6, you could change the decision to `empDept not = oldDept`. Then, the Yes branch of the decision structure would perform the `newPage()` module, and the No branch would be null. This format would more closely resemble the pseudocode in Figure 7-6, but the logic would be identical to the version shown here. In other words, you perform `newPage()` when `empDept = oldDept` is false or when `empDept not = oldDept` is true.

Eventually, you will read in an employee whose `empDept` is not the same as `oldDept`. That's when the control break routine, `newPage()`, executes. The `newPage()` module must perform two tasks:

- It must print headings at the top of a new page.
- It must update the control break field.

Figure 7-7 shows the `newPage()` module.

FIGURE 7-7: THE `newPage()` MODULE FOR EMPLOYEES BY DEPARTMENT REPORT PROGRAM




```
newPage()
      print head1
      print head2
      oldDept = empDept
return
```

TIP Notice that the steps in the `newPage()` module mimic steps in the `housekeeping()` module. You take advantage of this coincidence later in this chapter.

TIP In Chapter 4, you learned that specific programming languages each provide you with a means to physically advance printer paper to the top of a page. Usually, you insert a language-specific code just before the first character in the first heading that will appear on a page. For this book, if a sample report or print chart shows a heading printing at the top of the page, then you can assume that printing the heading causes the paper in the printer to advance to the top of a new page. The appropriate language-specific codes can be added when you code the program.

When you read an employee record in which `empDept` is not the same as `oldDept`, you cause a break in the normal flow of the program. The new employee record must "wait" while headings print and the control break field `oldDept` acquires a new value. After the `oldDept` field has been updated, and before the `mainLoop()` module ends, the waiting employee record prints on the new page. When you read the *next* employee record (and it is not `eof`), the `mainLoop()` module is reentered and the next employee's `empDept` field is compared to the updated `oldDept` field. If the new employee works in the same department as the one just preceding, then normal processing continues with the print-and-read statements.

The `newPage()` module in the employee report program performs two tasks required in all control break modules:

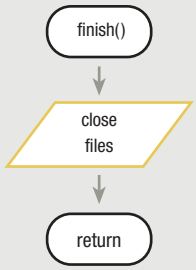
- It performs any necessary processing for the new group—in this case, it prints headings.
- It updates the control break field—in this case, the `oldDept` field.

TIP

As an alternative to updating the control break field within the control break routine, you could set `oldDept` equal to `empDept` just before you read each record. However, if there are 200 employees in Department 55, then you set `oldDept` to the same value 200 times. It's more efficient to set `oldDept` to a different value only when there is a change in the value of the department.

The `finish()` module for the Employees by Department report program requires only that you close the files. See Figure 7-8.

FIGURE 7-8: THE `finish()` MODULE FOR EMPLOYEES BY DEPARTMENT REPORT PROGRAM

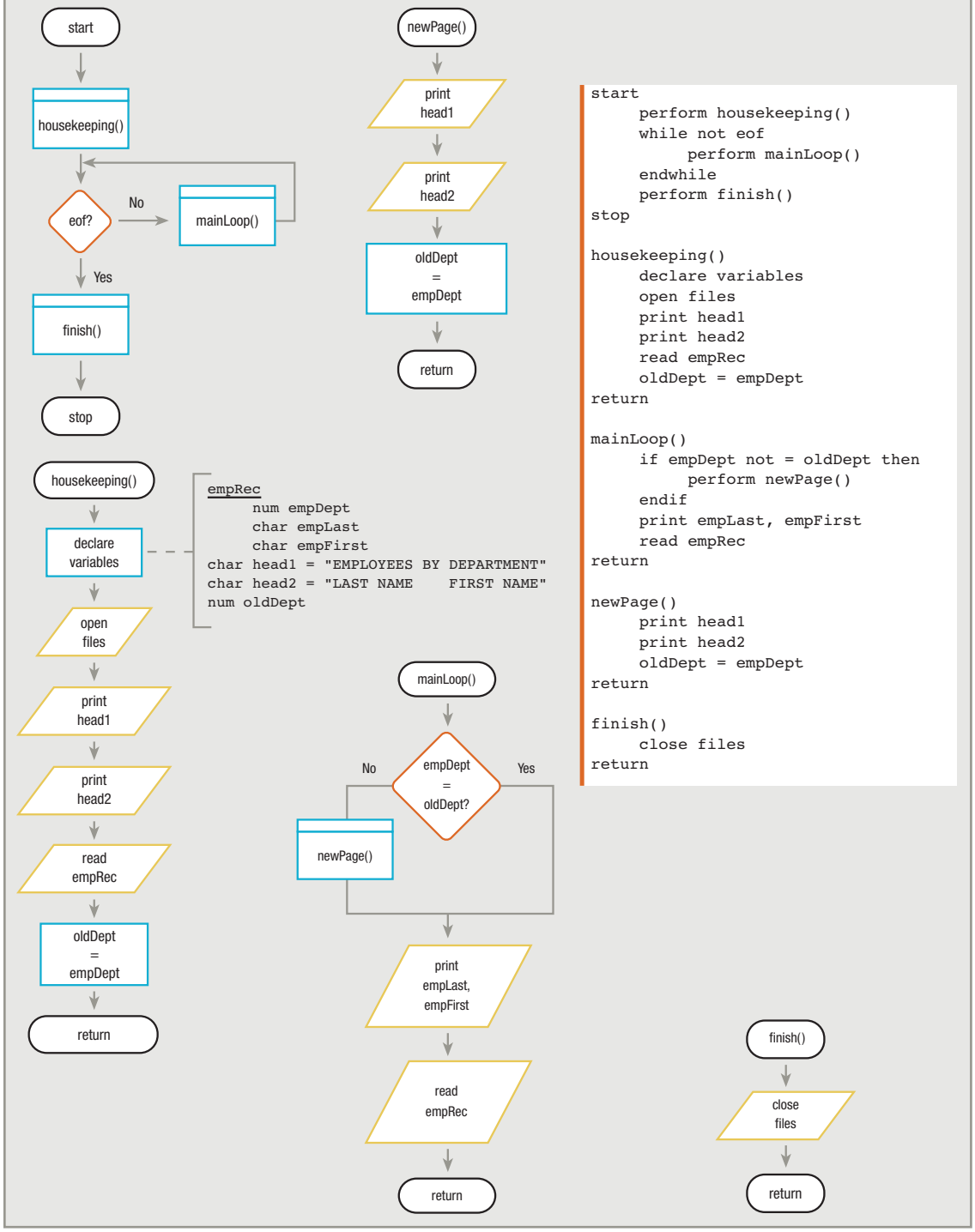



```
finish()
     close files
return
```

Notice that in the control break program described in Figures 7-4 through 7-8, the department numbers of employees in the input file do not have to follow each other incrementally. That is, the departments might be 1, 2, 3, and so on, but they also might be 1, 4, 12, 35, and so on. A control break occurs when there is a change in the control break field; the change does not necessarily have to be a numeric change of 1.

Figure 7-9 shows the entire Employees by Department control break program.

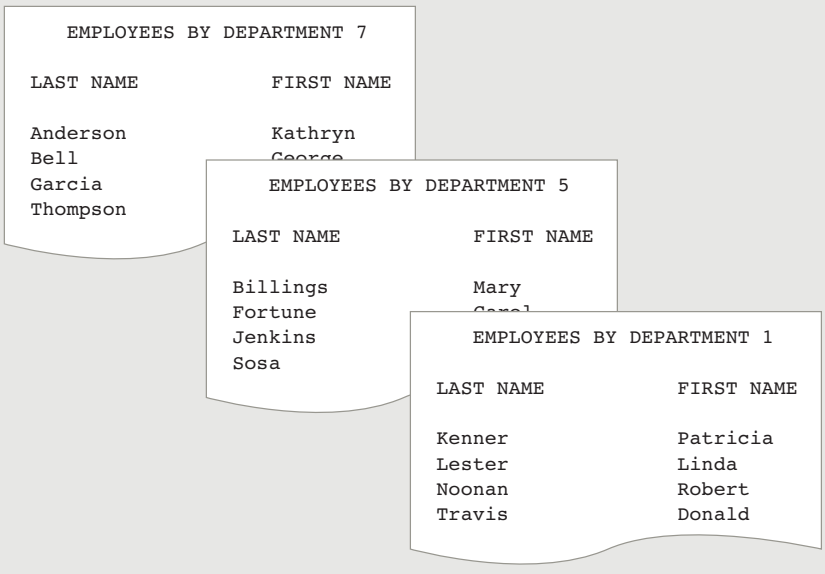
FIGURE 7-9: THE EMPLOYEES BY DEPARTMENT CONTROL BREAK PROGRAM



USING CONTROL DATA WITHIN A HEADING IN A CONTROL BREAK MODULE

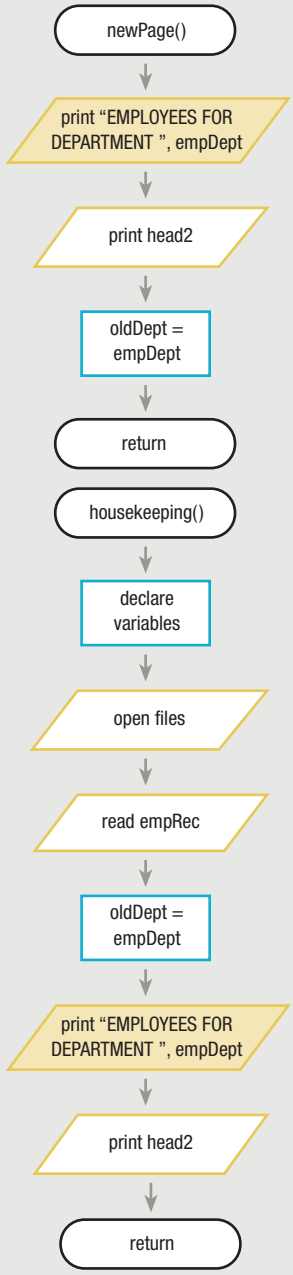
In the Employees by Department report program example in Figure 7-9, the control break module printed constant headings at the top of each new page; in other words, each page heading was the same. However, sometimes you need to use control data within the heading. For example, consider the sample report shown in Figure 7-10.

FIGURE 7-10: SAMPLE REPORT FOR EMPLOYEES BY DEPARTMENT IN WHICH DEPARTMENT NUMBERS APPEAR IN THE HEADING



The difference between Figure 7-3 and Figure 7-10 lies in the heading. Figure 7-10 shows variable data in the heading—a different department number prints at the top of each page of employees. To create this kind of program, you must make two changes in the existing program. First, you modify the `newPage()` module, as shown in Figure 7-11. Instead of printing a fixed heading on each new page, you print a heading that contains two parts: a constant beginning ("EMPLOYEES FOR DEPARTMENT") and a variable ending (the department number for the employees who appear on the page). Notice that you use the `empDept` number that belongs to the employee record that is waiting to be printed while this control break module executes. Additionally, you must modify the `housekeeping()` module to ensure that the first heading on the report prints correctly. As Figure 7-11 shows, you must modify the `housekeeping()` module from Figure 7-5 so that you read the first `empRec` prior to printing the headings. The reason is that you must know the first employee's department number before you can print the heading for the top of the first page.

FIGURE 7-11: MODIFIED `newPage()` AND `housekeeping()` MODULES FOR EMPLOYEES BY DEPARTMENT REPORT THAT DISPLAYS THE DEPARTMENT NUMBER IN THE HEADING




```
newPage()
     print "EMPLOYEES FOR
          DEPARTMENT ", empDept
     print head2
     oldDept = empDept
return
```

```
housekeeping()
     declare variables
     open files
     read empRec
     oldDept = empDept
     print "EMPLOYEES FOR
          DEPARTMENT ", empDept
     print head2
return
```

USING CONTROL DATA WITHIN A FOOTER IN A CONTROL BREAK MODULE

In the previous section, you learned how to use control break data in a heading. Figure 7-12 shows a different report format. For this report, the department number prints *following* the employee list for the department. A message that prints at the end of a page or other section of a report is called a **footer**. Headings usually require information about the *next* record; footers usually require information about the *previous* record.

FIGURE 7-12: SAMPLE REPORT FOR EMPLOYEES BY DEPARTMENT IN WHICH DEPARTMENT NUMBERS APPEAR IN THE FOOTER

```
    EMPLOYEES BY DEPARTMENT

LAST NAME            FIRST NAME

Anderson             Kathryn
Bell                 George
Garcia               Maria
Thompson             Olivia

END OF DEPARTMENT 7
```

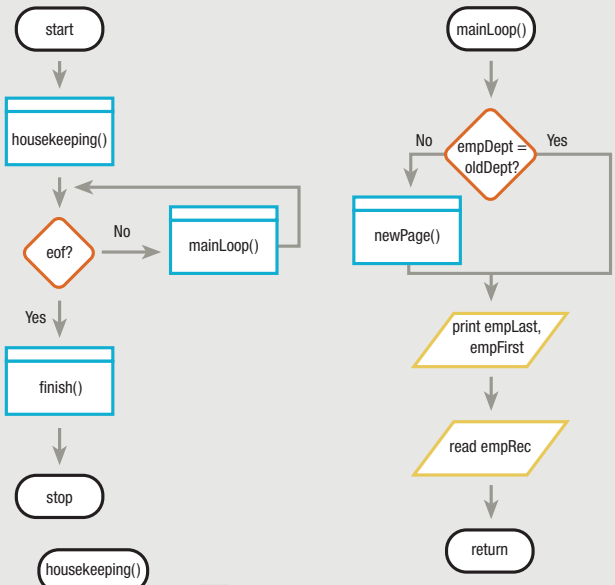
```
    EMPLOYEES BY DEPARTMENT

LAST NAME            FIRST NAME

Billings             Mary
Fortune              Carol
Jenkins              Justin
Sosa                 Charles

END OF DEPARTMENT 5
```

```
    EMPLOYEES BY DEPARTMENT

LAST NAME            FIRST NAME

Kenner               Patricia
Lester               Linda
Noonan               Robert
Travis               Donald

END OF DEPARTMENT 1
```

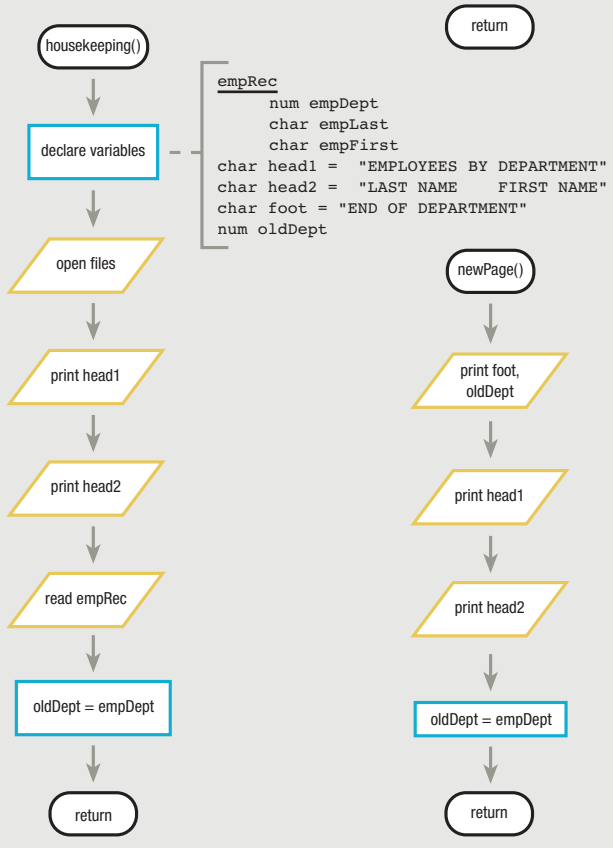
Figure 7-13 shows a program that prints a list of employees by department, including a footer that displays the department number at the end of each department's list. When you write a program that produces the report like the one shown in Figure 7-12, you continuously read records with `empLast`, `empFirst`, and `empDept` fields. Each time `empDept` does not equal `oldDept`, it means that you have reached a department break and that you should perform the `newPage()` module. The `newPage()` module has three tasks:

- It must print the footer for the previous department at the bottom of the employee list.
- It must print headings at the top of a new page.
- It must update the control break field.

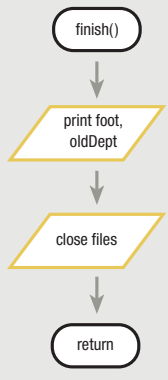
FIGURE 7-13: PROGRAM THAT LISTS EMPLOYEES BY DEPARTMENT, INCLUDING DEPARTMENT NUMBER IN THE FOOTER




```
start
     perform housekeeping()
     while not eof
          perform mainLoop()
     endwhile
     perform finish()
stop



housekeeping()
     declare variables
     open files
     print head1
     print head2
     read empRec
     oldDept = empDept
return

mainLoop()
     if empDept not = oldDept then
          perform newPage()
     endif
     print empLast, empFirst
     read empRec
return

newPage()
     print foot, oldDept
     print head1
     print head2
     oldDept = empDept
return

finish()
     print foot, oldDept
     close files
return
```




```
empRec
     num empDept
     char empLast
     char empFirst
char head1 =  "EMPLOYEES BY DEPARTMENT"
char head2 =  "LAST NAME    FIRST NAME"
char foot = "END OF DEPARTMENT"
num oldDept
```

When the `newPage()` module prints the footer at the bottom of the old page, you must use the `oldDept` number. For example, assume you have printed several employees from Department 12. When you read a record with an employee from Department 13 (or any other department), the first thing you must do is print "END OF DEPARTMENT 12". You print the correct department number by accessing the value of `oldDept`, not `empDept`. Then, you can print the other headings at the top of a new page and update `oldDept` to the current `empDept`, which in this example is 13.

The `newPage()` module in Figure 7-13 performs three tasks required in all control break routines: it processes the previous group, processes the new group, and updates the control break field.

When you printed the department number in the header in the example in the previous section, you needed a special step in the `housekeeping()` module. When you print the department number in the footer, the `finish()` module requires an extra step. Imagine that the last five records in the input file include two employees from Department 78, Amy and Bill, and three employees from Department 85, Carol, Don, and Ellen. The logical flow proceeds as follows:

1. After the first Department 78 employee (Amy) prints, you read the second Department 78 employee (Bill).
2. At the top of the `mainLoop()` module, Bill's department is compared to `oldDept`. The departments are the same, so the second Department 78 employee (Bill) is printed. Then, you read the first Department 85 employee (Carol).
3. At the top of `mainLoop()`, Carol's `empDept` and `oldDept` are different, so you perform the `newPage()` module while Carol's record waits in memory.
4. In the `newPage()` module, you print "END OF DEPARTMENT 78". Then, you print headings at the top of the next page. Finally, you set `oldDept` to 85, and then return to `mainLoop()`.
5. Back in `mainLoop()`, you print a line of data for the first Department 85 employee (Carol), whose record waited while `newPage()` executed. Then, you read the record for the second Department 85 employee (Don).
6. At the top of `mainLoop()`, you compare Don's department number to `oldDept`. The numbers are the same, so you print Don's employee data and read in the last Department 85 employee (Ellen).
7. At the top of `mainLoop()`, you determine that Ellen has the same department number, so you print Ellen's data and attempt to read from the input file, where you encounter `eof`.
8. The `eof` decision in the mainline logic sends you to the `finish()` module.

You have printed the last Department 85 employee (Ellen), but the department footer for Department 85 has not printed. That's because every time you attempt to read an input record, you don't know whether there will be more records. The mainline logic checks for the `eof` condition, but if it determines that it is `eof`, the logic does not flow back into the `mainLoop()` module, where the `newPage()` module can execute.

To print the footer for the last department, you must print a footer one last time within the `finish()` routine. The `finish()` module that is part of the complete program in Figure 7-13 illustrates this point. Taking this action is similar to printing the first heading in the `housekeeping()` module. The very first heading prints separately from all the others at the beginning; the very last footer must print separately from all the others at the end.

PERFORMING CONTROL BREAKS WITH TOTALS

Suppose you run a bookstore, and one of the files you maintain is called BOOKFILE, which has one record for every book title that you carry. Each record has fields such as `bookTitle`, `bookAuthor`, `bookCategory` (fiction, reference, self-help, and so on), `bookPublisher`, and `bookPrice`, as shown in the file description in Figure 7-14.

FIGURE 7-14: BOOKFILE FILE DESCRIPTION

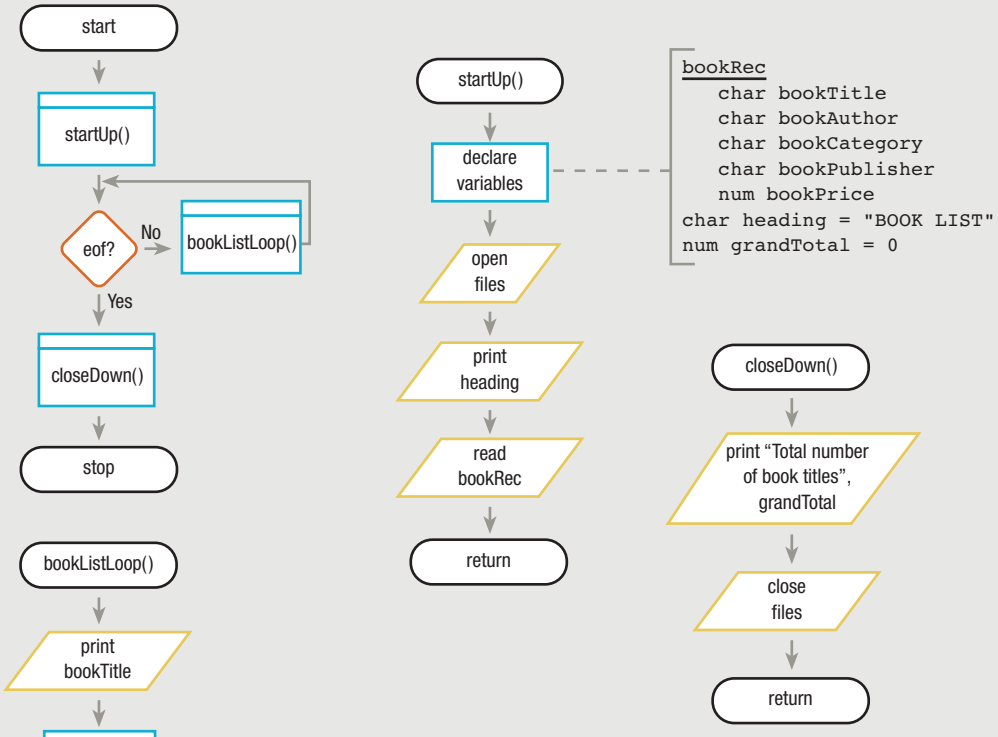
```
File name: BOOKFILE
Sorted by: Category
FIELD DESCRIPTION       DATA TYPE          COMMENTS
Title                   Character          30 characters
Author                  Character          15 characters
Category                Character          15 characters
Publisher               Character          15 characters
Price                   Numeric            2 decimals
```

Suppose you want to print a list of all the books that your store carries, with a total number of books at the bottom of the list, as shown in the sample report in Figure 7-15. You can use the logic shown in Figure 7-16. In the main loop module, named `bookListLoop()`, you print a book title, add 1 to `grandTotal`, and read the next record. At the end of the program, in the `closeDown()` module, you print `grandTotal` before you close the files. You can't print `grandTotal` any earlier in the program because the `grandTotal` value isn't complete until the last record has been read.

FIGURE 7-15: SAMPLE BOOK LIST REPORT

```
BOOK LIST

A Brief History of Time
The Scarlet Letter
Math Magic
She's Come Undone
The Joy of Cooking
Walden
A Bridge Too Far
The Time Traveler's Wife
The DaVinci Code

Programming Logic and Design
Forever Amber

Total number of book titles  512
```

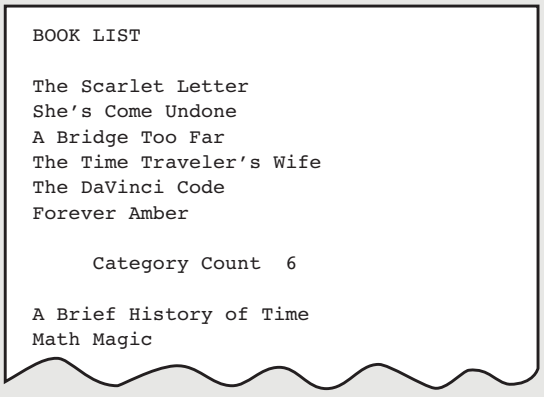
FIGURE 7-16: FLOWCHART AND PSEUDOCODE FOR BOOKSTORE PROGRAM




```
start
   perform startUp()
   while not eof
      perform bookListLoop()
   endwhile
   perform closeDown()
stop

startUp()
   declare variables
   open files
   print heading
   read bookRec
return

bookListLoop()
   print bookTitle
   grandTotal = grandTotal + 1
   read bookRec
return

closeDown()
   print "Total number of book titles", grandTotal
   close files
return
```

The logic of the book list report program is pretty straightforward. Suppose, however, that you decide you want a count for each category of book rather than just one grand total. For example, if all the book records contain a category that is either fiction, reference, or self-help, then the book records might be sorted in alphabetical order by category, and the output would consist of a list of all fiction books first, followed by a count; then all reference books, followed by a count; and finally all self-help books, followed by a count. The report is a control break report, and the control break field is `bookCategory`. See Figure 7-17 for a sample report.

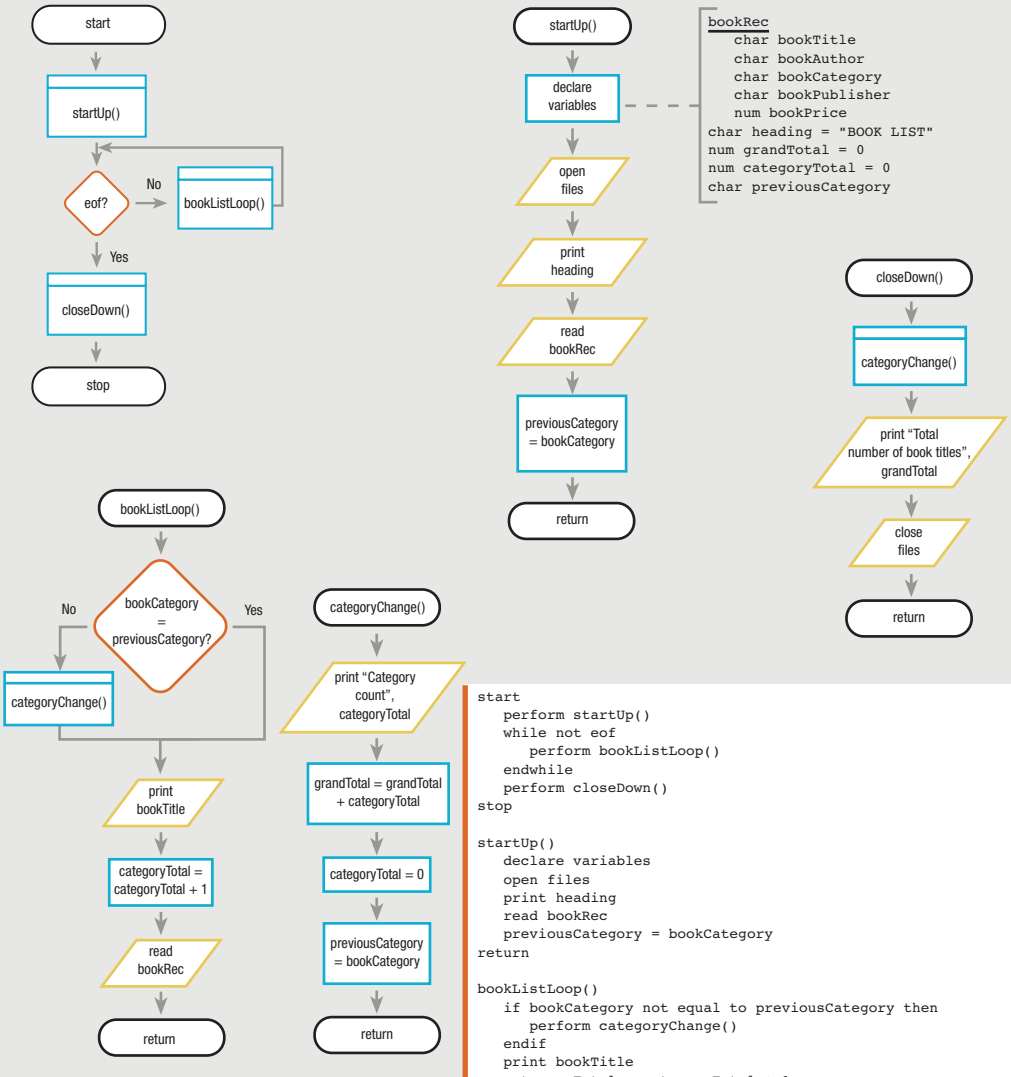
FIGURE 7-17: SAMPLE REPORT LISTING BOOKS BY CATEGORY WITH CATEGORY COUNTS



```
BOOK LIST

The Scarlet Letter
She's Come Undone
A Bridge Too Far
The Time Traveler's Wife
The DaVinci Code
Forever Amber

     Category Count  6

A Brief History of Time
Math Magic
```

To produce the report with subtotals by category, you must declare two new variables: `previousCategory` and `categoryTotal`. Every time you read a book record, you compare `bookCategory` to `previousCategory`; when there is a category change, you print the count of books for the previous category. The `categoryTotal` variable holds that count. See Figure 7-18.

FIGURE 7-18: FLOWCHART AND PSEUDOCODE FOR BOOKSTORE PROGRAM CONTAINING A COUNT AFTER EACH BOOK CATEGORY GROUP




```
start
   perform startUp()
   while not eof
      perform bookListLoop()
   endwhile
   perform closeDown()
stop

startUp()
   declare variables
   open files
   print heading
   read bookRec
   previousCategory = bookCategory
return

bookListLoop()
   if bookCategory not equal to previousCategory then
      perform categoryChange()
   endif
   print bookTitle
   categoryTotal = categoryTotal + 1
   read bookRec
return

categoryChange()
   print "Category count", categoryTotal
   grandTotal = grandTotal + categoryTotal
   categoryTotal = 0
   previousCategory = bookCategory
return

closeDown()
   perform categoryChange()
   print "Total number of book titles", grandTotal
   close files
return
```

TIP When you draw a flowchart, it usually is clearer to ask questions positively, as in "`bookCategory = previousCategory?`", and draw appropriate actions on the Yes or No side of a decision. In pseudocode, when action occurs only on the No side of a decision, it is usually clearer to ask negatively, as in "`bookCategory not equal to previousCategory?`" Figure 7-18 uses these tactics.

When you read the first record from the input file in the `startUp()` module of the program in Figure 7-18, you save the value of `bookCategory` in the `previousCategory` variable. Every time a record enters the `bookListLoop()` module, the program checks to see if the current record represents a new category of work, by comparing `bookCategory` to `previousCategory`. When you process the first record, the categories match, so the book title prints, the `categoryTotal` increases by 1, and you read the next record. If this next record's `bookCategory` value matches the `previousCategory` value, processing continues as usual: printing a line and adding 1 to `categoryTotal`.

At some point, `bookCategory` for an input record does not match `previousCategory`. At that point, you perform the `categoryChange()` module. Within the `categoryChange()` module, you print the count of the previous category of books. Then, you add `categoryTotal` to `grandTotal`. Adding a total to a higher-level total is called **rolling up the totals**.

You could write `bookListLoop()` so that as you process each book, you add 1 to `categoryTotal` and add 1 to `grandTotal`. Then, there would be no need to roll totals up in the `categoryChange()` module. If there are 120 fiction books, you add 1 to `categoryTotal` 120 times; you also would add 1 to `grandTotal` 120 times. This technique would yield correct results, but you can eliminate executing 119 addition instructions by waiting until you have accumulated all 120 category counts before adding the total figure to `grandTotal`.

This control break report containing totals performs the five tasks required in all control break routines that include totals:

- It performs any necessary processing for the previous group—in this case, it prints `categoryTotal`.
- It rolls up the current-level totals to the next higher level—in this case, it adds `categoryTotal` to `grandTotal`.
- It resets the current level's totals to zero—in this case, `categoryTotal` is set to zero.
- It performs any necessary processing for the new group—in this case, there is none.
- It updates the control break field—in this case, `previousCategory`.

The `closeDown()` routine for this type of program is more complicated than it might first appear. It seems as though you should print `grandTotal`, close the files, and return to the mainline logic. However, when you read the last record, the mainline `eof` decision sends the logical flow to the `closeDown()` routine. You have not printed the last `categoryTotal`, nor have you added the count for the last category to `grandTotal`. You must take care of both these tasks before printing `grandTotal`. You can perform these two tasks as separate steps in `closeDown()`, but it is often simplest just to remember to perform the control break routine `categoryChange()` one last time. The `categoryChange()` module already executes after every previous category completes—that is, every time you encounter a new category during the execution of the program. You also

can execute this module after the final category completes, at the end of the file. Encountering the end of the file is really just another form of break; it signals that the last category has finally completed. The `categoryChange()` module prints the category total and rolls the totals up to the `grandTotal` level.

TIP

When you call the `categoryChange()` module from within `closeDown()`, it performs a few tasks you don't need, such as setting the value of `previousCategory`. You have to weigh the convenience of calling the already-written `categoryChange()` module, and executing a few unneeded statements, against taking the time to write a new module that would execute only the statements that are absolutely necessary.

It is very important to note that this control break program works whether there are three categories of books or 300. Note further that it does not matter what the categories of books are. For example, the program never asks `bookCategory = "fiction"?`. Instead, the control of the program breaks when the category field *changes*, and it is in no way dependent on *what* that change is.

PERFORMING MULTIPLE-LEVEL CONTROL BREAKS

Let's say your bookstore from the last example is so successful that you have a chain of them across the country. Every time a sale is made, you create a record with the fields `bookTitle`, `bookPrice`, `bookCity`, and `bookState`. You want a report that prints a summary of books sold in each city and each state, similar to the one shown in Figure 7-19. A report such as this one, which does not include any information about individual records, but instead includes only group totals, is a **summary report**.

This program contains a **multiple-level control break**—that is, the normal flow of control (reading records and counting book sales) breaks away to print totals in response to more than just one change in condition. In this report, a control break occurs in response to either (or both) of two conditions: when the value of the `bookCity` variable changes, as well as when the value of the `bookState` variable changes.

Just as the file you use to create a single-level control break report must be presorted, so must the input file you use to create a multiple-level control break report. The input file that you use for the book sales report must be sorted by `bookCity` *within* `bookState`. That is, all of one state's records—for example, all records from IA—come first; then all of the records from another state, such as IL, follow. Within any one state, all of one city's records come first; then all of the next city's records follow. For example, the input file that produces the report shown in Figure 7-19 contains 200 records for book sales in Ames, IA, followed by 814 records for book sales in Des Moines, IA. The basic processing entails reading a book sale record, adding 1 to a counter, and reading the next book sale record. At the end of any city's records, you print a total for that city; at the end of a state's records, you print a total for that state.

FIGURE 7-19: SAMPLE RUN OF BOOK SALES BY CITY AND STATE REPORT

```
BOOK SALES BY CITY AND STATE

Ames                                 200
Des Moines                           814
Iowa City                            291
     Total for IA                   1305
Chicago                             1093
Crystal Lake                         564
McHenry                              213
Springfield                          365
     Total for IL                   2235
Springfield                          289
Worcester                            100
     Total for MA                    389
     Grand Total                    3929
```

The `housekeeping()` module of the Book Sales by City and State report program looks similar to the `housekeeping()` module in the previous control break program, in which there was a single control break for change in category of book. In each program, you declare variables, open files, and read the first record. This time, however, there are multiple fields to save and compare to the old fields. Here, you declare two special variables, `prevCity` and `prevState`, as shown in Figure 7-20. In addition, the Book Sales report shows three kinds of totals, so you declare three new variables that will serve as holding places for the totals in the Book Sales report: `cityCounter`, `stateCounter`, and `grandTotal`, which are all initialized to zero.

FIGURE 7-20: FLOWCHART AND PSEUDOCODE FOR `housekeeping()` MODULE IN BOOK SALES BY CITY AND STATE REPORT PROGRAM

This program prints both `bookState` and `bookCity` totals, so you need two control break modules, `cityBreak()` and `stateBreak()`. Every time there is a change in the `bookCity` field, the `cityBreak()` routine performs these standard control break tasks:

- It performs any necessary processing for the previous group—in this case, it prints totals for the previous city.
- It rolls up the current-level totals to the next higher level—in this case, it adds the city count to the state count.
- It resets the current level's totals to zero—in this case, it sets the city count to zero.
- It performs any necessary processing for the new group—in this case, there is none.
- It updates the control break field—in this case, it sets `prevCity` to `bookCity`.

Within the `stateBreak()` module, you must perform one new type of task, as well as the control break tasks you are familiar with. The new task is the first task: Within the `stateBreak()` module, you must first perform

`cityBreak()` automatically (because if there is a change in the state, there must also be a change in the city). The `stateBreak()` module does the following:

- It processes the lower-level break—in this case, `cityBreak()`.
- It performs any necessary processing for the previous group—in this case, it prints totals for the previous state.
- It rolls up the current-level totals to the next higher level—in this case, it adds the state count to the grand total.
- It resets the current level's totals to zero—in this case, it sets the state count to zero.
- It performs any necessary processing for the new group—in this case, there is none.
- It updates the control break field—in this case, it sets `prevState` to `bookState`.

The `mainLoop()` module of this multiple-level control break program checks for any change in two different variables: `bookCity` and `bookState`. When `bookCity` changes, a city total is printed, and when `bookState` changes, a state total is printed. As you can see from the sample report in Figure 7-19, all city totals for each state print before the state total for the same state, so it might seem logical to check for a change in `bookCity` before checking for a change in `bookState`. However, the opposite is true. For the totals to be correct, you must check for any `bookState` change first. You do so because when `bookCity` changes, `bookState` also *might* be changing, but when `bookState` changes, it means `bookCity` *must* be changing.

Consider the sample input records shown in Figure 7-21, which are sorted by `bookCity` within `bookState`. When you get to the point in the program where you read the first Illinois record (*The Scarlet Letter*), "Iowa City" is the value stored in the field `prevCity`, and "IA" is the value stored in `prevState`. Because the values in the `bookCity` and `bookState` variables in the new record are both different from the `prevCity` and `prevState` fields, both a city and state total will print. However, consider the problem when you read the first record for Springfield, MA (*Walden*). At this point in the program, `prevState` is IL, but `prevCity` is the same as the current `bookCity`; both contain Springfield. If you check for a change in `bookCity`, you won't find one at all, and no city total will print, even though Springfield, MA, is definitely a different city from Springfield, IL.

FIGURE 7-21: SAMPLE DATA FOR BOOK SALES BY CITY AND STATE REPORT

TITLE	PRICE	CITY	STATE
A Brief History of Time	20.00	Iowa City	IA
The Scarlet Letter	15.99	Chicago	IL
Math Magic	4.95	Chicago	IL
She's Come Undone	12.00	Springfield	IL
The Joy of Cooking	2.50	Springfield	IL
Walden	9.95	Springfield	MA
A Bridge Too Far	3.50	Springfield	MA

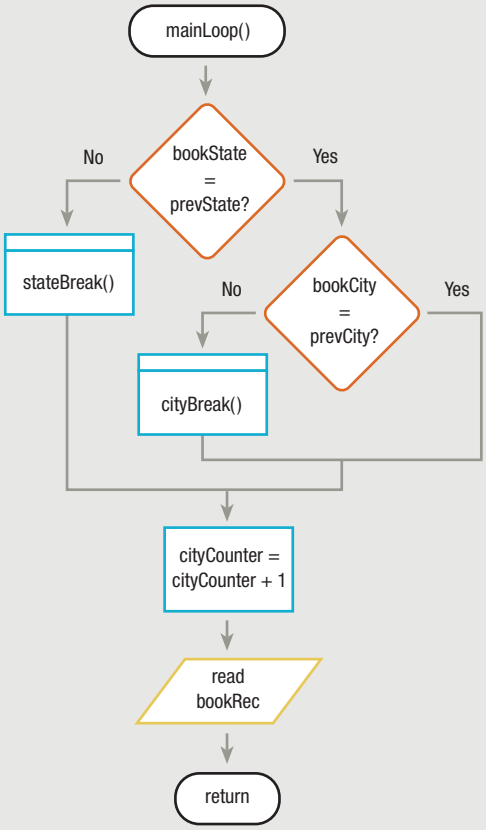
Cities in different states can have the same name; if two cities with the same name follow each other in your control break program and you have written it to check for a change in city name first, the program will not recognize that you are working with a

new city. Instead, you should always check for the major-level break first. If the records are sorted by `bookCity` within `bookState`, then a change in `bookState` causes a **major-level break**, and a change in `bookCity` causes a **minor-level break**. When the `bookState` value "MA" is not equal to the `prevState` value "IL", you force `cityBreak()`, printing a city total for Springfield, IL, before a state total for IL and before continuing with the Springfield, MA, record. You check for a change in `bookState` first, and if there is one, you perform `cityBreak()`. In other words, if there is a change in `bookState`, there is an implied change in `bookCity`, even if the cities happen to have the same name.

TIP If you needed totals to print by `bookCity` within a field defined as `bookCounty` within `bookState`, you could say you have minor-, intermediate-, and major-level breaks.

Figure 7-22 shows the `mainLoop()` module for the Book Sales by City and State report program. You check for a change in the `bookState` value. If there is no change, you check for a change in the `bookCity` value. If there is no change there either, you add 1 to the counter for the city and read the next record. When there is a change in the `bookCity` value, you print the city total and add the city total to the state total. When there is a change in the `bookState` value, you perform the break routine for the last city in the state, and then you print the state total and add it to the grand total.

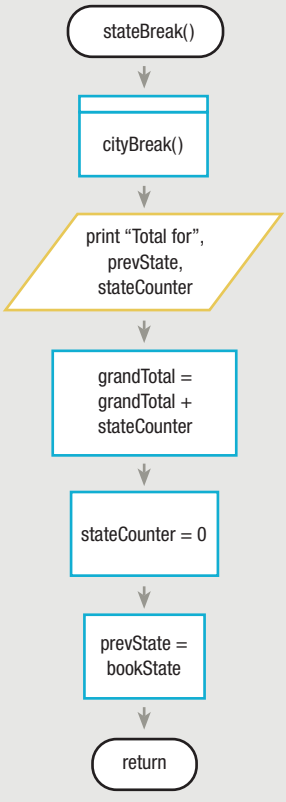
FIGURE 7-22: FLOWCHART AND PSEUDOCODE FOR `mainLoop()` FOR BOOK SALES BY CITY AND STATE REPORT PROGRAM




```
mainLoop()
     if bookState not equal prevState then
           perform stateBreak()
     else
           if bookCity not equal prevCity then
                 perform cityBreak()
           endif
     endif
     cityCounter = cityCounter + 1
     read bookRec
return
```

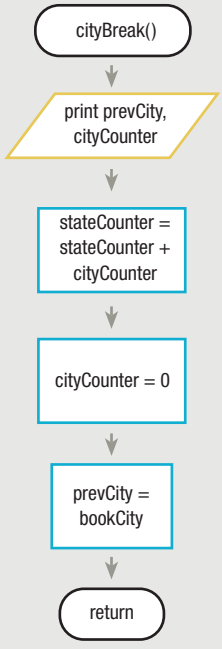
Figures 7-23 and 7-24 show the `stateBreak()` and `cityBreak()` modules. The two modules are very similar; the `stateBreak()` routine contains just one extra type of task. When there is a change in `bookState`, you perform `cityBreak()` automatically before you perform any of the other necessary steps to change states.

FIGURE 7-23: FLOWCHART AND PSEUDOCODE FOR `stateBreak()` MODULE




```
stateBreak()
      perform cityBreak()
      print "Total for", prevState, stateCounter
      grandTotal = grandTotal + stateCounter
      stateCounter = 0
      prevState = bookState
return
```

FIGURE 7-24: FLOWCHART AND PSEUDOCODE FOR `cityBreak()` MODULE



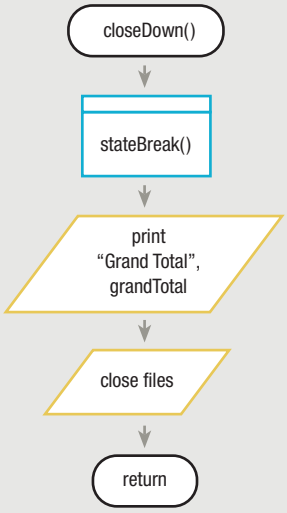

```
cityBreak()
      print prevCity, cityCounter
      stateCounter = stateCounter + cityCounter
      cityCounter = 0
      prevCity = bookCity
return
```

The sample report containing book sales by city and state shows that you print the grand total for all book sales, so within the `closeDown()` module, you must print the `grandTotal` variable. Before you can do so, however, you must perform both the `cityBreak()` and the `stateBreak()` modules one last time. You can accomplish this by performing `stateBreak()`, because the first step within `stateBreak()` is to perform `cityBreak()`.

Consider the sample data shown in Figure 7-21. While you continue to read records for books sold in Springfield, MA, you continue to add to the `cityCounter` for that city. At the moment you attempt to read one more record past the

end of the file, you do not know whether there will be more records; therefore, you have not yet printed either the `cityCounter` for Springfield or the `stateCounter` for MA. In the `closeDown()` module, you perform `stateBreak()`, which immediately performs `cityBreak()`. Within `cityBreak()`, the count for Springfield prints and rolls up to the `stateCounter`. Then, after the logic transfers back to the `stateBreak()` module, the total for MA prints and rolls up to `grandTotal`. Finally, you can print `grandTotal`, as shown in Figure 7-25.

FIGURE 7-25: FLOWCHART AND PSEUDOCODE FOR `closeDown()` MODULE




```
closeDown()
     perform stateBreak()
     print "Grand Total", grandTotal
     close files
return
```

Every time you write a program where you need control break routines, you should check whether you need to complete each of the following tasks within the modules:

- Performing the lower-level break, if any
- Performing any control break processing for the previous group
- Rolling up the current-level totals to the next higher level
- Resetting the current level's totals to zero
- Performing any control break processing for the new group
- Updating the control break field

PERFORMING PAGE BREAKS

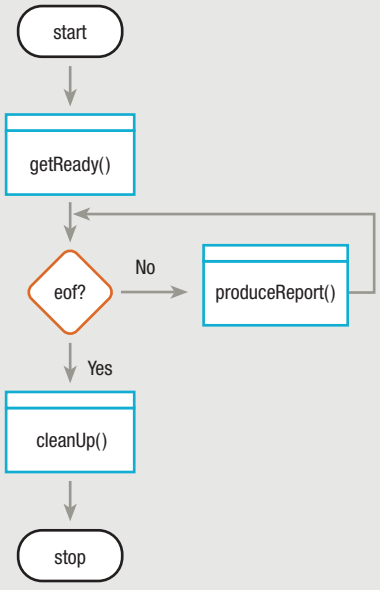
Many business programs use a form of control break logic to start a new page when a printed page fills up with output. In other words, you might want the change to a new page to be based on the number of lines already printed, rather than on the contents of an input field, such as department number. The logic in these programs involves counting the lines printed, pausing to print headings when the counter reaches some predetermined value, and then going on. This common business task is just another example of providing a break in the usual flow of control.

TIP

Some programmers may prefer to reserve the term *control break* for situations in which the break is based on the contents of one of the fields in an input record, rather than on the contents of a work field such as a line counter.

Let's say you have a file called CUSTOMERFILE containing 1000 customers, with two character fields that you have decided to call `custLast` and `custFirst`. You want to print a list of these customers, 60 detail lines to a page. The mainline logic of the program is familiar (see Figure 7-26). The only new feature is a variable called a line counter. You will use a **line-counter** variable to keep track of the number of printed lines, so that you can break to a new page after printing 60 lines.

FIGURE 7-26: MAINLINE LOGIC OF CUSTOMER REPORT PROGRAM




```
start
     perform getReady()
     while not eof
          perform produceReport()
     endwhile
     perform cleanUp()
stop
```

TIP

You first learned about detail lines in Chapter 3. Detail lines contain individual record data, as opposed to summary lines, which typically contain counts, totals, or other group information culled from multiple records.

TIP When creating a printed report, you need to clarify whether the user wants a specific number of *total* lines per page, including headings, or a specific number of *detail* lines per page following the headings. In other words, you must determine whether headings should "count" as part of the number of lines requested.

TIP Although you might require any specific number of lines per page, this example uses 60 because it represents a commonly used limit. Printing is most legible with the least waste at about six lines per inch, so 60 lines fit comfortably on standard 11-inch paper.

Within the `getReady()` module (Figure 7-27), you declare the variables, open the files, print the headings, and read the first record. Within the `produceReport()` module (Figure 7-28), you compare `lineCounter` to 60. When you process the first record, `lineCounter` is 0, so you print the record, add 1 to `lineCounter`, and read the next record.

FIGURE 7-27: THE `getReady()` MODULE FOR CUSTOMER REPORT PROGRAM

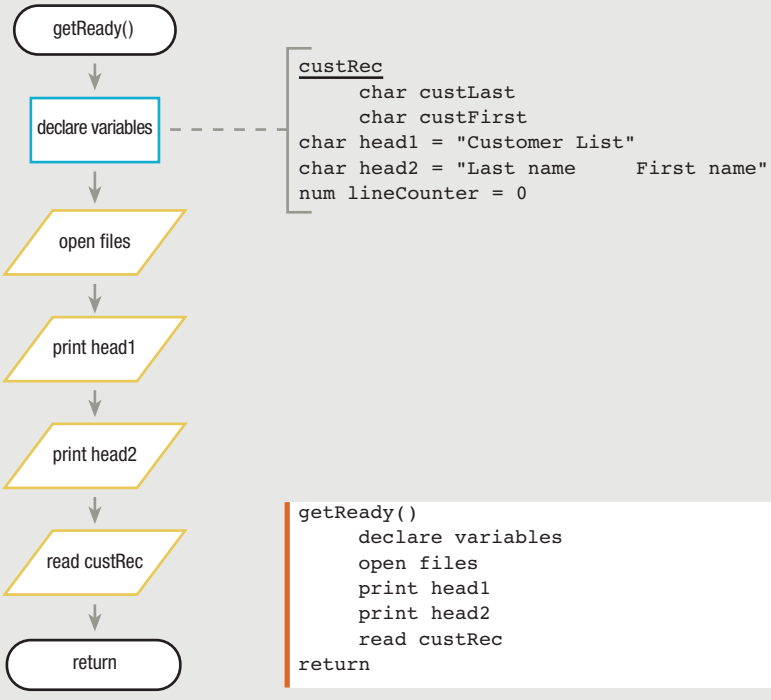
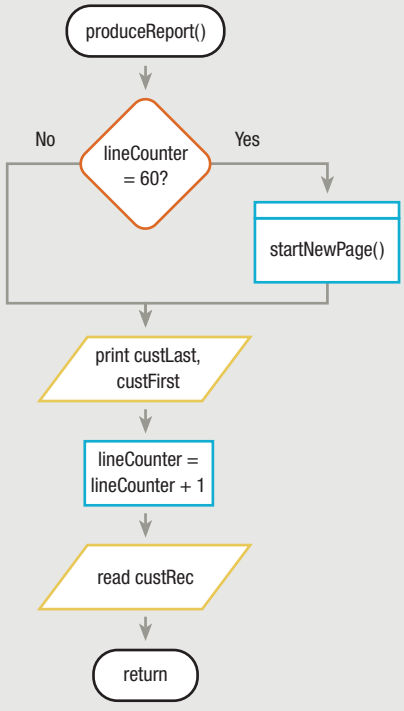


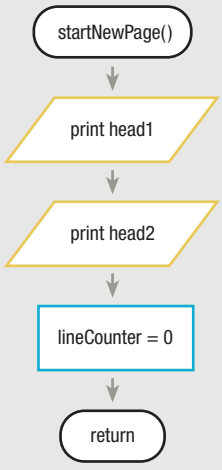
FIGURE 7-28: THE `produceReport()` MODULE FOR CUSTOMER REPORT PROGRAM




```
produceReport()
     if lineCounter = 60 then
          perform startNewPage()
     endif
     print custLast, custFirst
     lineCounter = lineCounter + 1
     read custRec
return
```

In Figure 7-27, instead of printing `head1` and `head2`, you could perform a module that starts a new page. Figure 7-29 shows a `startNewPage()` module that the `getReady()` module could call.

FIGURE 7-29: THE `startNewPage()` MODULE FOR CUSTOMER REPORT PROGRAM




```
startNewPage()
     print head1
     print head2
     lineCounter = 0
return
```

On every cycle through the `produceReport()` module, you check the line counter to see if it is 60 yet. When the first record is printed, `lineCounter` is 1. You read the second record, and if there is a second record (that is, if it is not `eof`), you return to the top of the `produceReport()` module. In that module, you compare `lineCounter` to 60, print another line, and add 1 to `lineCounter`, making it equal to 2.

After 60 records are read and printed, `lineCounter` holds a value of 60. When you read the 61st record (and if it is not `eof`), you enter the `produceReport()` module for the 61st time. The answer to the question `lineCounter = 60?` is Yes, and you break to perform the `startNewPage()` module. The `startNewPage()` module is a control break routine.

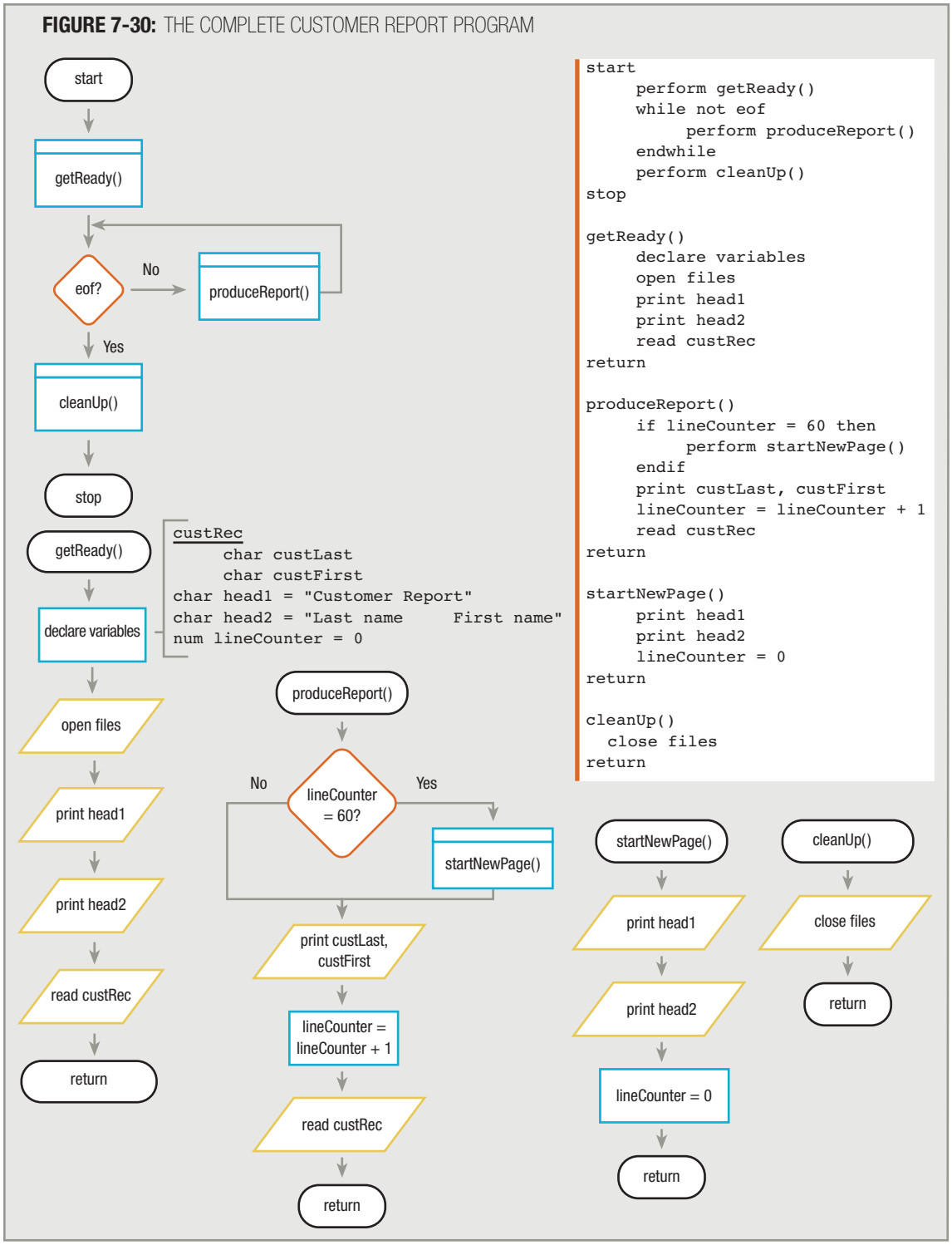
The `startNewPage()` module, shown in Figure 7-29, must print the headings that appear at the top of a new page, and it must set `lineCounter` back to zero. If you neglect to reset `lineCounter`, its value will increase with each successive record and never be equal to 60 again. When resetting `lineCounter` for a new page, you force execution of the `startNewPage()` module after 60 more records (120 total) print.

The `startNewPage()` module is simpler than many control break modules because no record counters or accumulators are being maintained. In fact, the `startNewPage()` module must perform only two of the tasks you have seen required by control break routines.

- It does not perform the lower-level break, because there is none.
- It does not perform any control break processing for the previous group, because there is none.
- It does not roll up the current-level totals to the next higher level, because there are no totals.
- It does not reset the current level's totals to zero, because there are no totals (other than `lineCounter`, which is the control break field).
- It does perform control break processing for the new group by printing headings at the top of the new page.
- It does update the control break field—the line counter.

You might want to employ one little trick to remove the statements that print the headings from the `getReady()` module. If you initialize `lineCounter` to 60 when defining the variables at the beginning of the program, on the first pass through `produceReport()`, you can "fool" the computer into printing the first set of headings automatically. When you initialize `lineCounter` to 60, you can remove the statements `print head1` and `print head2` from the `getReady()` module. With this change, when you enter the `produceReport()` module for the first time, `lineCounter` is already set to 60, and the `startNewPage()` module prints the headings and resets `lineCounter` to zero before processing the first record from the input file and starting to count the first page's detail lines. Figure 7-30 shows the entire program.

FIGURE 7-30: THE COMPLETE CUSTOMER REPORT PROGRAM



TIP

In the program in Figure 7-30, you might prefer to create a constant named LINES_PER_PAGE and set it to be equal to 60. Then, in the `produceReport()` module, you would compare `lineCounter` to this constant. Doing this would provide you with two advantages. First, the meaning of LINES_PER_PAGE would be clearer than the number 60. Second, if you needed to change the number of lines per page, you could do so using the declaration list instead of searching through the program to find the reference.

As with control break report programs that break based on the contents of one of a record's fields, in any program that starts new pages based on a line count, you always must update the line-counting variable that causes the unusual action. Using page breaks or control breaks (or both) within reports adds a new degree of organization to your printed output and makes it easier for the user to interpret and use.

CHAPTER SUMMARY

- A control break is a temporary detour in the logic of a program; programmers refer to a program as a control break program when a change in the value of a variable initiates special actions or causes special or unusual processing to occur. To generate a control break report, your input records must be organized in sorted order based on the field that will cause the breaks.
- You use a control break field to hold data from a previous record. You decide when to perform a control break routine by comparing the value in the control break field to the corresponding value in the current record. At minimum, the simplest control break routines perform necessary processing for the new group and update the control break field.
- Sometimes, you need to use control data within a control break module, such as in a heading that requires information about the next record, or in a footer that requires information about the previous record. The very first heading prints separately from all the others at the beginning; the very last footer must print separately from all the others at the end.
- A control break report contains and prints totals for the previous group, rolls up the current-level totals to the next higher level, resets the current level's totals to zero, performs any other needed control break processing, and updates the control break field.
- In a program containing a multiple-level control break, the normal flow of control breaks away for special processing in response to a change in more than one field. You should always test for a major-level break before a minor-level break, and include a call to the minor break routine within the major break module.
- Every time you write a program in which you need control break routines, you should check whether you need to perform each of the following tasks within the routines: any lower-level break, any control break processing for the previous group, rolling up the current-level totals to the next higher level, resetting the current level's totals to zero, any control break processing for the new group, and updating the control break field.
- To perform page breaks, you count the lines printed and pause to print headings when the counter reaches some predetermined value.

KEY TERMS

A **control break** is a temporary detour in the logic of a program.

A **control break program** is one in which a change in the value of a variable initiates special actions or causes special or unusual processing to occur.

A **control break report** lists items in groups. Frequently, each group is followed by a subtotal.

Programs that **sort** records take records that are not in order and rearrange them to be in order based on some field.

A **single-level control break** is a break in the logic of a program based on the value of a single variable.

A **control break field** is a variable that holds the value that signals a break in a program.

A **footer** is a message that prints at the end of a page or other section of a report.

Rolling up the totals is the process of adding a total to a higher-level total.

A **summary report** is one that does not include any information about individual records, but instead includes only group totals.

A **multiple-level control break** is one in which the normal flow of control breaks away for special processing in response to a change in more than one field.

A **major-level break** is a break in the flow of logic that is caused by a change in the value of a higher-level field.

A **minor-level break** is a break in the flow of logic that is caused by a change in the value of a lower-level field.

A **line-counter** variable keeps track of the number of printed lines on a page.

REVIEW QUESTIONS

1. A control break occurs when a program _____.

a. takes one of two alternate courses of action for every record
b. pauses to perform special processing based on the value of a field
c. ends prematurely, before all records have been processed
d. passes logical control to a module contained within another program

2. Which of the following is an example of a control break report?

a. a list of all employees in a company, with a message "Retain" or "Dismiss" following each employee record
b. a list of all students in a school, arranged in alphabetical order, with a total count at the end of the report
c. a list of all customers of a business in zip code order, with a count of the number of customers who reside in each zip code
d. a list of some of the patients of a medical clinic—those who have not seen a doctor for at least two years

3. Placing records in sequential order based on the value in one of the fields is called _____.

a. sorting
b. collating
c. merging
d. categorizing

4. In a program with a single-level control break, _____.

a. the input file must contain a variable that contains a single digit
b. the hierarchy chart must contain a single level below the main level
c. special processing occurs based on the value in a single field
d. the control break module must not contain any submodules

5. A control break field _____.

a. always prints prior to any group of records on a control break report
b. always prints after any group of records on a control break report
c. never prints on a report
d. causes special processing to occur

6. The value stored in a control break field _____.

a. can be printed at the end of each group of records
b. can be printed with each record
c. both of these
d. neither a nor b

7. Within any control break module, you must _____.

a. declare a control break field
b. set the control break field to zero
c. print the control break field
d. update the value in the control break field

8. An insurance agency employs 10 agents and wants to print a report of claims based on the insurance agent who sold each policy. The agent's name should appear in a heading prior to the list of each agent's claims. In the housekeeping module for this program, you should _____.

a. read the first record before printing the first heading
b. print the first heading before reading the first record
c. read all the records that represent clients of the first agent before printing the heading
d. print the first heading, but do not read the first record until the main loop

9. In contrast to using control break data in a heading, when you use control break data in a footer, you usually need data from the _____ record in the input data file.

a. previous
b. next
c. first
d. priming

10. An automobile dealer wants a list of cars sold, grouped by model, with a total dollar amount sold at the end of each group. The program contains four modules, appropriately named `housekeeping()`, `mainLoop()`, `modelBreak()`, and `finish()`. The total for the last car model group should be printed in the _____.

a. `mainLoop()` module, after the last time the control break module is called
b. `mainLoop()` module, as the last step in the module
c. `modelBreak()` module when it is called from within the `mainLoop()` module
d. `modelBreak()` module when it is called from within the `finish()` module

11. The Hampton City Zoo has a file that contains information about each of the animals it houses. Each animal record contains such information as the animal's ID number, date acquired by the zoo, and species. The zoo wants to print a list of animals, grouped by species, with a count after each group. As an example, a typical summary line might be "Species: Giraffe Count: 7". Which of the following happens within the control break module that prints the count?

a. The previous species count prints, and then the previous species field is updated.
b. The previous species field is updated, and then the previous species count prints.
c. Either of these will produce the desired results.
d. Neither a nor b will produce the desired results.

12. Adding a total to a higher-level total is called _____ the totals.

a. sliding
b. advancing
c. rolling up
d. replacing

13. The Academic Dean of Creighton College wants a count of the number of students who have declared each of the college's 45 major courses of study, as well as a grand total count of students enrolled in the college. Individual student records contain each student's name, ID number, major, and other data, and are sorted in alphabetical order by major. A control break module executes when the program encounters a change in student major. Within this module, what must occur?

a. The total count for the previous major prints.
b. The total count for the previous major prints, and the total count is added to the grand total.
c. The total count for the previous major prints, the total count for the major is added to the grand total, and the total count for the major is reset to zero.
d. The total count for the previous major prints, the total count for the major is added to the grand total, the total count for the major is reset to zero, and the grand total is reset to zero.

14. In a control break program containing printed group totals and a grand total, the final module that executes must _____.

a. print the group total for the last group
b. roll up the total for the last group
c. both of these
d. neither a nor b

15. A summary report _____.

a. contains detail lines
b. contains total lines
c. both of these
d. neither a nor b

16. The Cityscape Real Estate Agency wants a list of all housing units sold last year, including a subtotal of sales that occurred each month. Within each month group, there are also subtotals of each type of property—single-family homes, condominiums, commercial properties, and so on. This report is a _____ control break report.

a. single-level
b. multiple-level
c. semilevel
d. trilevel

17. The Packerville Parks Commission has a file that contains picnic permit information for the coming season. They need a report that lists each day's picnic permit information, including permit number and name of permit holder, starting on a separate page each day of the picnic season. (Figure 7-31 shows a sample page of output for the Packerville Parks report.) Within each day's permits, they want subtotals that count permits in each of the city's 30 parks. The permit records have been sorted by park name within date. In the main loop of the report program, the first decision should check for a change in _____.

FIGURE 7-31: SAMPLE PARKS REPORT

```
     Packerville Parks Commission - Daily Count of Permits by Park
Day: June 24

     Permit Number        Permit Holder
     200501932            Paul Martin
     200502003            Brownie Troop 176
     200502015            Dorothy Wintergreen
                                       Alcott Park Count - 3
     200500080            YMCA Day Camp
     200501200            Packerville Rotary Club
     200501453            Harold Martinez
     200502003            Wendy Sudo
                                       Browning Park Count - 4
```

a. park name
b. date
c. permit number
d. any of these

18. Which of the following is *not* a task you need to complete in any control break module that has multiple levels and totals at each level?

a. Perform lower-level breaks.
b. Roll up the totals.
c. Update the control break field.
d. Reset the current-level totals to the previous-level totals.

19. The election commission for the state of Illinois maintains a file that contains the name of each registered voter, the voter's county, and the voter's precinct within the county. The commission wants to produce a report that counts the voters in each precinct and county. The file should be sorted in _____.

a. county order within precinct
b. last name order within precinct
c. last name order within county
d. precinct order within county

20. A variable that determines when a new page should start based on the number of detail lines printed on a page is a _____.

a. detail counter
b. line counter
c. page counter
d. break counter

FIND THE BUGS

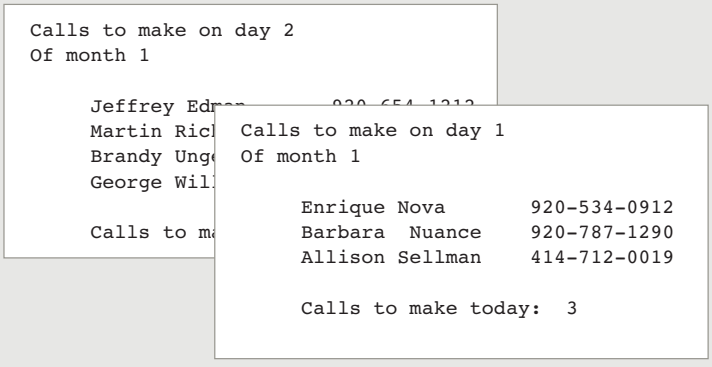
Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **This application prints a student report for an elementary school. Students have been sorted by grade level. A new page is started for each grade level, and the numeric grade level prints as part of the heading of the page.**

```
start
     perform getReady()
     while not eof
          perform produceReport()
     endwhile
     perform finishUp()
stop

getReady()
     declare variables
         studentRec
             num studentID
             char name
             num gradeLevel
          char heading1 = "Student Report by Grade Level"
          char heading2 = "Students in Grade "
     open files
     print heading1
     print heading2, gradeLevel
     read studentRec
return

produceReport()
     if gradeLevel = holdGradeLevel then
         perform newGrade()
     endif
     print studentId, name
     read studentRec
return

newGrade()
     print heading1
     print heading2, holdGradeLevel
      holdGradeLevel = gradeLevel
return

finishUp()
     close files
return
```

2. **The Friendly Insurance Company makes a point to phone a birthday greeting to each of its clients on his or her birthday. The following program is intended to produce a report that lists the clients a salesperson should call each day for the coming year. Input records include the client's name and phone number as well as a numeric month and day. The records have been sorted by day within month, and each day's list appears on a new page. (It is very likely that some days of the year do not have a client birthday.) At the end of each page is a count of the number of calls that should be made that day. Two pages of a sample report are shown in Figure 7-32.**

FIGURE 7-32: SAMPLE REPORT




```
start
     perform prepare()
     while not eof
          perform produceReport()
     endwhile
     perform finish()
stop

prepare()
     declare variables
         appointmentRec
             char clientName
             char phoneNumber
             num month
             num day
          num oldMonth
          num oldDay
          char heading1 = "Calls to make on day "
          char heading2 = "of month "
          char footer = "Calls to make today: "
          num countAppointments
```

```
     open files
     read appointmentRec
     print head1, day
     print heading2, month
     month = oldMonth
     day = oldDay
return

produceReport()
     if day not = oldDay then
         perform newDay()
      else
            if month not = oldMonth
                perform newMonth()
            endif
     endif
     print clientName, phoneNumber
     countAppointments = countAppointments + 1
return

newMonth()
     perform newDay()
     oldMonth = month
return

newDay()
    perform newMonth()
    print footer, countAppointments
    print heading1, day
    print heading1, month
    oldDay = day
return

finish()
     close files
return
```

EXERCISES

1. **What fields might you want to use as the control break fields to produce a report that lists all inventory items in a grocery store? (For example, you might choose to group items by grocery store department.) Design a sample report.**

2. **What fields might you want to use as the control break fields to produce a report that lists all the people you know? (For example, you might choose to group friends by city of residence.) Design a sample report.**

3. **Cool's Department Store keeps a record of every sale in the following format:**

```
DEPARTMENT STORE SALES FILE DESCRIPTION
File name: DEPTSALES
Sorted by: Department
FIELD DESCRIPTION       DATA TYPE           COMMENTS
Transaction Number      Numeric             a 6-digit number
Amount                  Numeric             2 decimal places
Department              Numeric             a 3-digit number
```

Create the logic for a program that would print each transaction's details, with a total at the end of each department.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Create the flowchart.
d. Create the pseudocode.

4. **A used-car dealer keeps track of sales in the following format:**

```
AUTO SALES FILE DESCRIPTION
File name: AUTO
Sorted by: Salesperson
FIELD DESCRIPTION       DATA TYPE       EXAMPLE
Salesperson             Character       Miller
Make of Car             Character       Ford
Vehicle Type            Character       Sedan
Sale Price              Numeric         0 decimal places; for example, 15000
```

By the end of the week, a salesperson may have sold no cars, one car, or many cars. Create the logic of a program that would print one line for each salesperson, with that salesperson's total sales for the week and commission earned, which is 4 percent of the total sales.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Create the flowchart.
d. Create the pseudocode.

5. A community college maintains student records in the following format:

```
STUDENT FILE DESCRIPTION
File name: STUDENTS
Sorted by: Hour of First Class
FIELD DESCRIPTION       DATA TYPE         EXAMPLE
Student Name            Character         Amy Lee
City                    Character         Woodstock
Hour of First Class     Numeric           08 for 8 a.m. or 14 for 2 p.m.
Phone Number            Numeric           8154379823
```

The records have been sorted by hour of the day. The Hour of First Class is a two-digit number based on a 24-hour clock (for example, a 1 p.m. first class is recorded as 13).

Create a report that students can use to organize carpools. The report lists the names and phone numbers of students from the city of Huntley. Note that some students come from cities other than Huntley; these students should not be listed on the report.

Start a new page for each hour of the day, so that all students starting classes at the same hour are listed on the same page. Include the hour that each page represents in the heading for that page.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Create the flowchart.
d. Create the pseudocode.

6. **The Stanton Insurance Agency needs a report summarizing the counts of life, health, and other types of insurance policies it sells. Input records contain policy number, name of insured, policy value, and type of policy, and have been sorted in alphabetical order by type of policy. At the end of the report, display a count of all the policies.**

   a. Design the output for this program; create either sample output or a print chart.
   b. Create the hierarchy chart.
   c. Create the flowchart.
   d. Create the pseudocode.

7. **If a university is organized into colleges (such as Liberal Arts), divisions (such as Languages), and departments (such as French), what would constitute the major, intermediate, and minor control breaks in a report that prints all classes offered by the university?**

8. **A zoo keeps track of the expense of feeding the animals it houses. Each record holds one animal's ID number, name, species (elephant, rhinoceros, tiger, lion, and so on), zoo residence (pachyderm house, large-cat house, and so on), and weekly food budget. The records take the following form:**

```
ANIMAL FEED RECORDS
File name: ANIMFOOD
Sorted by: Species within house
FIELD DESCRIPTION       DATA TYPE       EXAMPLE
Animal ID               Numeric         4116
Animal Name             Character       Elmo
Species                 Character       Elephant
House                   Character       Pachyderm
Weekly Food             Numeric         0 decimals, whole dollars; for example, 75
   Budget in Dollars
```

   Design a report that lists each animal's ID, name, and budgeted food amount. At the end of each species group, print a total budget for the species. At the end of each house (for example, the species lion, tiger, and leopard are all in the large-cat house), print the house total. At the end of the report, print the grand total.

   a. Design the output for this program; create either sample output or a print chart.
   b. Create the hierarchy chart.
   c. Create the flowchart.
   d. Create the pseudocode.

9. **A soft-drink manufacturer produces several flavors of drink—for example, cola, orange, and lemon. Additionally, each flavor has several versions, such as regular, diet, and caffeine-free. The manufacturer operates factories in several states.**

   Assume you have input records that list version, flavor, yearly production in gallons, and state (for example: Regular Cola 5000 Kansas). The records have been sorted in alphabetical order by version within flavor within state. Design the report that lists each version and flavor, with minor total production figures for each flavor and major total production figures for each state.

   a. Design the output for this program; create either sample output or a print chart.
   b. Create the hierarchy chart.
   c. Create the flowchart.
   d. Create the pseudocode.

10. **An art shop owner maintains records for each item in the shop, including the title of the work, the artist who made the item, the medium (for example, watercolor, oil, or clay), and the monetary value. The records are sorted by artist within medium. Design a report that lists all items in the store, with a minor total value following each artist's work, and a major total value following each medium. Allow only 40 detail lines per page.**

    a. Design the output for this program; create either sample output or a print chart.
    b. Create the hierarchy chart.
    c. Create the flowchart.
    d. Create the pseudocode.

DETECTIVE WORK

1. **Control break reports are just one type of frequently printed business report. Has paper consumption increased or decreased since computers became common office tools? How soon do experts predict we will have the "paperless office"?**

UP FOR DISCUSSION

1. **Suppose your employer asks you to write a control break program that lists all the company's employees, their salaries, and their ages, with breaks at each department to list a count of employees in that department. You are provided with the personnel file to use as input. You decide to take the file home with you so you can work on creating the report over the weekend. Is this acceptable? What if the file contained only employees' names and departments, and not more sensitive data such as salaries and ages?**

2. **Suppose your supervisor asks you to create a report that lists all employees by department and includes a break after each department to display the highest-paid employee in that department. Suppose you also know that your employer will use this report to lay off the highest-paid employee in each department. Would you agree to write the program? Instead, what if the report's purpose was to list the worst performer in each department in terms of sales? What if the report grouped employees by gender? What if the report grouped employees by race?**

3. **Suppose your supervisor asks you to write a control break report that lists employees in groups by the dollar value of medical insurance claims they have in a year. You fear the employer will use the report to eliminate workers who are driving up the organization's medical insurance policy costs. Do you agree to write the report? What if you know for certain that the purpose of the report is to eliminate workers?**

8 ARRAYS

After studying Chapter 8, you should be able to:

- Understand how arrays are used
- Understand how arrays occupy computer memory
- Manipulate an array to replace nested decisions
- Declare and initialize an array
- Declare and initialize constant arrays
- Load array values from a file
- Search an array for an exact match
- Use parallel arrays
- Force subscripts to remain within array bounds
- Improve search efficiency by using an early exit
- Search an array for a range match

UNDERSTANDING ARRAYS

An **array** is a series or list of variables in computer memory, all of which have the same name but are differentiated with special numbers called subscripts. A **subscript** is a number that indicates the position of a particular item within an array. Whenever you require multiple storage locations for objects, you are using a real-life counterpart of a programming array. For example, if you store important papers in a series of file folders and label each folder with a consecutive letter of the alphabet, then you are using the equivalent of an array. If you store mementos in a series of stacked shoeboxes, each labeled with a year, or if you sort mail into slots, each labeled with a name, then you are also using a real-life equivalent of a programming array.

TIP Besides the term "subscript," programmers also use the term "**index**" to refer to the number that indicates a position within an array.

When you look down the left side of a tax table to find your income level before looking to the right to find your income tax obligation, you are using an array. Similarly, if you look down the left side of a train schedule to find your station before looking to the right to find the train's arrival time, you also are using an array.

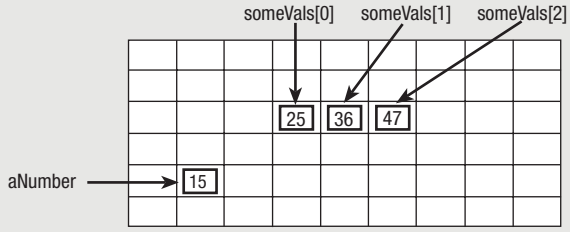
Each of these real-life arrays helps you organize real-life objects. You *could* store all your papers or mementos in one huge cardboard box, or find your tax rate or train's arrival time if both were printed randomly in one large book. However, using an organized storage and display system makes your life easier in each case. Using a programming array accomplishes the same results for your data.

TIP Some programmers refer to an array as a *table* or a *matrix*.

HOW ARRAYS OCCUPY COMPUTER MEMORY

When you declare an array, you declare a programming structure that contains multiple variables. Each variable within an array has the same name and the same data type; each separate array variable is one **element** of the array. Each array element occupies an area in memory next to, or contiguous to, the others, as shown in Figure 8-1. You indicate the number of elements an array will hold—the **size of the array**—when you declare the array along with your other variables.

FIGURE 8-1: APPEARANCE OF A THREE-ELEMENT ARRAY AND A SINGLE VARIABLE IN COMPUTER MEMORY



All array elements have the same group name, but each individual element also has a unique subscript indicating how far away it is from the first element. Therefore, any array's subscripts are always a sequence of integers, such as 0 through 5 or 0 through 10. Depending on the syntax rules of the programming language you use, you place the subscript within either parentheses or square brackets following the group name; when writing pseudocode or drawing a flowchart, you can use either form of notation. This text uses square brackets to hold array element subscripts so that you don't mistake array names for method names. For example, Figure 8-1 shows how a single variable and an array are stored in computer memory. The single variable named `aNumber` holds the value 15. The array named `someVals` contains three elements, so the elements are `someVals[0]`, `someVals[1]`, and `someVals[2]`. The value stored in `someVals[0]` is 25, `someVals[1]` holds 36, and `someVals[2]` holds 47. From the diagram in Figure 8-1, you can see that the memory location `someVals[0]` is zero elements away from the beginning of the array, the location of `someVals[1]` is one memory location away, and the location of `someVals[2]` is two elements away from the start of the array.

TIP In general, older programming languages such as COBOL and RPG use parentheses to hold their array subscripts. Newer languages such as C#, C++, and Java use square brackets.

TIP In many modern languages (for example, Java, Visual Basic .NET, C#, and C++), the first array element's subscript is 0; in others (for example, COBOL and RPG), it is 1. In Pascal, you can identify the starting number as any value you want. In languages in which the first subscript is 0, the subscript alone indicates the distance from the start of the array. In languages that use a starting subscript value other than 0, the compiler does the arithmetic for you to calculate the number of elements past the start of the array that you want to access. In all languages, however, the subscript values must be integers (whole numbers) and sequential.

Because the first element in an array in most programming languages is accessed using a subscript of value 0, the array is called a **zero-based array**. Because the lowest subscript you can use with an array is 0, the highest subscript you are allowed to use with an array is one less than the number of elements in the array. For example, an array with 10 elements uses subscripts 0 through 9, and an array with 200 elements uses subscripts 0 through 199. When you use arrays, you must always keep the limits of subscript values in mind.

TIP If you treat an array as though its lowest legal subscript is 1, when in fact it is 0, you will commit **off-by-one errors**. If you use an invalid subscript—for example, using a 10 in a 10-element array for which the subscripts should be 0 through 9—some language compilers will issue an error message and stop program execution, but others will allow you to make the mistake, resulting in incorrect output.

You are never required to use arrays within your programs, but learning to use arrays correctly can make many programming tasks far more efficient and professional. When you understand how to use arrays, you will be able to provide elegant solutions to problems that otherwise would require tedious programming steps.

TIP When you describe people or events as "elegant," you mean they possess a refined gracefulness. Similarly, programmers use the term "elegant" to describe programs that are well-designed and easy to understand and maintain.

MANIPULATING AN ARRAY TO REPLACE NESTED DECISIONS

Consider a program that keeps statistics for requests about apartments in a large apartment complex. The developer wants to keep track of inquiries so that future building projects are more likely to satisfy customer needs. In particular, the developer wants to keep track of how many requests there are for studio, one-, two-, and three-bedroom apartments. Each time an apartment request is received, a clerk adds a record to a file in the format shown in Figure 8-2.

FIGURE 8-2: FILE DESCRIPTION FOR APARTMENT REQUEST RECORDS

```
APARTMENT INQUIRY FILE DESCRIPTION
File name: APTREQUESTS
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Day of the month       Numeric      1 - 31, day request was made
Bedrooms requested     Numeric      0, 1, 2 or 3 for studio apartment
                                    or number of bedrooms
```

For example, if a call comes in on the third day of the month for a studio apartment, one record is created with a 3 in the date field and a 0 in the number of bedrooms field. If the next call is on the fourth day of the month for a three-bedroom apartment, a record with 4 and 3 is created. The contents of the data file appear as a series of numbers, as follows:

```
3 0
4 3
4 0
```

... and so on.

At the end of the month, after all the records have been collected, the file might contain hundreds of records, each holding a number that represents a date and another number (0, 1, 2, or 3) that represents the number of bedrooms the caller wanted. You want to write a program that summarizes the total number of each type of apartment requested during the month. A typical report appears in Figure 8-3.

FIGURE 8-3: TYPICAL APARTMENT REQUEST REPORT

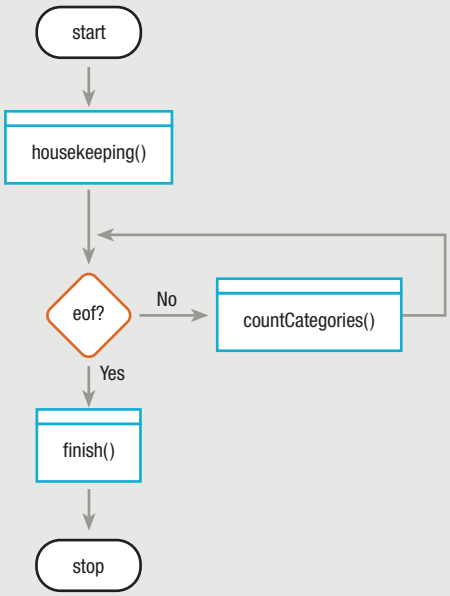
```
Apartment Request Report

Bedrooms   Inquiries

   0          91
   1          44
   2          67
   3         102
```

If all the records were sorted in order by the number of bedrooms requested, this report could be a control break report. You would simply read each record representing an inquiry on a studio apartment (zero bedrooms), counting the number of inquiries. When you read the first record requesting a different number of bedrooms, you would print the count for the previous apartment type, reset the count to zero, and update the control break field before continuing.

TIP You learned about control break logic in Chapter 7.

Assume, however, that the records have not been sorted by apartment type. Without using an array, could you write a program that would accumulate the four apartment-type totals? Of course you could. The program would have the same mainline logic as most of the other programs you have seen, as shown in Figure 8-4.

FIGURE 8-4: FLOWCHART AND PSEUDOCODE FOR MAINLINE LOGIC OF APARTMENT REQUEST REPORT PROGRAM

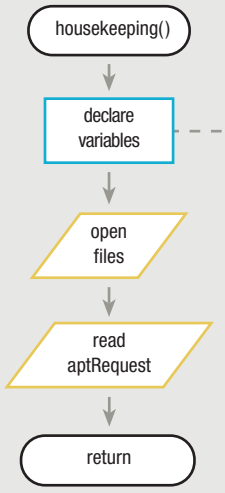



```
start
     perform housekeeping()
     while not eof
          perform countCategories()
     endwhile
     perform finish()
stop
```

TIP The program shown in Figures 8-4 through 8-7 accomplishes its purpose, but is cumbersome. Follow its logic here, so that you understand how the program works. Later in this chapter, you will see how to write the apartment request report program much more efficiently using arrays.

In the `housekeeping()` module of the apartment request report program (Figure 8-5), you declare variables including `day` and `bedrooms`. Then, you open the files and read the first record into memory. The headings *could* print in `housekeeping()` or—because no other printing takes place in this program until the `finish()` module—you can choose to wait and print the headings there.

FIGURE 8-5: THE `housekeeping()` MODULE FOR THE APARTMENT REQUEST PROGRAM WITHOUT AN ARRAY




```
aptRequest
   num day
   num bedrooms
char head1 = "Apartment Request Report"
char head2 = "Bedrooms   Inquiries"
num count0 = 0
num count1 = 0
num count2 = 0
num count3 = 0
```

```
housekeeping()
   declare variables
     aptRequest
       num day
       num bedrooms
     char head1 = "Apartment Request Report"
     char head2 = "Bedrooms   Inquiries"
     num count0 = 0
     num count1 = 0
     num count2 = 0
     num count3 = 0
   open files
   read aptRequest
return
```

TIP

In Figure 8-5, the variable list is identical for the flowchart and the pseudocode. It is included twice in this figure and in the next few for clarity because arrays are a new and complicated topic. In later examples in this book, the duplication of the variable list will be eliminated.

Within the `housekeeping()` module, you can declare four variables, `count0`, `count1`, `count2`, and `count3`; the purpose of these variables is to keep running counts of the number of requests for the four apartment types. Each of these four counter variables needs to be initialized to 0. You can tell by looking at the planned output that you need two heading lines, so `head1` is defined as "Apartment Request Report" and `head2` as "Bedrooms Inquiries".

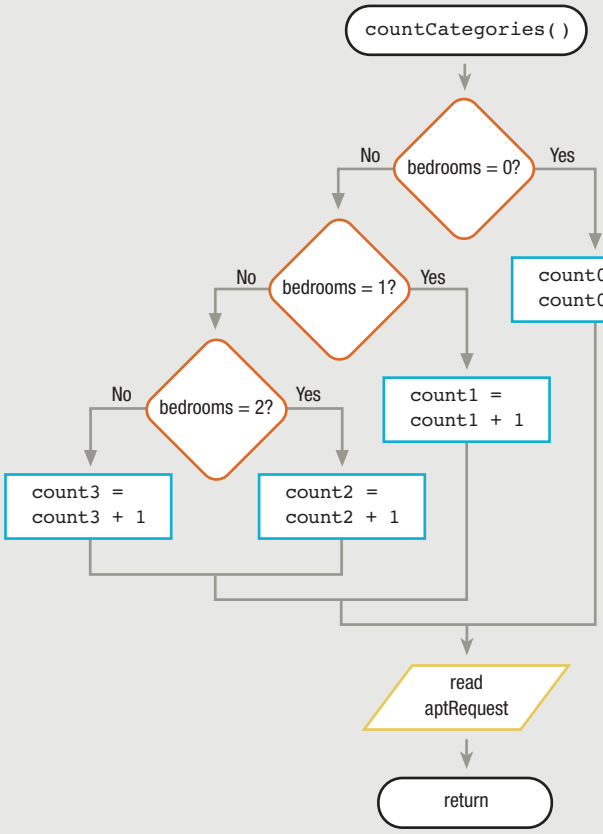
Eventually, four summary lines will be printed in the report, each with a number of bedrooms and a count of inquiries for that apartment type. These lines cannot be printed until the `finish()` module, however, because you won't have a complete count of each apartment type's requests until all input records have been read.

The logic within the `countCategories()` module of the program requires adding a 1 to `count0`, `count1`, `count2`, or `count3`, depending on the `bedrooms` variable. After 1 has been added to one of the four counters, you read the next record, and if it is not `eof`, you repeat the decision-making and counting process. When all records have been read, you proceed to the `finish()` module, where you print the four summary lines with the counts for the four apartment types. See Figures 8-6 and 8-7.

TIP

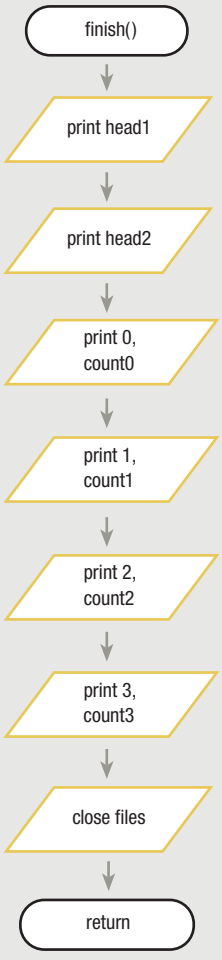
In the apartment request report program, assume that the input data has been previously edited to ensure that all apartment requests are for zero, one, two, or three bedrooms. In other words, there is no bad data. If this were not true, then the program would also need to include a step to check for incorrect data and take some appropriate action—perhaps ignoring it, or counting it in an error category.

FIGURE 8-6: THE `countCategories()` MODULE FOR THE APARTMENT REQUEST PROGRAM WITHOUT AN ARRAY




```
countCategories()
   if bedrooms = 0 then
      count0 = count0 + 1
   else
      if bedrooms = 1 then
         count1 = count1 + 1
      else
         if bedrooms = 2 then
            count2 = count2 + 1
         else
            count3 = count3 + 1
         endif
      endif
   endif
   read aptRequest
return
```

FIGURE 8-7: THE `finish()` MODULE FOR THE APARTMENT REQUEST PROGRAM WITHOUT AN ARRAY

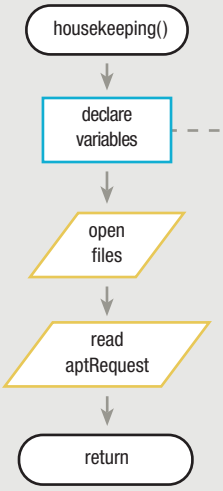



```
finish()
   print head1
   print head2
   print 0, count0
   print 1, count1
   print 2, count2
   print 3, count3
   close files
return
```

The apartment request report program works just fine, and there is absolutely nothing wrong with it logically; a decision is made for each of the first three types of apartments, defaulting to a three-bedroom apartment if the request is not for zero, one, or two bedrooms. But what if there were four types of apartments, or 12, or 30? With any of these scenarios, the basic logic of the program would remain the same; however, you would need to declare many additional counter variables. You also would need many additional decisions within the `countCategories()` module and many additional print statements within the `finish()` module to complete the processing.

Using an array provides an alternative approach to this programming problem, and greatly reduces the number of statements you need. When you declare an array, you provide a group name for a number of associated variables in memory. For example, the four apartment-type counters can be redefined as a single array named `count`. The individual elements become `count[0]`, `count[1]`, `count[2]`, and `count[3]`, as shown in the new `housekeeping()` module in Figure 8-8.

FIGURE 8-8: MODIFIED `housekeeping()` MODULE FOR APARTMENT REQUEST PROGRAM THAT DECLARES AN ARRAY TO COUNT REQUESTS

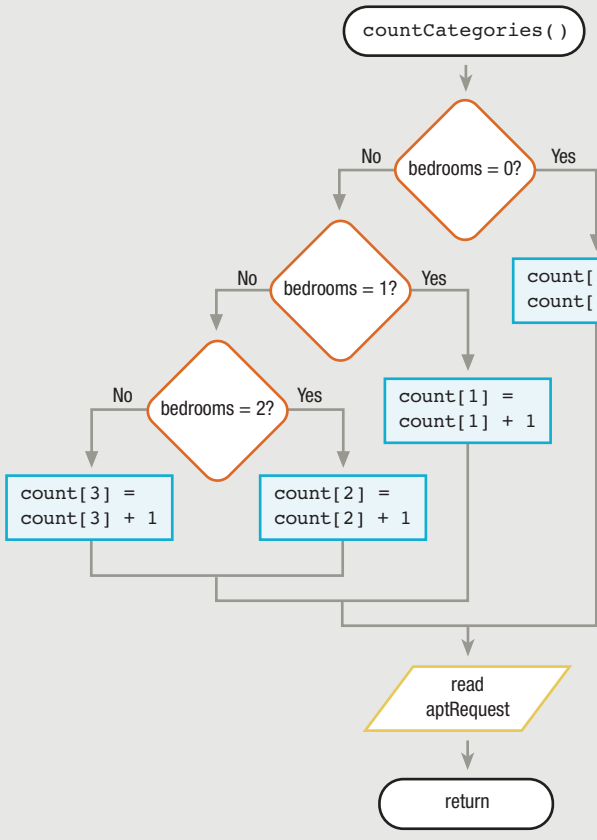



```
aptRequest
   num day
   num bedrooms
char head1 = "Apartment Request Report"
char head2 = "Bedrooms   Inquiries"
num count[0] = 0
num count[1] = 0
num count[2] = 0
num count[3] = 0
```

```
housekeeping()
   declare variables
     aptRequest
       num day
       num bedrooms
     char head1 = "Apartment Request Report"
     char head2 = "Bedrooms   Inquiries"
     num count[0] = 0
     num count[1] = 0
     num count[2] = 0
     num count[3] = 0
   open files
   read aptRequest
return
```

With the change to `housekeeping()` shown in Figure 8-8, the `countCategories()` module changes to the version shown in Figure 8-9.

FIGURE 8-9: MODIFIED `countCategories()` MODULE THAT USES `count` ARRAY

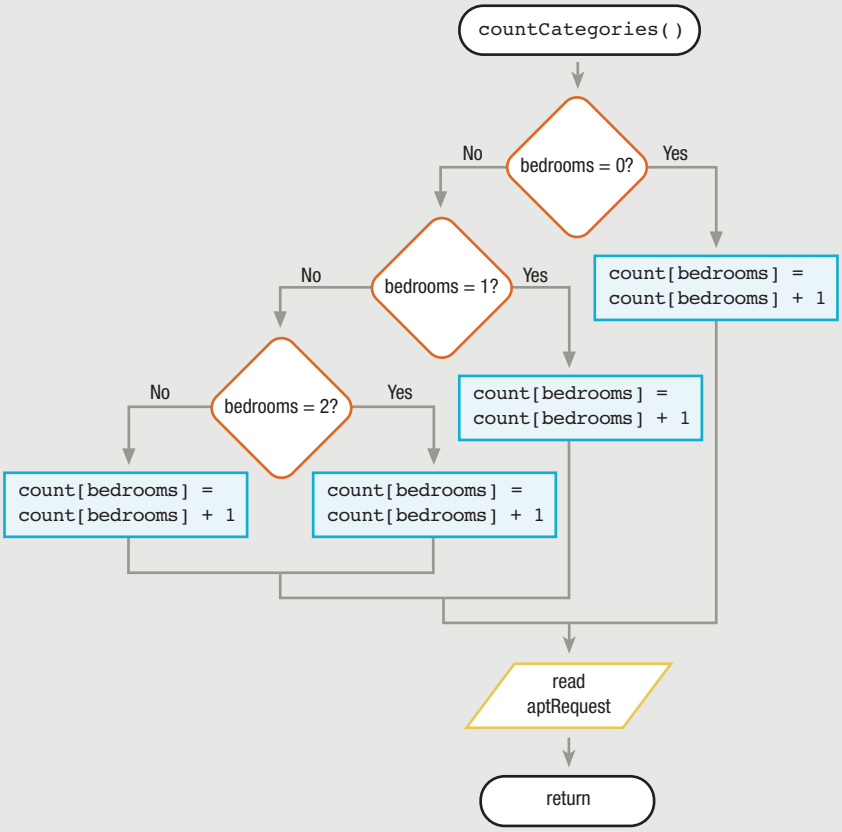



```
countCategories()
   if bedrooms = 0 then
      count[0] = count[0] + 1
   else
      if bedrooms = 1 then
         count[1] = count[1] + 1
      else
         if bedrooms = 2 then
            count[2] = count[2] + 1
         else
            count[3] = count[3] + 1
         endif
      endif
   endif
   read aptRequest
return
```

Figure 8-9 shows that when the `bedrooms` variable value is 0, one is added to `count[0]`; when the `bedrooms` value is 3, one is added to `count[3]`. In other words, one is added to one of the elements of the `count` array instead of to a single variable named `count0`, `count1`, `count2`, or `count3`. Is this a big improvement over the original? Of course it isn't. You still have not taken advantage of the benefits of using the array in this program.

The true benefit of using an array lies in your ability to use a variable as a subscript to the array, instead of using a constant such as 1 or 4. Notice in the `countCategories()` module in Figure 8-9 that within each decision, the value you are comparing to `bedrooms` and the constant you are using as a subscript in the resulting "Yes" process are always identical. That is, when the `bedrooms` value is 0, the subscript used to add 1 to the `count` array is 0; when the `bedrooms` value is 1, the subscript used for the `count` array is 1, and so on. Therefore, why not just use the value of `bedrooms` as a subscript? You can rewrite the `countCategories()` module as shown in Figure 8-10.

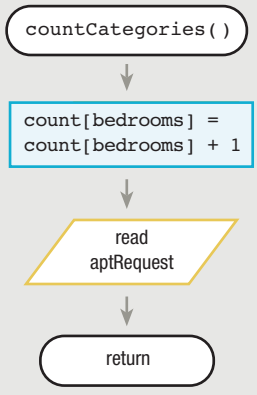
FIGURE 8-10: MODIFIED `countCategories()` MODULE USING THE VARIABLE `bedrooms` AS A SUBSCRIPT TO THE `count` ARRAY




```
countCategories()
   if bedrooms = 0 then
      count[bedrooms] = count[bedrooms] + 1
   else
      if bedrooms = 1 then
         count[bedrooms] = count[bedrooms] + 1
      else
         if bedrooms = 2 then
            count[bedrooms] = count[bedrooms] + 1
         else
            count[bedrooms] = count[bedrooms] + 1
         endif
      endif
   endif
   read aptRequest
return
```

Of course, the code segment in Figure 8-10 looks no more efficient than the one in Figure 8-9. However, notice that in Figure 8-10 the process that occurs after each decision is exactly the same. In each case, no matter what the value of `bedrooms`, you always add one to `count[bedrooms]`. If you are always going to take the same action no matter what the answer to a question is, why ask the question? Instead, you can write the `countCategories()` module as shown in Figure 8-11.

FIGURE 8-11: MODIFIED `countCategories()` MODULE, ELIMINATING NESTED DECISIONS

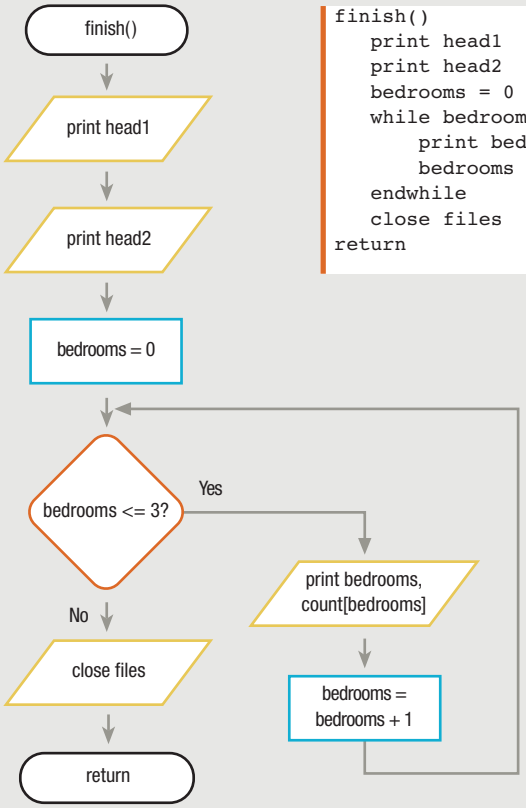



```
countCategories()
   count[bedrooms] = count[bedrooms] + 1
   read aptRequest
return
```

The two steps in Figure 8-11 represent the *entire* `countCategories()` module! When the value of `bedrooms` is 0, one is added to `count[0]`; when the value of `bedrooms` is 1, one is added to `count[1]`, and so on. *Now*, you have a big improvement to the previous `countCategories()` module from Figure 8-9. What's more, this `countCategories()` module does not change whether there are eight, 30, or any other number of types of apartment requests and `count` array elements, as long as the values in the `bedrooms` variable are numbered sequentially. To use more than four counters, you would declare additional `count` elements in the `housekeeping()` module, but the `countCategories()` logic would remain the same as it is in Figure 8-11.

The `finish()` module originally shown in Figure 8-7 can also be improved. Instead of four separate print statements, you can use a variable to control a printing loop, as shown in Figure 8-12. Because the `finish()` module follows the `eof` condition, all input records have been used, and the `bedrooms` variable is not currently holding any needed information. In `finish()`, you can set `bedrooms` to 0, and then print `bedrooms` and `count[bedrooms]`. Then add 1 to `bedrooms` and use the same set of instructions again. You can use `bedrooms` as a loop control variable to print the four individual `count` values. The improvement in this `finish()` module over the one shown in Figure 8-7 is not as dramatic as the improvement in the `countCategories()` module, but in a program with more `count` elements, the only change to the `finish()` module would be in the constant value you use to control the end of the loop. Twelve or 30 `count` values can print as easily as four if they are stored in an array.

FIGURE 8-12: MODIFIED `finish()` MODULE THAT USES AN ARRAY




```
finish()
   print head1
   print head2
   bedrooms = 0
   while bedrooms <= 3
       print bedrooms, count[bedrooms]
       bedrooms = bedrooms + 1
   endwhile
   close files
return
```

TIP

In the `finish()` module in Figure 8-12, instead of reusing the `bedrooms` variable as a subscript, many programmers prefer to declare a separate numeric work variable to initialize to 0, use it as a subscript to the array while printing, and increment it during each cycle through the loop. Their reasoning is that `bedrooms` is part of the input record and should be used only to hold actual data being input—not used as a work variable in the program. Use this approach if it makes more sense to you. You might be required to use this technique if the input data is accessed from databases containing an input field that is no longer available after the input has reached the `eof` condition.

Within the `finish()` module in Figure 8-12, the `bedrooms` variable is handy to use as a subscript, but any variable could have been used as long as it was:

- Numeric with no decimal places
- Initialized to 0
- Incremented by 1 each time the logic passed through the loop

In other words, nothing is linking `bedrooms` to the `count` array per se; within the `finish()` module, you can simply use the `bedrooms` variable as a subscript to indicate each successive element within the `count` array.

The apartment request report program *worked* when the `countCategories()` module contained a long series of decisions and the `finish()` module contained a long series of print statements, but the program is easier to write when you employ arrays. Additionally, the program is more efficient, easier for other programmers to understand, and easier to maintain. Arrays are never mandatory, but often they can drastically cut down on your programming time and make a program easier to understand.

ARRAY DECLARATION AND INITIALIZATION

In the apartment request report program, the four `count` array elements were declared and initialized to 0s in the `housekeeping()` module. The `count` values need to start at 0 so they can be added to during the course of the program. Originally (see Figure 8-8), you provided initialization in the `housekeeping()` module as:

```
num count[0] = 0
num count[1] = 0
num count[2] = 0
num count[3] = 0
```

Separately declaring and initializing each `count` element is acceptable only if there are a small number of `count`s. If the apartment request report program were updated to keep track of 30 types of apartments, you would have to initialize 30 separate `count` fields. It would be tedious to write 30 separate declaration statements.

Programming languages do not require the programmer to name each of the 30 `count`s: `count[0]`, `count[1]`, and so on. Instead, you can make a declaration such as one of those in Figure 8-13.

FIGURE 8-13: DECLARING A 30-ELEMENT ARRAY NAMED `count` IN SEVERAL COMMON LANGUAGES

Declaration	Programming Language
DIM COUNT(30)	BASIC, Visual Basic
int count[30];	C#, C++
int[] count = new int[30];	Java
COUNT OCCURS 30 TIMES PICTURE 9999.	COBOL
array count [1..30] of integer;	Pascal

TIP C, C++, C#, and Java programmers typically use lowercase variable names. COBOL and BASIC programmers often use all uppercase. Visual Basic programmers are likely to begin with an uppercase letter.

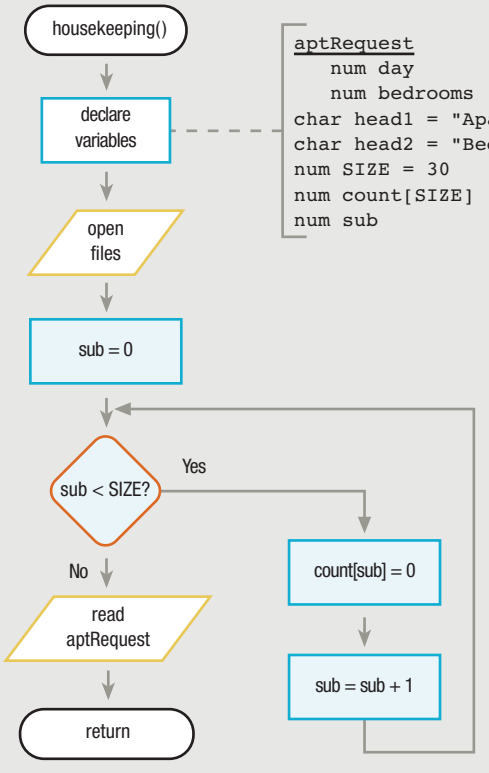
TIP The terms `int` and `integer` in the code samples within Figure 8-13 both indicate that the `count` array will hold whole-number values. The value 9999 in the COBOL example indicates that each `count` will be a four-digit integer. These terms are more specific than the `num` identifier this book uses to declare all numeric variables.

All the declarations in Figure 8-13 have two things in common: They name the `count` array and indicate that there will be 30 separate numeric elements. For flowcharting or pseudocode purposes, a statement such as `num count[30]` indicates the same thing.

Declaring a numeric array does not necessarily set its individual elements to 0 (although it does in some programming languages, such as BASIC, Visual Basic, and Java). Most programming languages allow the equivalent of `num count[30] all set to 0`; you should use a statement like this when you want to initialize an array in your flowcharts or pseudocode. Explicitly initializing all variables is a good programming practice; assuming anything about noninitialized variable values is a dangerous practice. Array elements are no exception to this rule.

Alternatively, to start all array elements with the same initial value, you can use an initialization loop within the `housekeeping()` module. An **initialization loop** is a loop structure that provides initial values for every element in any array. To create an initialization loop, you must use a numeric variable as a subscript. For example, if you declare a field named `sub`, and initialize `sub` to 0, then you can use a loop like the one shown in the `housekeeping()` module in Figure 8-14 to set all the array elements to 0. As the value of `sub` increases from 0 through 29, each corresponding `count` element is assigned 0.

FIGURE 8-14: A `housekeeping()` MODULE DEMONSTRATING ONE METHOD OF INITIALIZING ARRAY ELEMENTS




```
aptRequest
   num day
   num bedrooms
char head1 = "Apartment Request Report"
char head2 = "Bedrooms   Inquiries"
num SIZE = 30
num count[SIZE]
num sub
```

```
housekeeping()
    declare variables
      aptRequest
        num day
        num bedrooms
      char head1 = "Apartment Request Report"
      char head2 = "Bedrooms   Inquiries"
      num SIZE = 30
      num count[SIZE]
      num sub
    open files
    sub = 0
    while sub < SIZE
        count[sub] = 0
        sub = sub + 1
    endwhile
    read aptRequest
return
```

TIP

In Figure 8-14, a named constant SIZE is initialized to 30. This constant is then used in both the array declaration and the loop that controls how many elements are set to 0. Using a constant such as SIZE is a convenient way to make sure you access all the array elements. Additionally, if you want to alter the program to handle some other number of apartment types, the only change you need to make to the program is to provide a different value for the constant. You first learned about named constants in Chapter 4.

DECLARING AND INITIALIZING CONSTANT ARRAYS

The array that you used to accumulate apartment-type requests in the previous section contained four variables whose values were altered during the execution of the program. The values in which you were most interested, the count of the number of requests for each type of apartment, were created during an actual run, or execution, of the program. In other words, if 1,000 prospective tenants are interested in studio apartments, you don't know that fact at the beginning of the program. Instead, that value is accumulated during the execution of the program and not known until the end.

Some arrays are not variable, but are meant to be constant. With some arrays, the final desired values are fixed at the beginning of the program.

For example, let's say you own an apartment building with five floors, including a basement, and you have records for all your tenants with the information shown in Figure 8-15. The combination of each tenant's floor number and apartment letter provides you with a specific apartment—for example, apartment 0D or 3B.

FIGURE 8-15: TENANT FILE DESCRIPTION

```
TENANT FILE DESCRIPTION
File name: TENANTS
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Tenant name            Character    Full name, first and last
Floor number           Numeric      0 through 4 - 0 is basement
Apartment letter       Character    Single letter - A through F
```

Every month, you print a rent bill for each tenant. Your rent charges are based on the floor of the building, as shown in Figure 8-16.

FIGURE 8-16: RENTS BY FLOOR

```
Floor               Rent in $
0 (the basement)        350
1                       400
2                       475
3                       600
4 (the penthouse)      1000
```

To create a computer program that prints each tenant's name and rent due, you could use five decisions concerning the floor number. However, it is more efficient to use an array to hold the five rent figures. The array's values are constant because you set them once at the beginning of the program, and they never change.

TIP Remember that another name for an array is a *table*. If you can use paper and pencil to list items like tenants' rent values in a table format, then using an array is an appropriate programming option.

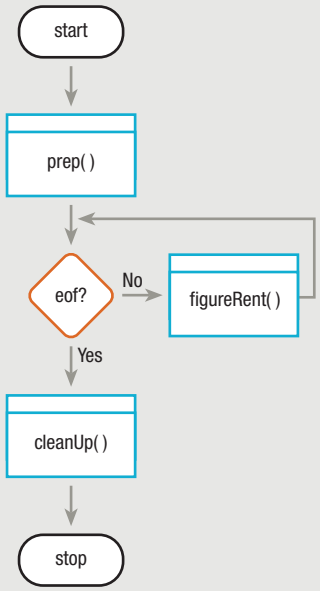
TIP In most programming languages, you would include a modifier such as `const` or `final` in front of the array name to declare it to be truly constant, so that you could not alter any of its elements' values later in the program.

TIP Some programmers use the term "compile-time arrays" to refer to arrays that receive their usable values through initialization at the start of a program, whereas arrays that do not receive their ultimate values until the program is being used are run-time arrays.

The mainline logic for this program is shown in Figure 8-17. The housekeeping module is named `prep()`. When you declare variables within the `prep()` module, you create an array for the five rent figures and set `num rent[0] = 350`, `num rent[1] = 400`, and so on. The rent amounts are **hard coded** into the array; that is, they are explicitly assigned to the array elements. The `prep()` module is shown in Figure 8-18.

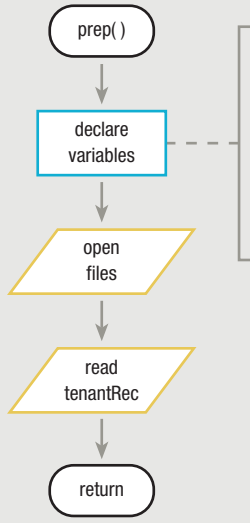
TIP The `prep()` module name was chosen as a change of pace from `housekeeping()`, which has been used in many examples in this book. Some programmers advocate being consistent in naming modules from program to program; others prefer varying names as long as the names are meaningful.

FIGURE 8-17: FLOWCHART AND PSEUDOCODE FOR MAINLINE LOGIC OF RENT PROGRAM




```
start
   perform prep()
   while not eof
      perform figureRent()
   endwhile
   perform cleanUp()
stop
```

FIGURE 8-18: FLOWCHART AND PSEUDOCODE FOR `prep()` MODULE OF RENT PROGRAM




```
tenantRec
   char tenName
   num tenFloor
   char tenAptLetter
num rent[0] = 350
num rent[1] = 400
num rent[2] = 475
num rent[3] = 600
num rent[4] = 1000
```

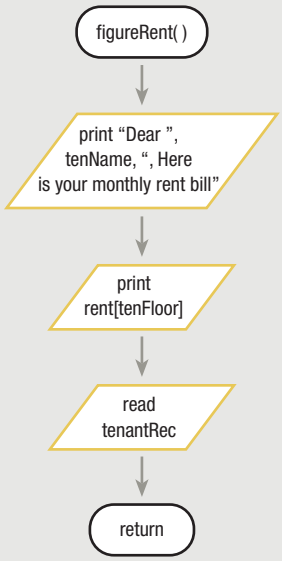
```
prep()
      declare variables
      open files
      read tenantRec
return
```

TIP

As an alternative to defining `rent[0]`, `rent[1]`, and so on, as in Figure 8-18, most programming languages allow a more concise version that takes the general form `num rent[5] = 350, 400, 475, 600, 1000`. When you use this form of array initialization, the first value you list is assigned to the first array element, and the subsequent values are assigned in order. Most programming languages allow you to assign fewer values than there are array elements declared, but none allow you to assign more values.

At the end of the `prep()` module, you read a first record into memory. The record contains a tenant name (`tenName`), floor (`tenFloor`), and apartment letter (`tenAptLetter`). When the logic enters `figureRent()` (the main loop), you can print three items: "Dear ", `tenName`, and ", Here is your monthly rent bill" (the quote begins with a comma that follows the recipient's name). Then, you must print the rent amount. Instead of making a series of selections such as `if tenFloor = 0 then print rent[0]` and `if tenFloor = 1 then print rent[1]`, you want to take advantage of the `rent` array. The solution is to create a `figureRent()` module that looks like Figure 8-19. You use the `tenFloor` variable as a subscript to access the correct `rent` array element. When deciding which variable to use as a subscript with an array, ask yourself, "Of all the values available in the array, what does the correct selection depend on?" When printing a `rent` value, the rent you use depends on the floor on which the tenant lives, so the correct action is `print rent[tenFloor]`.

FIGURE 8-19: FLOWCHART AND PSEUDOCODE FOR THE `figureRent()` MODULE OF THE RENT PROGRAM

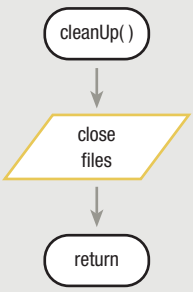



```
figureRent()
     print "Dear ", tenName, ", Here is your monthly rent bill"
     print rent[tenFloor]
     read tenantRec
return
```

TIP Every programming language provides ways to space your output for easy reading. For example, a common technique to separate "Dear" from the tenant's name is to include a space after the *r* in *Dear*, as in `print "Dear ", tenName`.

The `cleanUp()` module for this program is very simple—just close the files. See Figure 8-20.

FIGURE 8-20: THE `cleanUp()` MODULE FOR THE RENT PROGRAM




```
cleanUp()
     close files
return
```

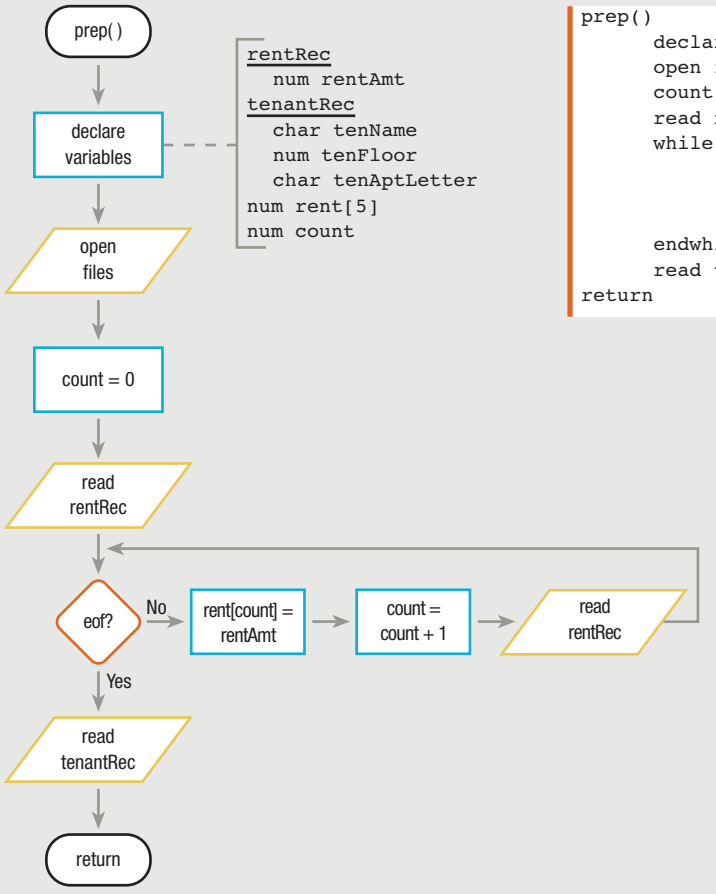
Without a `rent` array, the `figureRent()` module would have to contain four decisions and five different resulting actions. With the `rent` array, there are no decisions. Each tenant's rent is simply based on the `rent` element that corresponds to the `tenFloor` variable because the floor number indicates the positional value of the corresponding rent. Arrays can really lighten the workload required to write a program.

LOADING AN ARRAY FROM A FILE

Writing the rent program from the previous section requires you to set values for five `rent` array elements within the `prep()` module. If you write the rent program for a skyscraper, you may have to initialize 100 array elements. Additionally, when the building management changes the rent amounts, you must alter the array element values within the program to reflect the new rent charges. If the rent values change frequently, it is inconvenient to have hard-coded values in your program. Instead, you can write your program so that it loads the array rent amounts from a file. The array of rent values is an example of an array that gets its values during the execution of the program.

A file that contains all the rent amounts can be updated by apartment building management as frequently as needed. Suppose you periodically receive a file named RENTFILE that is created by the building management and always contains the current rent values. You can write the rent program so that it accepts all records from this input file within the `prep()` module. Figure 8-21 shows how this is accomplished.

FIGURE 8-21: FLOWCHART AND PSEUDOCODE FOR `prep()` MODULE THAT READS RENT VALUES FROM AN INPUT FILE




```
prep()
      declare variables
      open files
      count = 0
      read rentRec
      while not eof
              rent[count] = rentAmt
              count = count + 1
              read rentRec
      endwhile
      read tenantRec
return
```

In the `prep()` module in Figure 8-21, you set the variable `count` to 0 and read a `rentRec` record from RENTFILE. Each record in RENTFILE contains just one field—a numeric `rentAmt` value. For this program, assume that the rent records in RENTFILE are stored in order by floor. When you read the first `rentAmt`, you store it in the first element of the `rent` array. You increase the `count` to 1, read the second record, and, assuming it's not `eof`, you store the second rent in the second element of the `rent` array. After RENTFILE is exhausted and the `rent` array is filled with appropriate rent amounts for each floor, you begin to read the file containing the `tenantRec` records, and then the program proceeds as usual.

TIP You could choose to close RENTFILE at the end of the `prep()` module. Unlike the tenant file and the printer, it will not be used again in the program. Alternatively, you can wait and close all the files at the end of the program.

When you use this method—reading the rents from an input file instead of hard coding them into the program—clerical employees can update the `rentRec` values in RENTFILE. Your program takes care of loading the rents into the program array from the most recent copy of RENTFILE, ensuring that each rent is always accurate and up to date. Using this technique, you avoid the necessity of changing code within the program with each rent update.

TIP Another way to organize RENTFILE is to include two fields within each record—for example, `rentFloor` and `rentAmt`. Then, the records would not have to be read into your program in floor-number order. Instead, you could use the `rentFloor` variable as a subscript to indicate which position in the array to use to store the `rentAmt`.

TIP You might question how the program knows which file's `eof` condition is tested when a program uses two or more input files. In some programming languages, the `eof` condition is tested on the file most recently read. In many programming languages, you have to provide more specific information along with the `eof` question, perhaps `rentRec eof?` or `tenantRec eof?`

TIP The RENTFILE example assumes that management provides you with a file that contains no more records than the number of rents your program is prepared to hold. A more elegant program would check to make sure there are not too many rents. You will learn how to perform such checks later in this chapter.

SEARCHING FOR AN EXACT MATCH IN AN ARRAY

In both the apartment request program and the rent program that you've seen in this chapter, the fields that the arrays depend on conveniently hold small whole numbers. The number of bedrooms available in apartments are zero through three, and the floors of the building are zero through four. Unfortunately, real life doesn't always happen in small integers. Sometimes, you don't have a variable that conveniently holds an array position; sometimes, you have to search through an array to find a value you need.

Consider a mail-order business in which orders come in with a customer name, address, item number ordered, and quantity ordered, as shown in Figure 8-22.

FIGURE 8-22: MAIL-ORDER CUSTOMER FILE DESCRIPTION

```
MAIL-ORDER CUSTOMER FILE DESCRIPTION
File name: CUSTREC
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Customer name          Character
Address                Character
Item number            Numeric      A 3-digit number
Quantity               Numeric      A value from 1 through 99
```

The item numbers are three-digit numbers, but perhaps they are not consecutive 000 through 999. Instead, over the years, items have been deleted and new items have been added. For example, there might no longer be an item with number 005 or 129. Sometimes, there might be a hundred-number gap or more between items.

For example, let's say that this season you are down to the items shown in Figure 8-23. When a customer orders an item, you want to determine whether the order is for a valid item number. You could use a series of six decisions to determine whether the ordered item is valid; in turn, you would compare whether each customer's item number is equal to one of the six allowed values. However, a superior approach is to create an array that holds the list of valid item numbers. Then, you can search through the array for an exact match to the ordered item. If you search through the entire array without finding a match for the item the customer ordered, you can print an error message, such as "No such item."

Suppose you create an array with the six elements shown in Figure 8-24. If a customer orders item 307, a clerical worker can tell whether it is valid by looking down the list and verifying that 307 is a member of the list. In a similar fashion, you can use a loop to test each `validItem` against the ordered item number.

FIGURE 8-23: AVAILABLE ITEMS IN MAIL-ORDER COMPANY

```
ITEM NUMBER
106
108
307
405
457
688
```

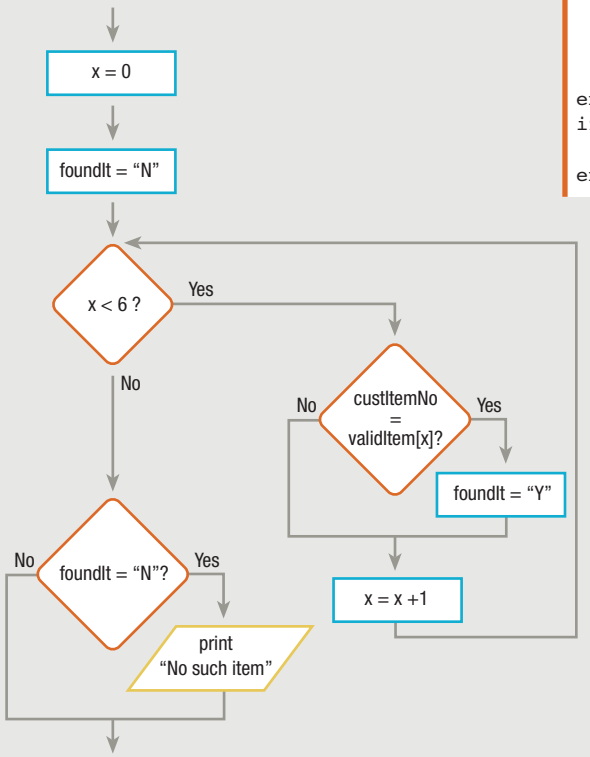
FIGURE 8-24: ARRAY OF VALID ITEM NUMBERS

```
num validItem[0] = 106
num validItem[1] = 108
num validItem[2] = 307
num validItem[3] = 405
num validItem[4] = 457
num validItem[5] = 688
```

The technique for verifying that an item number exists involves setting a subscript to 0 so that you can start searching from the first array element, and initializing a flag variable to indicate that you have not yet determined whether the customer's order is valid. A **flag** is a variable that you set to indicate whether some event has occurred; frequently, it holds a True or False value. For example, you can set a character variable named `foundIt` to "N", indicating "No". Then you compare the customer's ordered item number to the first item in the array. If the customer-ordered item matches the first item in the array, you can set the flag variable to "Y", or any other value that is not "N". If the items do not match, you increase the subscript and continue to look down the list of numbers stored in the array. If you check all six valid item numbers and the customer item matches none of them, then the flag variable `foundIt` still holds the value "N". If the flag variable is "N" after you have looked through the entire list, you can issue an error message indicating

that no match was ever found. Assuming you declare the customer item as `custItemNo` and the subscript as `x`, then Figure 8-25 shows a flowchart segment and the pseudocode that accomplishes the item verification.

FIGURE 8-25: FLOWCHART AND PSEUDOCODE SEGMENTS FOR FINDING AN EXACT MATCH TO A CUSTOMER ITEM NUMBER




```
x = 0
foundIt = "N"
while x < 6
      if custItemNo = validItem[x] then
            foundIt = "Y"
      endif
      x = x + 1
endwhile
if foundIt = "N" then
     print "No such item"
endif
```

USING PARALLEL ARRAYS

In a mail-order company, when you read a customer's order, you usually want to accomplish more than simply verifying that the item exists. You want to determine the price of the ordered item, multiply that price by the quantity ordered, and print a bill. Suppose you have prices for six available items, as shown in Figure 8-26.

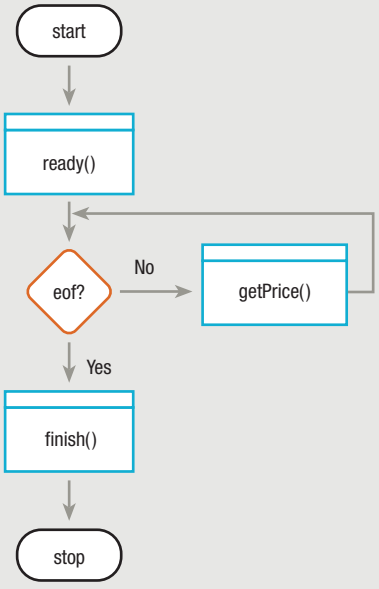
FIGURE 8-26: AVAILABLE ITEMS WITH PRICES FOR MAIL-ORDER COMPANY

```
ITEM NUMBER          ITEM PRICE
106                   0.59
108                   0.99
307                   4.50
405                  15.99
457                  17.50
688                  39.00
```

You *could* write a program in which you read a customer order record and then use the customer's item number as a subscript to pull a price from an array. To use this method, you need an array with at least 689 elements. If a customer orders item 405, the price is found at `validItem[custItemNo]`, which is `validItem[405]`, or the 406th element of the array (because the 0th element is the first element of the array). Such an array would need 689 elements (because the highest item number is 688), but because you sell only six items, you would waste 683 of the memory positions. Instead of reserving a large quantity of memory that remains unused, you can set up this program to use two arrays.

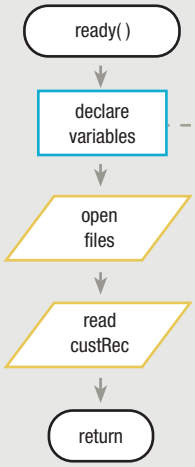
Consider the mainline logic in Figure 8-27 and the `ready()` module in Figure 8-28. Two arrays are set up within the `ready()` module. One contains six elements named `validItem`; all six elements are valid item numbers. The other array also has six elements. These are named `validItemPrice`; all six elements are prices. Each price in this `validItemPrice` array is conveniently and purposely in the same position as the corresponding item number in the other `validItem` array. Two corresponding arrays such as these are **parallel arrays** because each element in one array is associated with the element in the same relative position in the other array.

FIGURE 8-27: MAINLINE LOGIC FOR THE PRICE PROGRAM




```
start
     perform ready()
     while not eof
          perform getPrice()
     endwhile
     perform finish()
stop
```

FIGURE 8-28: THE `ready()` MODULE FOR THE PRICE PROGRAM

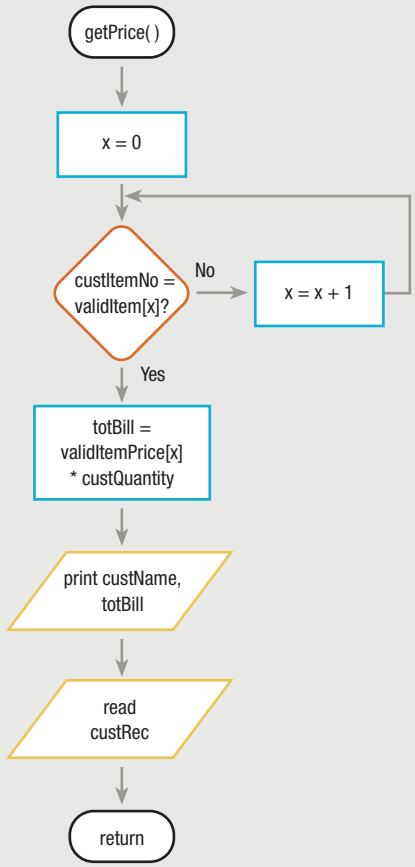



```
custRec
   char custName
   char custAddress
   num custItemNo
   num custQuantity

num validItem[0] = 106
num validItem[1] = 108
num validItem[2] = 307
num validItem[3] = 405
num validItem[4] = 457
num validItem[5] = 688

num validItemPrice[0] = 0.59
num validItemPrice[1] = 0.99
num validItemPrice[2] = 4.50
num validItemPrice[3] = 15.99
num validItemPrice[4] = 17.50
num validItemPrice[5] = 39.00

num totBill
num x
char foundIt
```

```
ready()
     declare variables
     open files
     read custRec
return
```

You can write the `getPrice()` module as shown in Figure 8-29. The general procedure is to read each item number, look through each of the `validItem` values separately, and when a match for the `custItemNo` variable on the input record is found, pull the corresponding parallel price out of the list of `validItemPrice` values.

FIGURE 8-29: THE `getPrice()` MODULE FOR THE PRICE PROGRAM




```
getPrice()
     x = 0
     while custItemNo not equal to validItem[x]
          x = x + 1
     endwhile
     totBill = validItemPrice[x] * custQuantity
     print custName, totBill
     read custRec
return
```

TIP

In this book, you have repeatedly seen the flowchart decision that asks the `eof` question phrased as a positive question ("`eof?`") so the program continues while the answer is No. You also have seen the pseudocode decision that asks the `eof` question in a negative form ("`while not eof`") so that the program continues while the condition is true. Figure 8-29 follows the same convention—the flowchart compares the customer item number to a valid item using a positive question so the loop continues while the answer is No, whereas the pseudocode asks if the customer item number is *not* equal to a valid item number, continuing while the answer is Yes. The logic is the same either way.

You must create a variable to use as a subscript for the arrays. If you name the subscript `x` (see the declaration of `x` in the variable list in Figure 8-28), then you can start by setting `x` equal to 0. Then, if `custItemNo` is the same as `validItem[x]`, you can use the corresponding price from the other table, `validItemPrice[x]`, to calculate the customer's bill.

TIP

Some programmers object to using a cryptic variable name such as `x` because it is not descriptive. These programmers would prefer a name such as `priceIndex`. Others approve of short names like `x` when the variable is used only in a limited area of a program, as it is used here, to step through an array. There are many style issues on which programmers disagree. As a programmer, it is your responsibility to find out what conventions are used among your peers in your organization.

Within the `getPrice()` module, the variable used as a subscript, `x`, is set to 0. If `custItemNo` is *not* the same as `validItem[x]`, then add 1 to `x`. Because `x` now holds the value 1, you next compare the customer's requested item number to `validItem[1]`. The value of `x` keeps increasing, and eventually a match between `custItemNo` and some `validItem[x]` should be found.

After you find a match for the `custItemNo` variable in the `validItem` array, you know that the price of that item is in the same position in the other array, `validItemPrice`. When `validItem[x]` is the correct item, `validItemPrice[x]` must be the correct price.

Suppose that a customer orders item 457, and walk through the flowchart yourself to see if you come up with the correct price.

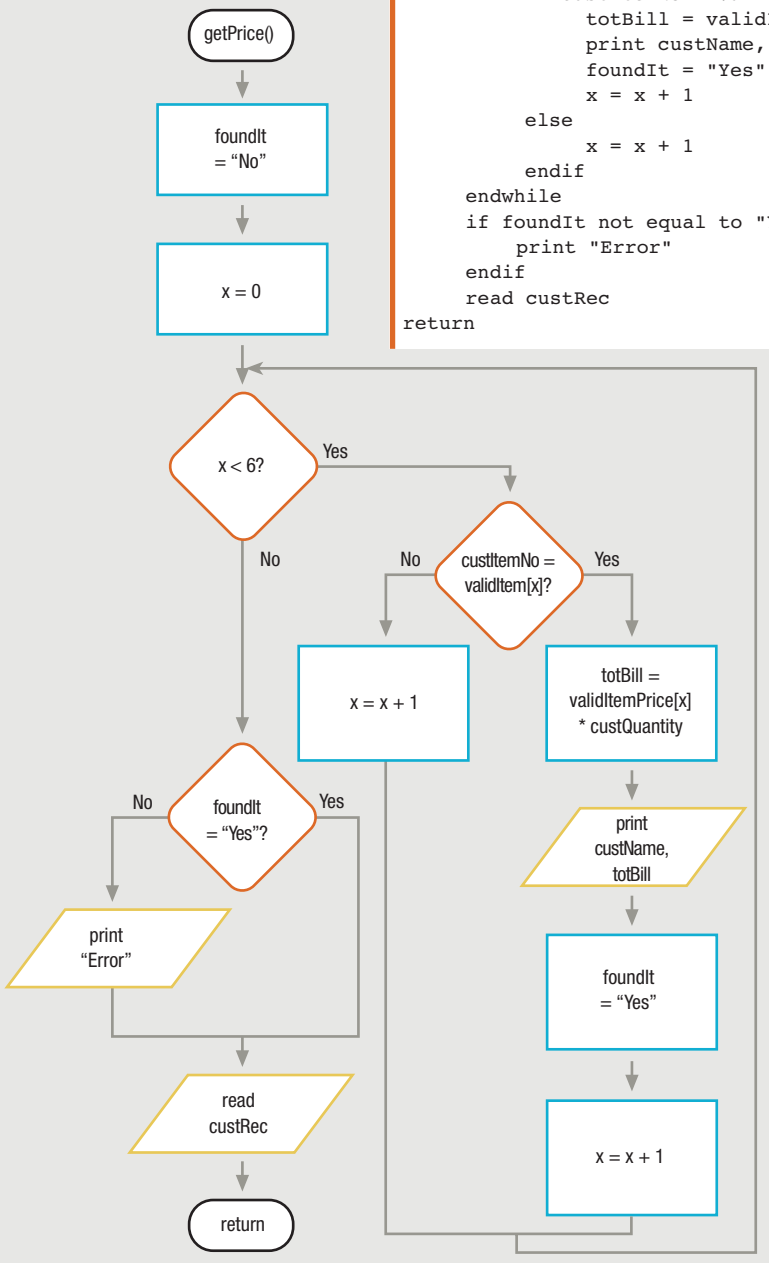
REMAINING WITHIN ARRAY BOUNDS

The `getPrice()` module in Figure 8-29 is not perfect. The logic makes one dangerous assumption: that every customer will order a valid item number. If a customer is looking at an old catalog and orders item 107, the program will never find a match. The value of `x` will just continue to increase until it reaches a value higher than the number of elements in the array. At that point, one of two things happens. When you use a subscript value that is higher than the number of elements in an array, some programming languages stop execution of the program and issue an error message. Other programming languages do not issue an error message but continue to search through computer memory beyond the end of the array. Either way, the program doesn't end elegantly. When you use a subscript that is not within the range of acceptable subscripts, your subscript is said to be **out of bounds**. Ordering a wrong item number is a frequent customer error; a good program should be able to handle the mistake and not allow the subscript to go out of bounds.

You can improve the price-finding program by adding a flag variable and a test to the `getPrice()` module. You can set the flag when you find a valid item in the `validItem` array, and after searching the array, check whether the flag has been altered. See Figure 8-30.

FIGURE 8-30: THE `getPrice()` MODULE USING THE `foundIt` FLAG

```
getPrice()
      foundIt = "No"
      x = 0
      while x < 6
           if custItemNo = validItem[x] then
                totBill = validItemPrice[x] * custQuantity
                print custName, totBill
                foundIt = "Yes"
                x = x + 1
           else
                x = x + 1
           endif
      endwhile
      if foundIt not equal to "Yes" then
          print "Error"
      endif
      read custRec
return
```



In the `ready()` module, you can declare a variable named `foundIt` that acts as a flag. When you enter the `getPrice()` module, you can set `foundIt` equal to "No". Then, after setting `x` to 0, check to see if `x` is still less than 6. If it is, compare `custItemNo` to `validItem[x]`. If they are equal, you know the position of the item's price, and you can use the price to print the customer's bill and set the `foundIt` flag to "Yes". If `custItemNo` is not equal to `validItem[x]`, you increase `x` by 1 and continue to search through the array. When `x` is 6, you shouldn't look through the array anymore; you've gone through all six legitimate items, and you've reached the end. The legitimate subscripts for a six-element array are 0 through 5; your subscript variable should not be used with the array when it reaches 6. If `foundIt` doesn't have a "Yes" in it at this point, it means you never found a match for the ordered item number; you never took the Yes path leading from the `custItemNo = validItem[x]?` question. If `foundIt` does not have "Yes" stored in it, you should print an error message; the customer has ordered a nonexistent item.

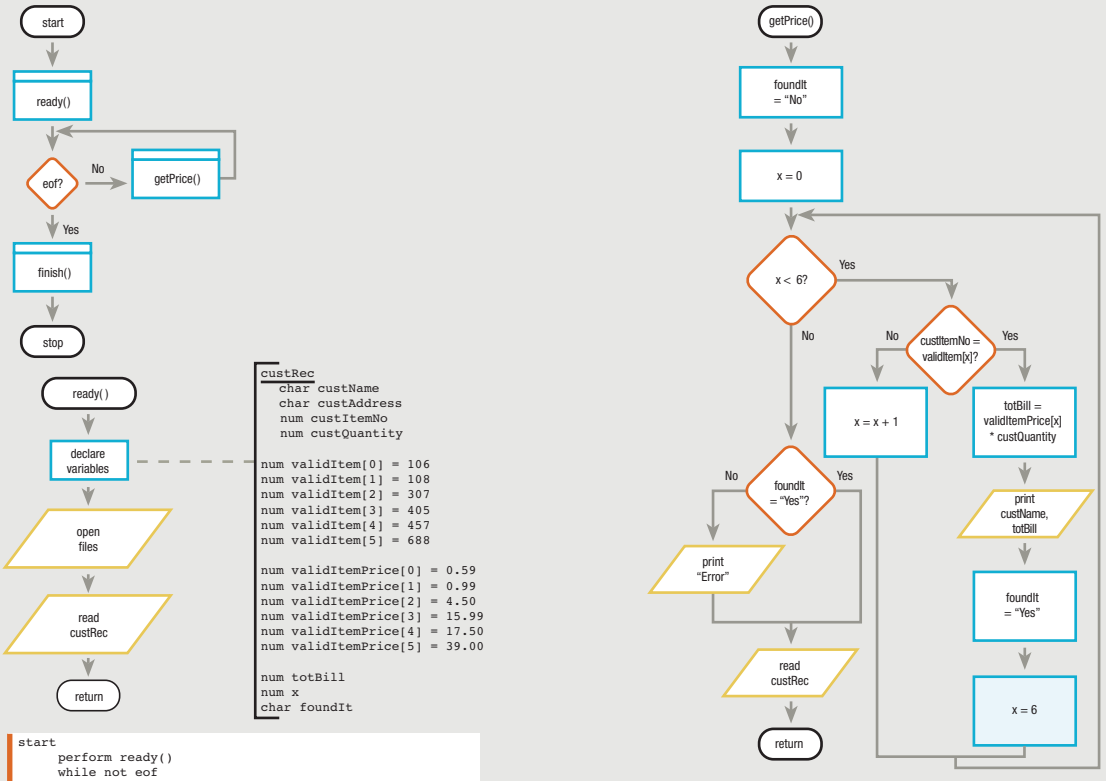
IMPROVING SEARCH EFFICIENCY USING AN EARLY EXIT

The mail-order program is still a little inefficient. The problem is that if lots of customers order item 106 or 108, their price is found on the first or second pass through the loop. The program continues searching through the item array, however, until `x` reaches the value 6. One way to stop the search once the item has been found, and `foundIt` is set to "Yes", is to set `x` to 6 immediately. (Setting a variable to a specific value, particularly when the new value is an abrupt change, is also called **forcing** the variable to that value.) Then, when the program loops back to check whether `x` is still less than 6, the loop will be exited and the program won't bother checking any of the higher item numbers. Leaving a loop as soon as a match is found is called an **early exit**; it improves the program's efficiency. The larger the array, the more beneficial it becomes to exit the searching loop as soon as you find what you're looking for.

TIP Some programmers prefer to use a flag variable for early exits; others think it is fine to force a loop control variable to a value that stops loop execution if that is more convenient.

Figure 8-31 shows the final version of the price program. Notice the improvement to the `getPrice()` module. You search the `validItem` array, element by element. If an item number is not matched in a given location, the subscript is increased and the next location is checked. As soon as an item number is located in the array, you print a line, turn on the flag, and force the subscript to a high number (6) so the program will not check the item number array any further.

FIGURE 8-31: THE FINAL VERSION OF THE PRICE PROGRAM THAT EFFICIENTLY SEARCHES FOR PRICES BASED ON THE ITEM A CUSTOMER ORDERS




```
start
     perform ready()
     while not eof
          perform getPrice()
     endwhile
     perform finish()
stop

ready()
     declare variables
     open files
     read custRec
return

getPrice()
     foundIt = "No"
     x = 0
     while x < 6
          if custItemNo = validItem[x] then
               totBill = validItemPrice[x] * custQuantity
               print custName, totBill
               foundIt = "Yes"
               x = 6
          else
               x = x + 1
          endif
     endwhile
     if foundIt not equal to "Yes" then
          print "Error"
     endif
     read custRec
return

finish()
     close files
return
```

TIP Notice that the price program is most efficient when the most frequently ordered items are stored at the beginning of the array. When you use this technique, only the seldom-ordered items require many cycles through the searching loop before finding a match.

TIP Remember that you can make programs that contain arrays more flexible by declaring a constant to hold the size of the array. Then, whenever you need to refer to the size of the array within the program—for example, when you loop through the array during a search operation—you can use the variable name instead of a hard-coded value like 6. If the program must be altered later to accommodate more or fewer array elements, you need to make only one change—you change the value of the array-size variable where it is declared.

SEARCHING AN ARRAY FOR A RANGE MATCH

In the previous example, customer item numbers needed to exactly match item numbers stored in a table to determine the correct price of an item. Sometimes, however, instead of finding exact matches, programmers want to work with ranges of values in arrays. A **range of values** is any set of contiguous values, such as 1 through 5.

Recall the customer file description from earlier in this chapter, shown again in Figure 8-32. Suppose the company decides to offer quantity discounts, as shown in Figure 8-33.

FIGURE 8-32: MAIL-ORDER CUSTOMER FILE DESCRIPTION

```
MAIL-ORDER CUSTOMER FILE DESCRIPTION
File name: CUSTREC
FIELD DESCRIPTION      DATA TYPE    COMMENTS
Customer name          Character
Address                Character
Item number            Numeric      A 3-digit number
Quantity               Numeric      A value from 1 through 99
```

FIGURE 8-33: DISCOUNTS ON ORDERS BY QUANTITY

```
Number of items ordered                Discount %
1-9                                    0
10-24                                  10
25-48                                  15
49 or more                             25
```

You want to be able to read a record and determine a discount percentage based on the value in the quantity field. One ill-advised approach might be to set up an array with as many elements as any customer might ever order, and store the appropriate discount for each possible number, as shown in Figure 8-34.

FIGURE 8-34: USABLE—BUT INEFFICIENT—DISCOUNT ARRAY

```
num discount[0] = 0
num discount[1] = 0
num discount[2] = 0
.
.
num discount[9] = 0
num discount[10] = 10
.
.
num discount[48] = 15
num discount[49] = 25
num discount[50] = 25
.
.
```

This approach has three drawbacks:

- It requires a very large array that uses a lot of memory.
- You must store the same value repeatedly. For example, each of the first 10 elements receives the same value, 0, because if a customer orders from zero through nine items, there is no discount. Similarly, each of the next 15 elements receives the same value, 10.
- Where do you stop adding array elements? Is a customer order quantity of 75 items enough? What if a customer orders 100 or 1,000 items? No matter how many elements you place in the array, there's always a chance that a customer will order more.

A better approach is to create just four discount array elements, one for each of the possible discount rates, as shown in Figure 8-35.

FIGURE 8-35: SUPERIOR DISCOUNT ARRAY

```
num discount[0] = 0
num discount[1] = 10
num discount[2] = 15
num discount[3] = 25
```

With the new four-element `discount` array, you need a parallel array to search through, to find the appropriate level for the discount. At first, beginning programmers might consider creating an array named `discountRange` and testing whether the quantity ordered equals one of the four stored values. For example:

```
num discountRange[0] = 0 through 9
num discountRange[1] = 10 through 24
num discountRange[2] = 25 through 48
num discountRange[3] = 49 and higher
```

However, you cannot create an array like the previous one. Each element in any array is simply a single variable. Any variable can hold a value such as 6 or 12, but it can't hold every value 6 *through* 12. Similarly, the `discountRange[0]` variable can hold a 1, 2, 9, or any other single value, but it can't hold 0 *through* 9; there is no such numeric value.

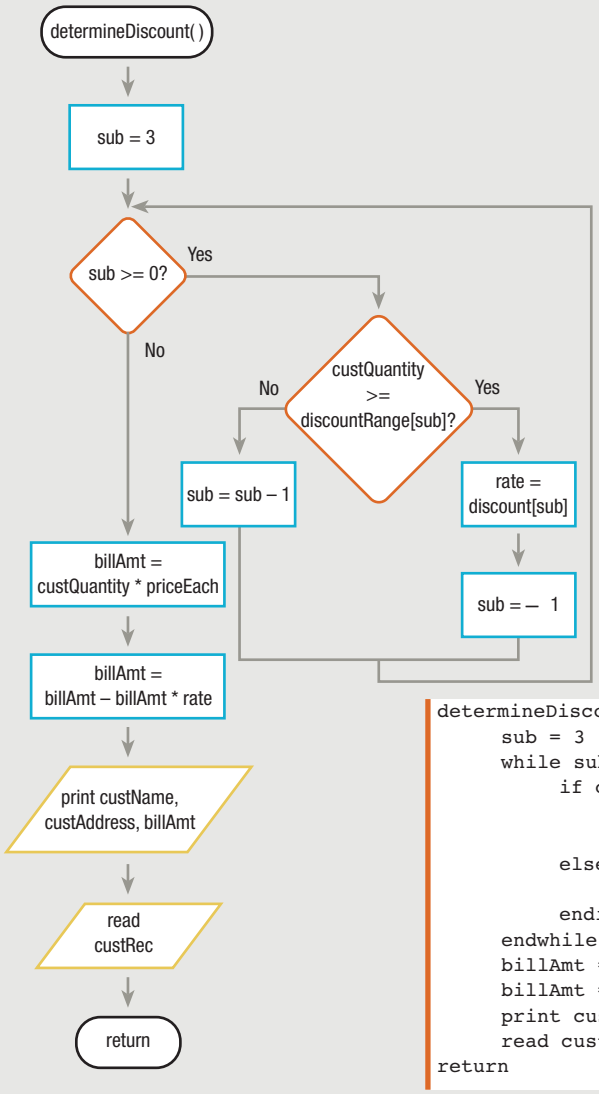
One solution is to create an array that holds only the low-end value of each range, as Figure 8-36 shows.

FIGURE 8-36: THE `discountRange` ARRAY USING LOW END OF EACH DISCOUNT RANGE

```
num discountRange[0] = 0
num discountRange[1] = 10
num discountRange[2] = 25
num discountRange[3] = 49
```

Using such an array, you can compare each `custQuantity` value with each `discountRange` value in turn. You can start with the *last* range limit (`discountRange[3]`). If `custQuantity` is at least that value, 49, the customer gets the highest discount rate (`discount[3]`). If `custQuantity` is not at least `discountRange[3]`, then you check to see if it is at least `discountRange[2]`, or 25. If so, the customer receives `discount[2]`, and so on. If you declare a variable named `rate` to hold the correct discount rate, and another variable named `sub` to use as a subscript, then you can use the `determineDiscount()` module shown in Figure 8-37. This module uses a loop to find the appropriate discount rate for an order, then calculates and prints a customer bill.

FIGURE 8-37: FLOWCHART AND PSEUDOCODE FOR DISCOUNT DETERMINATION




```
determineDiscount()
     sub = 3
     while sub >= 0
          if custQuantity >= discountRange[sub]
               rate = discount[sub]
               sub = – 1
          else
               sub = sub – 1
          endif
     endwhile
     billAmt = custQuantity * priceEach
     billAmt = billAmt – billAmt * rate
     print custName, custAddress, billAmt
     read custRec
return
```

TIP An alternative approach is to store the high end of every range in an array. Then, you start with the *lowest* element and check for values *less than or equal to* each array element value before using the appropriate discount in the parallel array.

When using an array to store range limits, you use a loop to make a series of comparisons that would otherwise require many separate decisions. Your program is written using fewer instructions than would be required if you did not use an array, and modifications to your program will be easier to make in the future.

CHAPTER SUMMARY

- An array is a series or list of variables in computer memory, all of which have the same name but are differentiated with special numbers called subscripts.
- When you declare an array, you declare a programming structure that contains multiple elements, each of which has the same name and the same data type. Each array element has a unique integer subscript indicating how far away the individual element is from the first element.
- You often can use a variable as a subscript to an array, replacing multiple nested decisions.
- You can declare and initialize all of the elements in an array using a single statement that provides a type, a name, and a quantity of elements for the array. You also can initialize array values within an initialization loop.
- You can use a constant array when the final desired values are fixed at the beginning of the program.
- You can load an array from a file. This step is often performed in a program's housekeeping module.
- Searching through an array to find a value you need involves initializing a subscript, using a loop to test each array element, and setting a flag when a match is found.
- In parallel arrays, each element in one array is associated with the element in the same relative position in the other array.
- Your programs should ensure that subscript values do not go out of bounds—that is, take on a value out of the range of legal subscripts.
- When you need to compare a value to a range of values in an array, you can store either the low- or high-end value of each range for comparison.

KEY TERMS

An **array** is a series or list of variables in computer memory, all of which have the same name but are differentiated with special numbers called subscripts.

A **subscript** is a number that indicates the position of a particular item within an array.

An **index** is a subscript.

Each separate array variable is one **element** of the array.

The **size of an array** is the number of elements it can hold.

In a **zero-based array**, the first element is accessed using a subscript of 0.

Off-by-one errors usually occur when you assume an array's first subscript is 1 but it actually is 0.

An **initialization loop** is a loop structure that provides initial values for every element in any array.

Hard-coded values are explicitly assigned.

A **flag** is a variable that you set to indicate whether some event has occurred.

Parallel arrays are two or more arrays in which each element in one array is associated with the element in the same relative position in the other array or arrays.

When you use a subscript that is not within the range of acceptable subscripts, your subscript is said to be **out of bounds**.

Forcing a variable to a value is assigning a specific value to it, particularly when the assignment causes a sudden change in value.

Leaving a loop as soon as a match is found is called an **early exit**.

A **range of values** is any set of contiguous values.

REVIEW QUESTIONS

1. **A subscript is a(n) _____.**
   a. element in an array
   b. alternate name for an array
   c. number that indicates the position of a particular item within an array
   d. number that represents the highest value stored within an array

2. **Each variable in an array must have the same _____ as the others.**
   a. subscript
   b. data type
   c. value
   d. memory location

3. **Each variable in an array is called a(n) _____.**
   a. element
   b. subscript
   c. component
   d. data type

4. **The subscripts of any array are always _____.**
   a. characters
   b. fractions
   c. integers
   d. strings of characters

5. **Suppose you have an array named `number`, and two of its elements are `number[1]` and `number[4]`. You know that _____.**
   a. the two elements hold the same value
   b. the two elements are at the same memory location
   c. the array holds exactly four elements
   d. there are exactly two elements between those two elements

6. **Suppose you want to write a program that reads customer records and prints a summary of the number of customers who owe more than $1,000 each, in each of 12 sales regions. Customer fields include `name`, `zipCode`, `balanceDue`, and `regionNumber`. At some point during record processing, you would add 1 to an array element whose subscript would be represented by _____.**

   a. `name`
   b. `zipCode`
   c. `balanceDue`
   d. `regionNumber`

7. **Arrays are most useful when you use a _____ as a subscript.**

   a. numeric constant
   b. character
   c. variable
   d. file name

8. **Suppose you create a program with a seven-element array that contains the names of the days of the week. In the `housekeeping()` module, you display the day names using a subscript named `dayNum`. In the same program, you display the same array values again in the `finish()` module. In the `finish()` module, you _____ as a subscript to the array.**

   a. must use `dayNum`
   b. can use `dayNum`, but can also use another variable
   c. must not use `dayNum`
   d. must use a numeric constant

9. **Declaring a numeric array sets its individual elements' values to _____.**

   a. zero in every programming language
   b. zero in some programming languages
   c. consecutive digits in every programming language
   d. consecutive digits in some programming languages

10. **A _____ array is one in which the stored values are fixed permanently at the start of the program.**

    a. constant
    b. variable
    c. persistent
    d. continual

11. **When you create an array of values that you explicitly set upon creation, using numeric constants, the values are said to be _____.**

    a. postcoded
    b. precoded
    c. soft coded
    d. hard coded

12. Many arrays contain values that change periodically. For example, a bank program that uses an array containing mortgage rates for various terms might change several times a day. The newest values are most likely _____.

a. typed into the program by a programmer who then recompiles the program before it is used
b. calculated by the program, based on historical trends
c. read into the program from a file that contains the current rates
d. typed in by a clerk each time the program is executed for a customer

13. A _____ is a variable that you set to indicate a True or False state.

a. subscript
b. flag
c. counter
d. banner

14. Two arrays in which each element in one array is associated with the element in the same relative position in the other array are _____ arrays.

a. cohesive
b. perpendicular
c. hidden
d. parallel

15. In most programming languages, the subscript used to access the last element in an array declared as `num values[12]` is _____.

a. 0
b. 11
c. 12
d. 13

16. In most programming languages, a subscript for a 10-element array is out of bounds when it _____.

a. is lower than 0
b. is higher than 9
c. both of these
d. neither a nor b

17. If you perform an early exit from a loop while searching through an array for a match, you _____.

a. quit searching as soon as you find a match
b. quit searching before you find a match
c. set a flag as soon as you find a match, but keep searching for additional matches
d. repeat a search only if the first search was unsuccessful

18. In programming terminology, the values 4 through 20 represent a(n) _____ of values.

a. assortment
b. range
c. diversity
d. collection

19. Each element in a five-element array can hold _____ value(s).

a. one
b. five
c. at least five
d. an unlimited number of

20. After the annual dog show in which the Barkley Dog Training Academy awards points to each participant, the Academy assigns a status to each dog based on the following criteria:

Points Earned	Level of Achievement
0–5	Good
6–7	Excellent
8–9	Superior
10	Unbelievable

The Academy needs a program that compares a dog's points earned with the grading scale, in order to award a certificate acknowledging the appropriate level of achievement. Of the following, which set of values would be most useful for the contents of an array used in the program?

a. 0, 6, 9, 10
b. 5, 7, 8, 10
c. 5, 7, 9, 10
d. any of these

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. This application prints a summary report for an aluminum can recycling drive at a high school. When a student brings in cans, a record is created that contains two fields—the student's year in school (1, 2, 3, or 4) and the number of cans submitted. Student records have not been sorted. The report lists each of the four classes and the total number of cans recycled for each class.

```
start
     perform housekeeping()
     while not eof
          perform accumulateCans()
     endwhile
     perform finish()
stop

housekepping()
     declare variables
         studentRec
             num year
             num cans
         char heading1 = "Can Recycling Report"
         char heading2 = "Year         Cans"
         const num SIZE = 4
         num collected[SIZE] all set to 0
     open files
     read studentRec
return

accumulateCans()
     if year < 1 OR year >= SIZE then
           year = 0
     endif
     collected[SIZE] = collected[SIZE] + cans
     read studentRec
return


finish()
     print heading1
     print heading2
     year = 1
     while year < SIZE
          print year, collected[SIZE]
          year = year + 1
     endwhile
     close files
return
```

2. **This application prints a report card for each student at Pedagogic College. A record has been created for each student containing the student's name, address, and zip code, as well as a numeric average (from 0 through 100) for all the student's work for the semester. A report card is printed for each student containing the student's name, address, city, state, and zip code, as well as a letter grade based on the following scale:**

   90–100 A
   80–89 B
   70–79 C
   60–69 D
   59 and below F

   The student's city and state are determined from the student's zip code. A file is read containing three fields—zip code, city, and state—for each of the 100 zip codes the college serves. For this program, assume that all the student averages have been verified to be between 0 and 100 inclusive and that all the zip codes have been verified as valid and stored in the zip code file.

```
start
     perform housekeeping()
     while not eof
          perform produceGradeReport()
     endwhile
     perform finish()
stop

housekepping()
     declare variables
         studentRec
             char name
             char address
             num zipCode
             num average
         zipRec
             num zip
             char city
             char state
```

```
            const num ZIPSIZE = 100
            num storedZip[ZIPSIZE]
            char storedCity[ZIPSIZE]
            char storedState[SIZE]

            const num GRADESIZE = 5
            const num gradeLevel[1] = 80
            const num gradeLevel[2] = 70
            const num gradeLevel[3] = 60
            const num gradeLevel[4] = 0

            const char grade[0] = 'A'
            const char grade[1] = 'B'
            const char grade[2] = 'C'
            const char grade[3] = 'S'
            const char grade[4] = 'F'

           num zipCodeCount
           char zipFound
           num sub
      open files
      zipCodeCount = 0
      read zipRec
      while not eof
           zip = storedZip[x]
           storedCity[x] = city
           storedState[x] = state
           zipCodeCount = zipCodeCount + 1
          read zipRec
      endwhile
      read studentRec
return
```

```
produceGradeReport()
     print "Grade Report"
     print name
     print address
     zipFound = "N"
     sub = 0
     while zipFound = "N"
          if zipCode = storedZip[ZIPCODESIZE]
               print storedCity[ZIPCODESIZE]
               print storedState[ZIPCODESIZE]
               print zipCode
               zipFound = "Y"
          endif
          sub = sub + 1
      endwhile
      sub = 0
      while sub < GRADESIZE
          if average >= gradeLevel[sub] then
              print grade[sub]
              sub = 0
          endif
      endwhile
      read studentRec
return

finish()
     close files
return
```

EXERCISES

1. **The city of Cary is holding a special census. The census takers collect one record for each citizen, as follows:**

```
CENSUS FILE DESCRIPTION
File name: CENSUS
Not sorted
FIELD DESCRIPTION        DATA TYPE       EXAMPLE
Age                      Numeric         42
Gender                   Character       F
Marital Status           Character       M
Voting District          Numeric         18
```

The voting district field contains a number from 1 through 22.

Design the logic of a program that would produce a count of the number of citizens residing in each of the 22 voting districts.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

2. **The Midville Park District maintains records containing information about players on its soccer teams. Each record contains a player's first name, last name, and team number. The teams are:**

```
Soccer Teams
TEAM NUMBER          TEAM NAME
1                    Goal Getters
2                    The Force
3                    Top Guns
4                    Shooting Stars
5                    Midfield Monsters
```

Design the logic for a report that lists all players along with their team numbers and team names.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

3. **Create the logic for a program that produces a count of the number of players registered for each team listed in Exercise 2.**

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

4. **An elementary school contains 30 classrooms numbered 1 through 30. Each classroom can contain any number of students up to 35. Each student takes an achievement test at the end of the school year and receives a score from 0 through 100. One record is created for each student in the school; each record contains a student ID, classroom number, and score on the achievement test. Design the logic for a program that lists the total points scored for each of the 30 classroom groups.**
   a. Design the output for this program; create either sample output or a print chart.
   b. Create the hierarchy chart.
   c. Draw the flowchart.
   d. Write the pseudocode.

5. **Modify Exercise 4 so that each classroom's average of the test scores prints, rather than each classroom's total.**

6. **The school in Exercises 4 and 5 maintains a file containing the teacher's name for each classroom. Each record in this file contains a room number from 1 through 30, and the last name of the teacher. Modify Exercise 5 so that the correct teacher's name appears on the list with his or her class's average.**

7. **A fast-food restaurant sells the following products:**

```
Fast-Food Items
PRODUCT           PRICE
Cheeseburger      2.49
Pepsi             1.00
Chips              .59
```

   Design the logic for a program that reads a record containing a customer number and item name, and then prints either the correct price or the message "Sorry, we do not carry that" as output.
   a. Draw the flowchart.
   b. Write the pseudocode.

8. **Each week, the home office for a fast-food restaurant franchise distributes a file containing new prices for the items it carries. The file contains the item name and current price. Design the logic for a program that loads the current values into arrays. Then, the program reads a record containing a customer number and item name, and prints either the correct price or the message "Sorry, we do not carry that" as output.**
   a. Draw the flowchart.
   b. Write the pseudocode.

9. The city of Redgranite is holding a special census. The census takers collect one record for each citizen as follows:

```
CENSUS FILE DESCRIPTION
File name: CENSUS
Not sorted
FIELD DESCRIPTION        DATA TYPE          EXAMPLE
Age                      Numeric            42
Gender                   Character          F
Marital Status           Character          M
Voting District          Numeric            18
```

Design the logic of a program that produces a count of the number of citizens in each of the following age groups: under 18, 18 through 30, 31 through 45, 46 through 64, and 65 and older.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

10. A company desires a breakdown of payroll by department. Input records are as follows:

```
PAYROLL FILE DESCRIPTION
File name: PAY
FIELD DESCRIPTION          DATA TYPE          EXAMPLE
Employee Last Name         Character          Dykeman
Employee First Name        Character          Ellen
Department                 Numeric            3
Hourly Salary              Numeric            18.50
Hours Worked               Numeric            40
```

Input records are organized in alphabetical order by employee, *not* in department number order.

The output is a list of the seven departments in the company (numbered 1 through 7) and the total gross payroll (rate times hours) for each department.

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

11. Modify Exercise 10 so that the report lists department names as well as numbers. The department names are:

```
Department Names and Numbers
DEPARTMENT NUMBER       DEPARTMENT NAME
1                       Personnel
2                       Marketing
3                       Manufacturing
4                       Computer Services
5                       Sales
6                       Accounting
7                       Shipping
```

12. Modify the report created in Exercise 11 so that it prints a line of information for each employee before printing the department summary at the end of the report. Each detail line must contain the employee's name, department number, department name, hourly wage, hours worked, gross pay, and withholding tax.

Withholding taxes are based on the following percentages of gross pay:

```
Withholding Taxes
WEEKLY SALARY           WITHHOLDING %
0.00-200.00             10
200.01-350.00           14
350.01-500.00           18
500.01-up               22
```

13. The Perfect Party Catering Company keeps records concerning the events it caters as follows:

```
EVENT FILE DESCRIPTION
File name: CATER
FIELD DESCRIPTION          DATA TYPE       EXAMPLE
Event Number               Numeric         15621
Host Name                  Character       Profeta
Month                      Numeric         10
Day                        Numeric         15
Year                       Numeric         2007
Meal Selection             Numeric         4
Number of Guests           Numeric         150
```

Additionally, a meal file contains the meal selection codes (such as 4), name of entree (such as "Roast beef"), and current price per guest (such as 19.50). Assume there are eight numbered meal records in the file.

Design the logic for a program that produces a report that lists each event number, host name, date, meal, guests, gross total price for the party, and price for the party after discount. Print the month *name*—for example, "October"—rather than "10". Print the meal selection—for example, "Roast beef"—rather than "4". The gross total price for the party is the price per guest for the meal times the number of guests. The final price includes a discount based on the following table:

```
Discounts for Large Parties
NUMBER OF GUESTS       DISCOUNT
1–25                   $0
26–50                  $75
51–100                 $125
101–250                $200
251 and over           $300
```

a. Design the output for this program; create either sample output or a print chart.
b. Create the hierarchy chart.
c. Draw the flowchart.
d. Write the pseudocode.

14. *Daily Life Magazine* wants an analysis of the demographic characteristics of its readers. The Marketing Department has collected reader survey records in the following format:

```
Magazine Reader FILE DESCRIPTION
File name: MAGREADERS
Not sorted
FIELD DESCRIPTION        DATA TYPE          EXAMPLE
Age                      Numeric            31
Gender                   Character          M
Marital Status           Character          S
Annual Income            Numeric            45000
```

a. Create the logic for a program that would produce a count of readers by age groups as follows: under 20, 20–29, 30–39, 40–49, and 50 and older.
b. Create the logic for a program that would produce a count of readers by gender within age group—that is, under 20 females, under 20 males, under 30 females, under 30 males, and so on.
c. Create the logic for a program that would produce a count of readers by income groups as follows: under $20,000, $20,000–$24,999, $25,000–$34,999, $35,000–$49,999, and $50,000 and up.

15. Glen Ross Vacation Property Sales employs seven salespeople as follows:

Salespeople

ID NUMBER	NAME
103	Darwin
104	Kratz
201	Shulstad
319	Fortune
367	Wickert
388	Miller
435	Vick

When a salesperson makes a sale, a record is created including the date, time, and dollar amount of the sale, as follows: The time is expressed in hours and minutes, based on a 24-hour clock. The sale amount is expressed in whole dollars.

SALE FIELD DESCRIPTION

File name: SALES

FIELD DESCRIPTION	DATA TYPE	EXAMPLE
Salesperson	Numeric	319
Month	Numeric	02
Day	Numeric	21
Year	Numeric	2008
Time	Numeric	1315
Sale Amount	Numeric	95900

Salespeople earn a commission that differs for each sale, based on the following rate schedule:

Commission Rates

SALE AMOUNT	RATE
$0–$50,000	.04
$50,001–$125,000	.05
$125,001–$200,000	.06
$200,001 and up	.07

Design the output and either the flowchart or pseudocode that produces each of the following reports:

a. A report listing each salesperson number, name, total sales, and total commissions
b. A report listing each month of the year as both a number and a word (for example, “01 January”), and the total sales for the month for all salespeople
c. A report listing total sales as well as total commissions earned by all salespeople for each of the following time frames, based on hour of the day: 00–05, 06–12, 13–18, and 19–23

DETECTIVE WORK

1. **Find at least five definitions of an array.**
2. **Using Help in Microsoft Excel or another spreadsheet program, discover how to use the `vlookup()` function. How is this function used?**
3. **What is a Fibonacci sequence? How do Fibonacci sequences apply to natural phenomena? Why do programmers use an array when working with this mathematical concept?**

UP FOR DISCUSSION

1. **A train schedule is an everyday, real-life example of an array. Think of at least four more.**
2. **Every element in an array always has the same data type. Why is this necessary?**

9 ADVANCED ARRAY MANIPULATION

After studying Chapter 9, you should be able to:

- Describe the need for sorting data
- Swap two values in computer memory
- Use a bubble sort
- Use an insertion sort
- Use a selection sort
- Use indexed files
- Use a linked list
- Use multidimensional arrays

UNDERSTANDING THE NEED FOR SORTING RECORDS

When you store data records, they exist in some sort of order; that is, one record is first, another second, and so on. When records are in **sequential order**, they are arranged one after another on the basis of the value in some field. Examples of records in sequential order include employee records stored in numeric order by Social Security number or department number, or in alphabetic order by last name or department name. Even if the records are stored in a random order—for example, the order in which a data-entry clerk felt like entering them—they still are in *some* order, although probably not the order desired for processing or viewing. When this is the case, the data records need to be **sorted**, or placed in order, based on the contents of one or more fields. When you sort data, you can sort either in **ascending order**, arranging records from lowest to highest value within a field, or **descending order**, arranging records from highest to lowest value. Here are some examples of occasions when you would need to sort records:

- A college stores students' records in ascending order by student ID number, but the registrar wants to view the data in descending order by credit hours earned so he can contact students who are close to graduation.
- A department store maintains customer records in ascending order by customer number, but at the end of a billing period, the credit manager wants to contact customers whose balances are 90 or more days overdue. The manager wants to list these overdue customers in descending order by the amount owed, so the customers maintaining the biggest debt can be contacted first.
- A sales manager keeps records for her salespeople in alphabetical order by last name, but needs to list the annual sales figure for each salesperson so she can determine the median annual sale amount. The **median** value in a list is the value of the middle item when the values are listed in order; it is not the same as the arithmetic average, or **mean**.

TIP

To help you understand the difference between median and mean, consider the following five values: 0, 7, 10, 11, 12. The median value is the middle position's value (when the values are listed in numerical order), or 10. The mean, however, is the sum (40) divided by the number of values (5), which evaluates to 8. The median is used as a statistic in many cases because it represents a more typical case—half the values are below it and half are above it. Unlike the median, the mean is skewed by a few very high or low values.

TIP

Sorting is usually reserved for a relatively small number of data items. If thousands of customer records are stored, and they frequently need to be accessed in order based on different fields (alphabetical order by customer name one day, zip code order the next), the records would probably not be sorted at all, but would be indexed or linked. You learn about indexing and linking later in this chapter.

When computers sort data, they always use numeric values when making comparisons between values. This is clear when you sort records by fields such as a numeric customer ID or balance due. However, even alphabetic sorts are numeric, because everything that is stored in a computer is stored as a number using a series of 0s and 1s. In every popular computer coding scheme, "B" is numerically one greater than "A", and "y" is numerically one less than "z". Unfortunately, whether "A" is represented by a number that is greater or smaller than the number representing "a" depends on your system. Therefore, to obtain the most useful and accurate list of alphabetically sorted records, either the data-entry personnel should be consistent in the use of capitalization, or the programmer should convert all the data to consistent capitalization.

TIP

Because "A" is always less than "B", alphabetic sorts are always considered ascending sorts. The most popular coding schemes include ASCII, Unicode, and EBCDIC. Each is a code in which a number represents every computer character. Appendix B contains additional information about these codes.

TIP

It's possible that as a professional programmer, you will never have to write a program that sorts records, because organizations can purchase prewritten, or "canned," sorting programs. Additionally, many popular language compilers come with built-in methods that can sort data for you. However, it is beneficial to understand the sorting process so that you can write a special-purpose sort when needed. Understanding sorting also improves your array-manipulating skills.

UNDERSTANDING HOW TO SWAP TWO VALUES

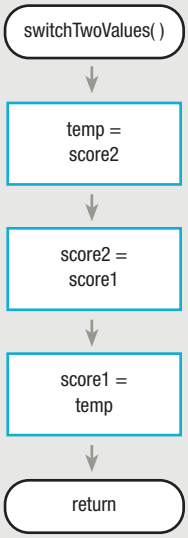
Many sorting techniques have been developed. A concept that is central to most sorting techniques involves **swapping** two values. When you swap the values stored in two variables, you reverse their positions; you set the first variable equal to the value of the second, and the second variable equal to the value of the first. However, there is a trick to reversing any two values. Assume you have declared two variables as follows:

```
num score1 = 90
num score2 = 85
```

You want to swap the values so that `score1` is 85 and `score2` is 90. If you first assign `score1` to `score2` using a statement such as `score2 = score1`, both `score1` and `score2` hold 90 and the value 85 is lost. Similarly, if you first assign `score2` to `score1` using a statement such as `score1 = score2`, both variables hold 85 and the value 90 is lost.

The solution to swapping the values lies in creating a temporary variable to hold one of the scores; then, you can accomplish the swap as shown in Figure 9-1. First, the value in `score2`, 85, is assigned to a temporary holding variable, named `temp`. Then, the `score1` value, 90, is assigned to `score2`. At this point, both `score1` and `score2` hold 90. Then, the 85 in `temp` is assigned to `score1`. Therefore, after the swap process, `score1` holds 85 and `score2` holds 90.

FIGURE 9-1: A MODULE THAT SWAPS TWO VALUES




```
switchTwoValues()
     temp = score2
     score2 = score1
     score1 = temp
return
```

TIP In Figure 9-1, you can accomplish identical results by assigning `score1` to `temp`, assigning `score2` to `score1`, and finally assigning `temp` to `score2`.

USING A BUBBLE SORT

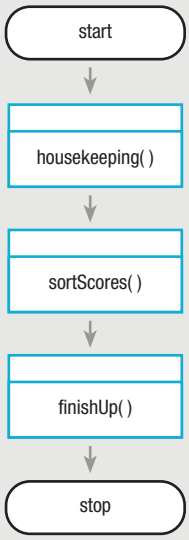
One of the simplest sorting techniques to understand is a bubble sort. You can use a bubble sort to arrange records in either ascending or descending order. In a **bubble sort**, items in a list are compared with each other in pairs, and when an item is out of order, it swaps values with the item below it. With an ascending bubble sort, after each adjacent pair of items in a list has been compared once, the largest item in the list will have "sunk" to the bottom. After many passes through the list, the smallest items rise to the top like bubbles in a carbonated drink.

TIP A bubble sort is sometimes called a **sinking sort**.

Assume that five student test scores are stored in a file and you want to sort them in ascending order for printing. To begin, you can define three modules in the mainline logic, as shown in Figure 9-2: `housekeeping()`, `sortScores()`, and `finishUp()`.

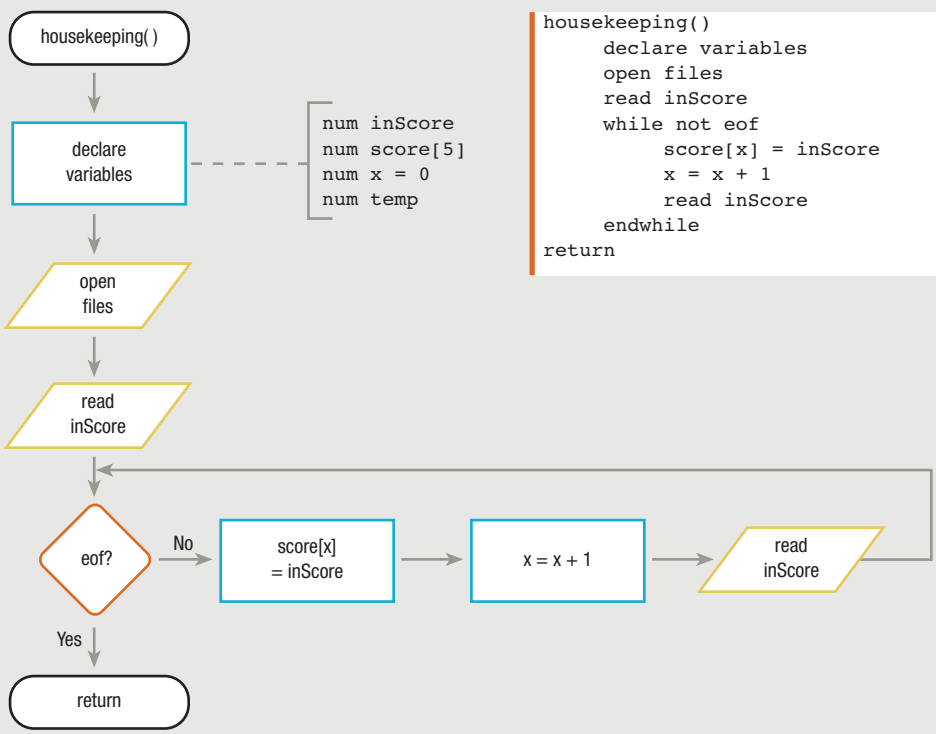
The `housekeeping()` module of this program defines a variable name for each individual score in the input file `(inScore)` and sets up an array of five elements `(score)` in which to store the five scores. The entire file is then read into memory, one score at a time, and each score is stored in one element of the array. See Figure 9-3.

FIGURE 9-2: MAINLINE LOGIC FOR THE SCORE-SORTING PROGRAM




```
start
     perform housekeeping()
     perform sortScores()
     perform finishUp()
stop
```

FIGURE 9-3: THE `housekeeping()` MODULE FOR THE SCORE-SORTING PROGRAM




```
housekeeping()
     declare variables
     open files
     read inScore
     while not eof
          score[x] = inScore
          x = x + 1
          read inScore
     endwhile
return
```

When the program logic leaves the `housekeeping()` module and enters the `sortScores()` module, five scores have been placed in the array. For example, assume they are:

```
score[0] = 90
score[1] = 85
score[2] = 65
score[3] = 95
score[4] = 75
```

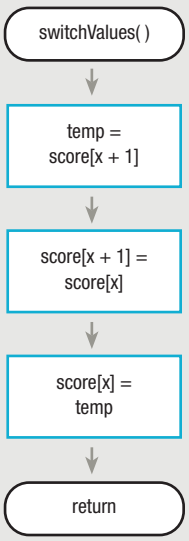
To begin sorting this list of scores, you compare the first two scores. If they are out of order, you reverse their positions, or swap their values. That is, if `score[0]` is more than `score[1]`, then `score[0]` assumes the value 85 and `score[1]` takes on the value 90. After this swap, the scores are in slightly better order than they were originally.

You could reverse the values of `score[0]` and `score[1]` using the following code:

```
switchValues()
     temp = score[1]
     score[1] = score[0]
     score[0] = temp
return
```

However, this code segment's usefulness is limited because it switches only the first two elements of the `score` array. If you use hard values such as 0 and 1 as subscripts, then you must write additional statements to swap the values in positions 1 and 2, 2 and 3, and 3 and 4. A more universal `switchValues()` module is shown in Figure 9-4. This module switches *any* two adjacent elements in the `score` array when the variable `x` represents the position of the first of the two elements, and the value `x + 1` represents the subsequent position.

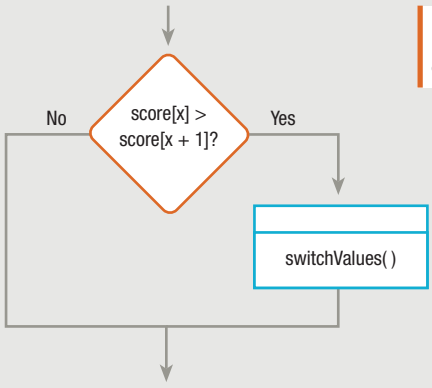
FIGURE 9-4: THE `switchValues()` MODULE THAT SWAPS ANY TWO ADJACENT VALUES IN AN ARRAY




```
switchValues()
     temp = score[x + 1]
     score[x + 1] = score[x]
     score[x] = temp
return
```

For an ascending sort, you need to perform the `switchValues()` module whenever any given element `x` of the `score` array has a value greater than the next element, `x + 1`, of the `score` array. For any `x`, if the xth element is not greater than the element at position `x + 1`, the switch should not take place. For example, when `score[x]` is 90 and `score[x + 1]` is 85, a swap should occur. On the other hand, when `score[x]` is 65 and `score[x + 1]` is 95, then no swap should occur. See Figure 9-5.

FIGURE 9-5: DECISION SHOWING WHEN TO CALL `switchValues()` MODULE



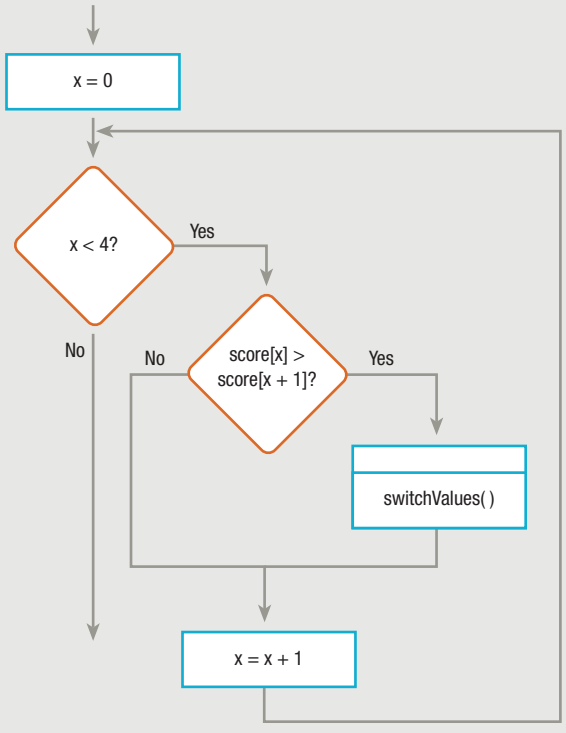

```
if score[x] > score[x + 1] then
     perform switchValues()
endif
```

TIP For a descending sort, in which you want to end up with the highest value first, write the decision so that you perform the switch when `score[x]` is *less than* `score[x + 1]`.

TIP In the sort, you could use either greater than (>) or greater than or equal to (>=) to compare adjacent values. Using the greater than comparison to determine when to switch values in the sort is more efficient than using greater than or equal to, because if two compared values are equal, there is no need to swap them.

You must execute the decision `score[x] > score[x + 1]?` four times—when `x` is 0, 1, 2, and 3. You should not attempt to make the decision when `x` is 4, because then you would compare `score[4]` to `score[4 + 1]`, and there is no valid position for `score[5]` in the array. (Remember that the valid subscripts in a five-element array are the values 0 through 4.) Therefore, Figure 9-6 shows the correct loop, which compares the first two array elements, swapping them if they are out of order, increases the subscript, and continues to test array element values and make appropriate swaps while the array subscript, `x`, is less than 4.

FIGURE 9-6: LOOP THAT COMPARES ENTIRE LIST OF FIVE SCORES, MAKING NECESSARY SWAPS




```
x = 0
while x < 4
     if score[x] > score[x + 1] then
          perform switchValues()
     endif
     x = x + 1
endwhile
```

If you have these original scores:

```
score[0] = 90
score[1] = 85
score[2] = 65
score[3] = 95
score[4] = 75
```

then the logic proceeds like this:

1. Set `x` to 0.
2. The value of `x` is less than 4, so enter the loop.
3. Compare `score[x]`, 90, to `score[x + 1]`, 85. The two scores are out of order, so they are switched.

The list is now:

```
score[0] = 85
score[1] = 90
score[2] = 65
score[3] = 95
score[4] = 75
```

4. After the swap, add 1 to `x` so `x` is 1.
5. Return to the top of the loop. The value of `x` is less than 4, so enter the loop a second time.
6. Compare `score[x]`, 90, to `score[x + 1]`, 65. These two values are out of order, so swap them.

Now the result is:

```
score[0] = 85
score[1] = 65
score[2] = 90
score[3] = 95
score[4] = 75
```

7. Add 1 to `x`, so `x` is now 2.
8. Return to the top of the loop. The value of `x` is less than 4, so enter the loop.
9. Compare `score[x]`, 90, to `score[x + 1]`, 95. These values are in order, so no switch is made.
10. Add 1 to `x`, making it 3.
11. Return to the top of the loop. The value of `x` is less than 4, so enter the loop.
12. Compare `score[x]`, 95, to `score[x + 1]`, 75. These two values are out of order, so switch them.

Now the list is as follows:

```
score[0] = 85
score[1] = 65
score[2] = 90
score[3] = 75
score[4] = 95
```

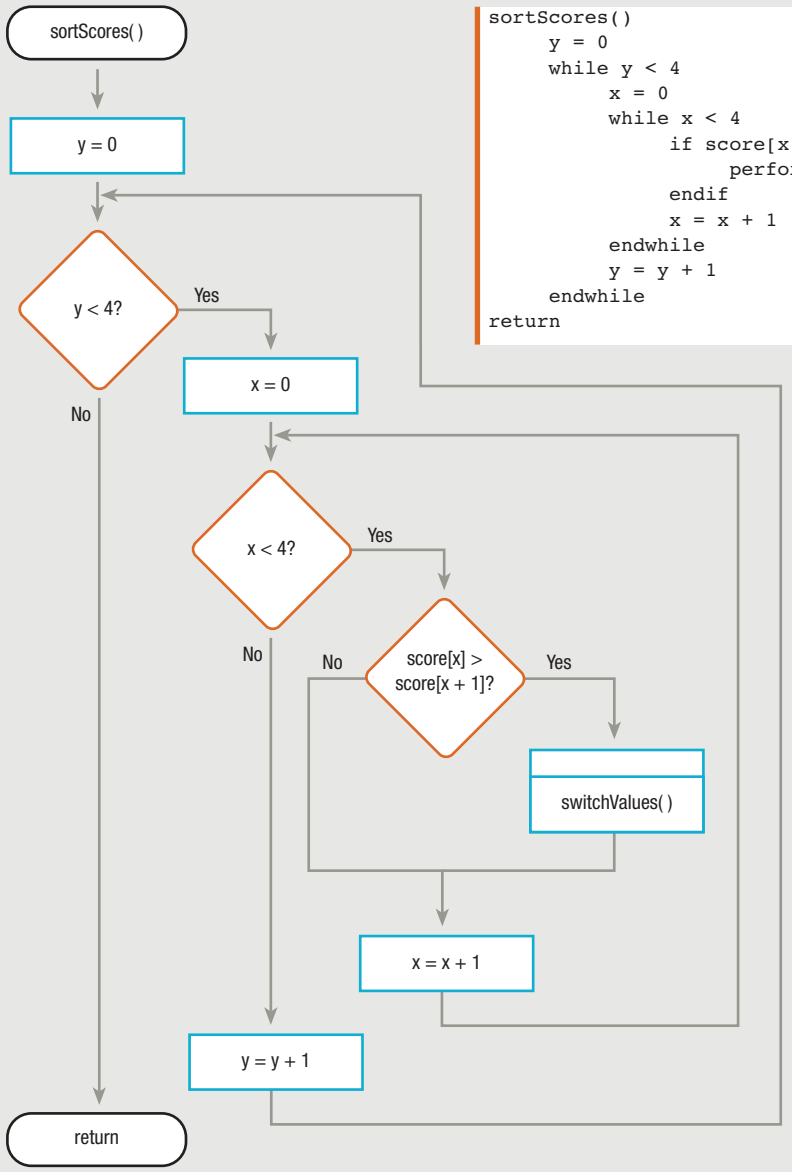
13. Add 1 to `x`, making it 4.
14. Return to the top of the loop. The value of `x` is 4, so do not enter the loop again.

When `x` reaches 4, every element in the list has been compared with the one adjacent to it. The highest score, a 95, has "sunk" to the bottom of the list. However, the scores still are not in order. They are in slightly better ascending order than they were to begin with, because the largest value is at the bottom of the list, but they are still out of order. You need to repeat the entire procedure illustrated in Figure 9-6 so that 85 and 65 (the current `score[0]` and `score[1]` values) can switch places, and 90 and 75 (the current `score[2]` and `score[3]` values) can switch places. Then, the scores will be 65, 85, 75, 90, and 95. You will have to perform the procedure to go through the list yet again to swap the 85 and 75.

As a matter of fact, if the scores had started out in the worst possible order (95, 90, 85, 75, 65), the process shown in Figure 9-6 would have to take place four times. In other words, you would have to pass through the list of values four times, making appropriate swaps, before the numbers would appear in perfect ascending order. You need to place the loop in Figure 9-6 within another loop that executes four times.

Figure 9-7 shows the complete logic for the `sortScores()` module. The `sortScores()` module uses a loop control variable named `y` to cycle through the list of scores four times. The `y` variable is added to the variable list declared in `housekeeping()`. With an array of five elements, it takes four comparisons to work through the array once, comparing each pair, and it takes four sets of those comparisons to ensure that every element in the entire array is in sorted order.

FIGURE 9-7: THE `sortScores()` MODULE




```
sortScores()
     y = 0
     while y < 4
          x = 0
          while x < 4
               if score[x] > score[x + 1] then
                    perform switchValues()
               endif
               x = x + 1
          endwhile
          y = y + 1
     endwhile
return
```

When you sort the elements in an array this way, you use nested loops—an inner loop within an outer loop. The general rule is that, whatever the number of elements in the array, the greatest number of pair comparisons you need to make during each loop is *one less* than the number of elements in the array. You use an inner loop to make the pair comparisons. In addition, the number of times you need to process the list of values is *one less* than the number of elements in the array. You use an outer loop to control the number of times you walk through the list. As an example, if you want to sort a 10-element array, you make nine pair comparisons on each of nine rotations through the loop, executing a total of 81 score comparison statements.

TIP

In many cases, you do not want to sort a single data item such as a score. Instead, you might want to sort data records that contain fields such as ID number, name, and score, placing the records in score order. The sorting procedure remains basically the same, but you need to store entire records in an array. Then, you make your comparisons based on a single field, but you make your swaps using entire records.

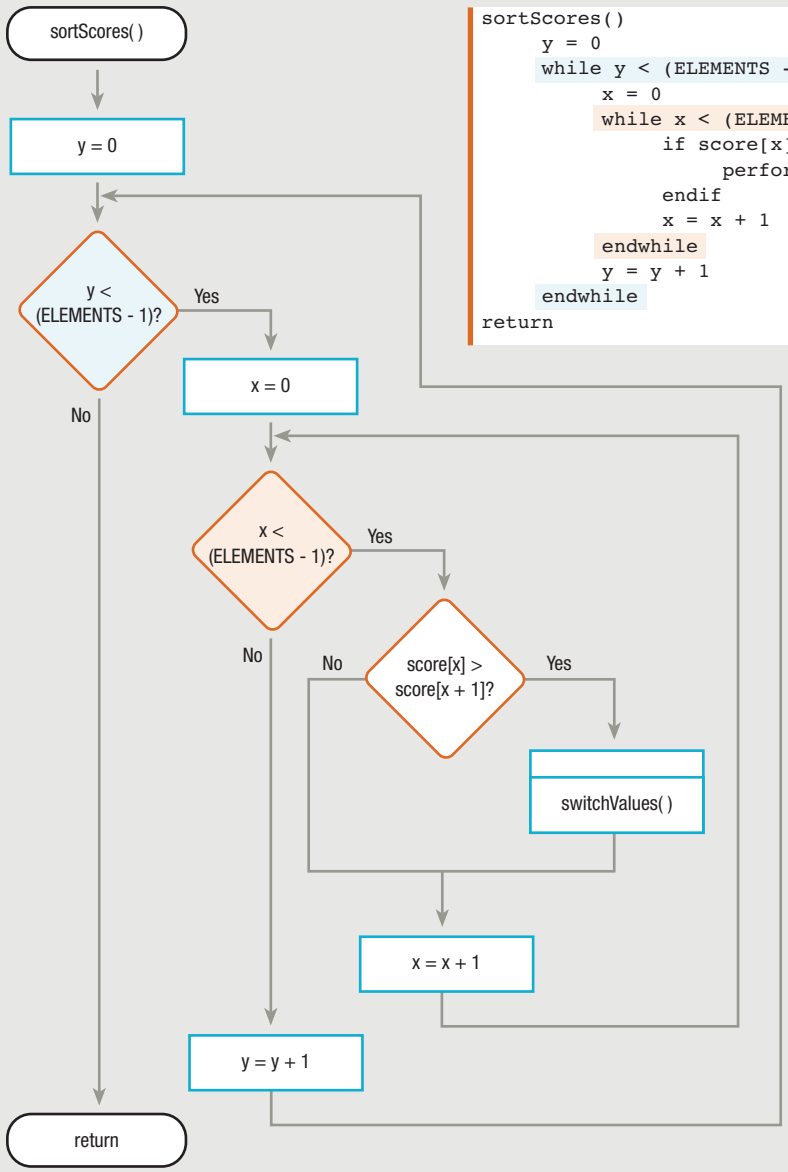
REFINING THE BUBBLE SORT BY USING A CONSTANT FOR THE ARRAY SIZE

Keep in mind that when performing a bubble sort, you need to perform one fewer pair comparison than you have elements. You also pass through the list of elements one fewer time than you have elements. In Figure 9-7, you sorted a five-element loop, so you performed the inner loop while `x` was less than 4 and the outer loop while `y` was less than 4. You can add a refinement that makes the sorting logic easier to understand. When performing a bubble sort on an array, you compare two separate loop control variables with a value that equals the number of elements in the list. If the number of elements in the array is stored in a constant named `ELEMENTS`, the general logic for a bubble sort is shown in Figure 9-8.

To use the logic shown in Figure 9-8, you must declare `ELEMENTS` along with any other variables and constants in the `housekeeping()` module. There you can set the value of `ELEMENTS` to 5, because you know there are five elements in the array to be sorted. Besides being useful for sorting, the `ELEMENTS` constant is also useful in any module that prints the scores, sums them, or performs any other activity with the list. For example, Figure 9-9 shows an entire program that uses a bubble sort. Not only does the `sortScores()` module use `ELEMENTS` to control the number of passes through the array to perform the sort, but the `finishUp()` module in Figure 9-9 also uses the `ELEMENTS` constant to control the print loop. One advantage to using a named constant instead of an unnamed, literal constant (such as 5) in your program is that if you modify the program array to accommodate more or fewer scores in the future, you can simply change the value in the named constant once where it is defined. Then, you do not need to alter every instance of a literal constant number throughout the program; the named location automatically holds the correct value in each place in the program where it is used.

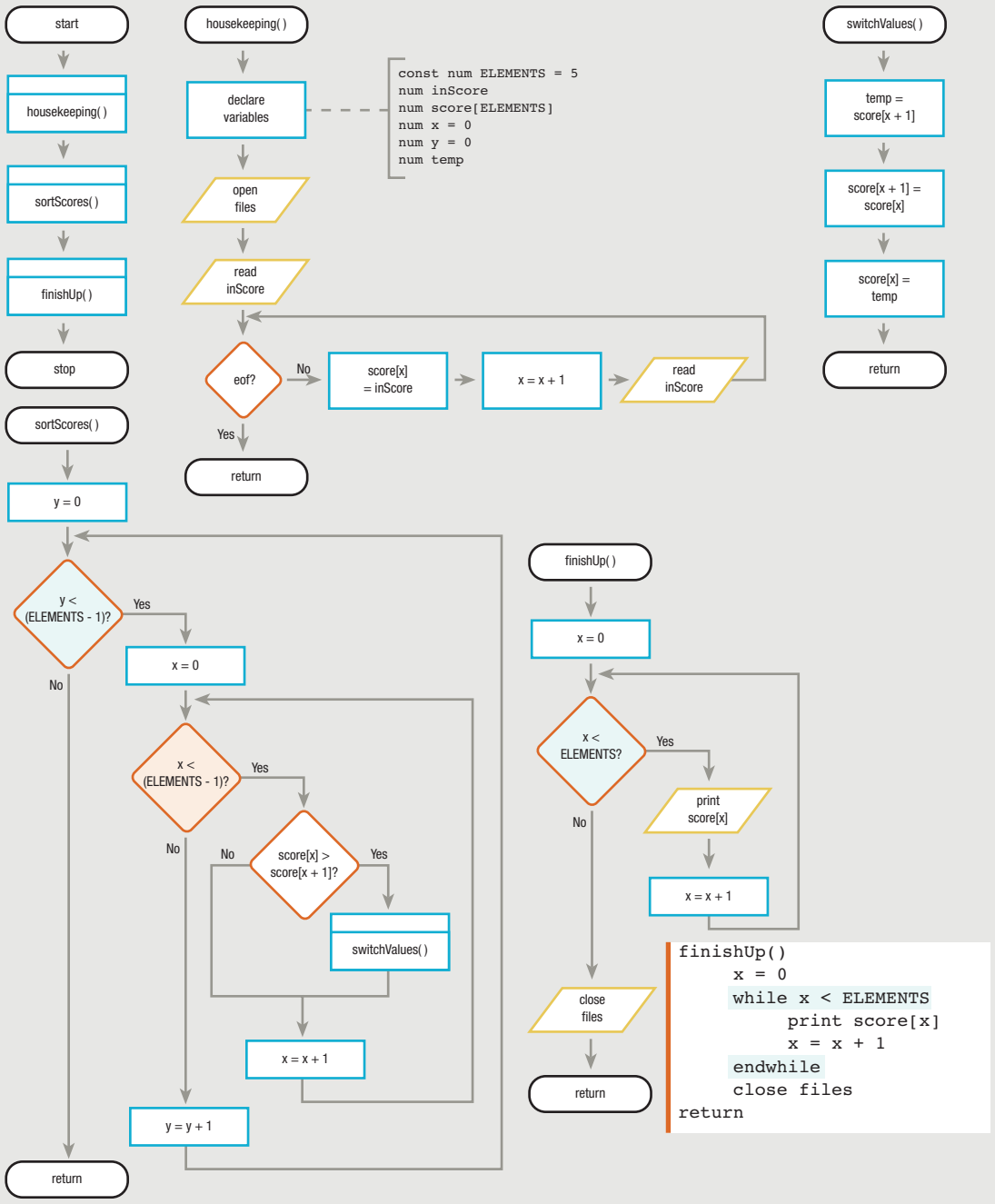
Figure 9-9 shows pseudocode for the `finishUp()` module only; pseudocode for the other modules has been shown in previous figures in this chapter.

FIGURE 9-8: GENERIC BUBBLE SORT MODULE USING A NAMED CONSTANT FOR NUMBER OF ELEMENTS




```
sortScores()
     y = 0
     while y < (ELEMENTS - 1)
          x = 0
          while x < (ELEMENTS - 1)
               if score[x] > score[x + 1] then
                    perform switchValues()
               endif
               x = x + 1
          endwhile
          y = y + 1
     endwhile
return
```

FIGURE 9-9: A COMPLETE SCORE-SORTING PROGRAM THAT PRINTS THE SORTED SCORES

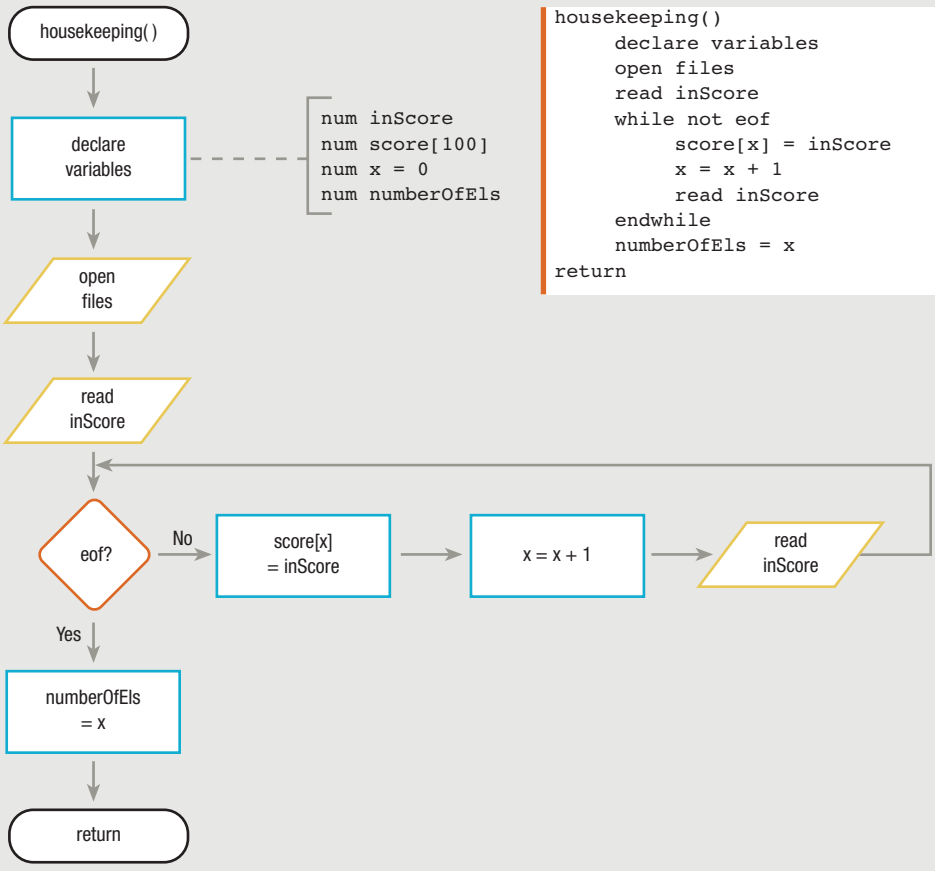


SORTING A LIST OF VARIABLE SIZE

In the score-sorting program in Figure 9-9, an `ELEMENTS` constant was initialized to the number of elements to be sorted near the start of the program—within the `housekeeping()` module. Sometimes, you don't want to create a constant such as `ELEMENTS` at the start of the program. You might not know how many array elements will hold valid values—for example, sometimes when you run the program, the input file contains only three or four scores to sort, and sometimes it contains 20. In other words, what if the size of the list to be sorted varies? Rather than initializing a constant to a fixed value, you can count the input scores, and then give a variable the value of the number of array elements to use after you know how many scores exist.

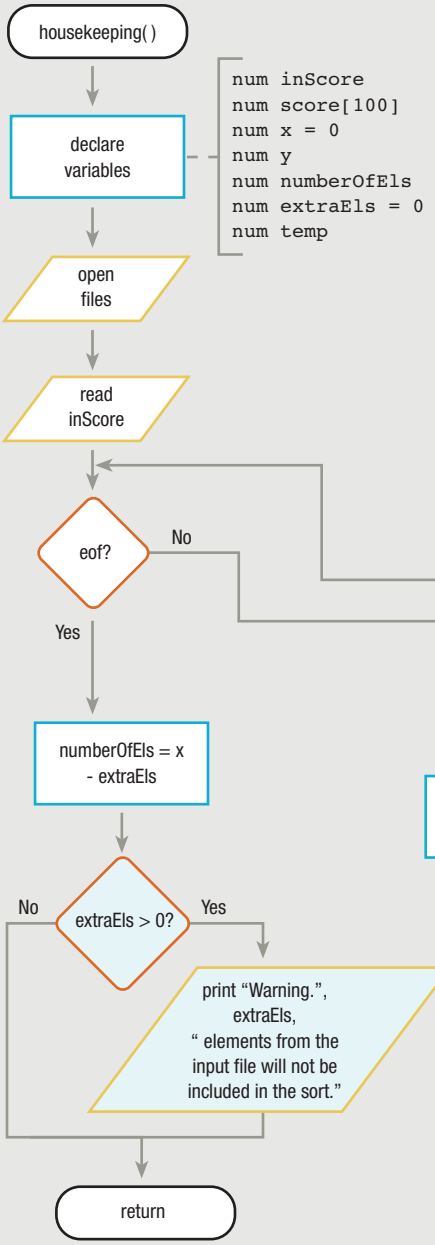
To keep track of the number of elements stored in an array, you can create a `housekeeping()` module such as the one shown in Figure 9-10. When you read each `inScore` during `housekeeping()`, you increase `x` by 1 in order to place each new score into a successive element of the `score` array. In this example, the `score` array is created to hold 100 elements, a number larger than you anticipate you will need. The variable `x` is initialized to 0. After you read one `inScore` value and place it in the first element of the array, `x` is increased to 1. After a second score is read and placed in `score[1]`, `x` is increased to 2, and so on. After you reach `eof`, `x` holds the number of elements that have been placed in the array, so you can set a variable named `numberOfEls` to the value of `x`. With this approach, it doesn't matter if there are not enough `inScore` values to fill the array. You simply make one fewer pair comparison than the number of the value held in `numberOfEls`. Using this technique, you avoid always making a larger fixed number of pair comparisons. For example, if there are 35 scores in the input file, `numberOfEls` will be set to 35 in the `housekeeping()` module, and when the program sorts, it will use 35 as a cutoff point for the number of pair comparisons to make. The sorting program will never make pair comparisons on array elements 36 through 100—those elements will just "sit there," never being involved in a comparison or swap.

FIGURE 9-10: THE `housekeeping()` MODULE FOR A SCORE-SORTING PROGRAM THAT ACCOMMODATES A VARIABLE-SIZE INPUT FILE



When you count the input records and use the `numberOfEls` variable, it does not matter if there are not enough scores to fill the array. However, it does matter if there are more scores than the array can hold. Every array must have a finite size, and it is an error to try to store data past the end of the array. When you don't know how many elements will be stored in an array, you must overestimate the number of elements you declare. If the number of scores in the `score` array can be 100 or fewer, then you can declare the `score` array to have a size of 100, and you can use 100 elements or fewer. Figure 9-11 shows the pseudocode that provides one possibility for an additional improvement to the `housekeeping()` module in Figure 9-10. If you use the logic in Figure 9-11, you read `inScore` values until `eof`, but if the array subscript `x` equals or exceeds 100, you display a warning message and do not attempt to store any additional `inScore` values in the `score` array. When a program uses the `housekeeping()` logic shown in Figure 9-11, after `x` becomes 100, only a warning message is displayed—no new elements are added to the array. To provide additional information to the user, extra elements are counted when they exist, and a message is displayed so the user understands exactly how many unsorted elements exist in the input file.

FIGURE 9-11: FLOWCHART AND PSEUDOCODE FOR `housekeeping()` THAT PREVENTS OVEREXTENDING THE ARRAY



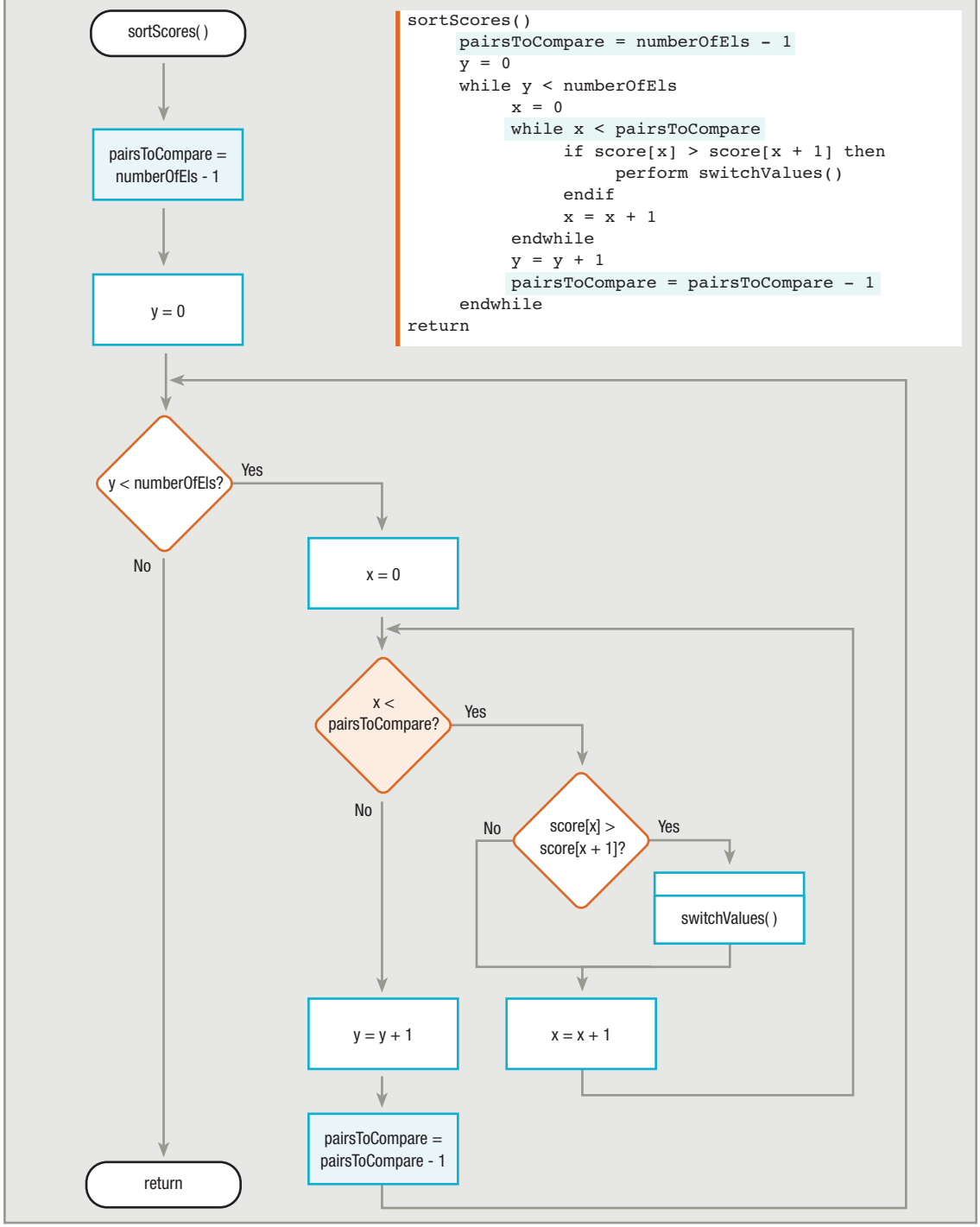

```
housekeeping()
      declare variables
      open files
      read inScore
      while not eof
            if x >= 100 then
                  print "Warning! Too many scores"
                  extraEls = extraEls + 1
            else
                  score[x] = inScore
            endif
            x = x + 1
            read inScore
      endwhile
      numberOfEls = x - extraEls
      if extraEls > 0 then
            print "Warning.", extraEls,
            " elements from the input file will not be
                  included in the sort."
      endif
return
```

REFINING THE BUBBLE SORT BY REDUCING UNNECESSARY COMPARISONS

You can make additional improvements to the bubble sort created in the previous sections. As illustrated in Figure 9-8, when performing the sorting module for a bubble sort, you pass through a list, making comparisons and swapping values if two values are out of order. If you are performing an ascending sort, then after you have made one pass through the list, the largest value is guaranteed to be in its correct final position at the bottom of the list. Similarly, the second-largest element is guaranteed to be in its correct second-to-last position after the second pass through the list, and so on. If you continue to compare every element pair in the list on every pass through the list, you are comparing elements that are already guaranteed to be in their final correct position.

On each pass through the array, you can afford to stop your pair comparisons one element sooner. In other words, after the first pass through the list, there is no longer a need to check the bottom element; after the second pass, there is no need to check the two bottom elements. You can avoid comparing these already-in-place values by creating a new variable, `pairsToCompare`, and setting it equal to the value of `numberOfEls - 1`. On the first pass through the list, every pair of elements is compared, so `pairsToCompare` *should* equal `numberOfEls - 1`. In other words, with five array elements to sort, there are four pairs to compare. For each subsequent pass through the list, `pairsToCompare` should be reduced by 1, because after the first pass there's no need to check the bottom element anymore. See Figure 9-12 to examine the use of the `pairsToCompare` variable.

FIGURE 9-12: FLOWCHART AND PSEUDOCODE FOR `sortScores()` MODULE USING `pairsToCompare` VARIABLE




```
sortScores()
     pairsToCompare = numberOfEls - 1
     y = 0
     while y < numberOfEls
          x = 0
          while x < pairsToCompare
               if score[x] > score[x + 1] then
                    perform switchValues()
               endif
               x = x + 1
          endwhile
          y = y + 1
          pairsToCompare = pairsToCompare - 1
     endwhile
return
```

REFINING THE BUBBLE SORT BY ELIMINATING UNNECESSARY PASSES

A final improvement that could be made to the bubble sort module in Figure 9-12 is one that reduces the number of passes through the array. If array elements are so badly out of order that they are in reverse order, then it takes many passes through the list to place it in order; it takes one fewer pass than the value in `numberOfEls` to complete all the comparisons and swaps needed to get the list in order. However, when the array elements are in order or nearly in order to start, all the elements might be correctly arranged after only a few passes through the list. All subsequent passes result in no swaps. For example, assume the original scores are as follows:

```
score[0] = 65
score[1] = 75
score[2] = 85
score[3] = 90
score[4] = 95
```

The bubble sort module in Figure 9-12 would pass through the array list four times, making four sets of pair comparisons. It would always find that each `score[x]` is *not* greater than the corresponding `score[x + 1]`, so no switches would ever be made. The scores would end up in the proper order, but they *were* in the proper order in the first place; therefore, a lot of time would be wasted.

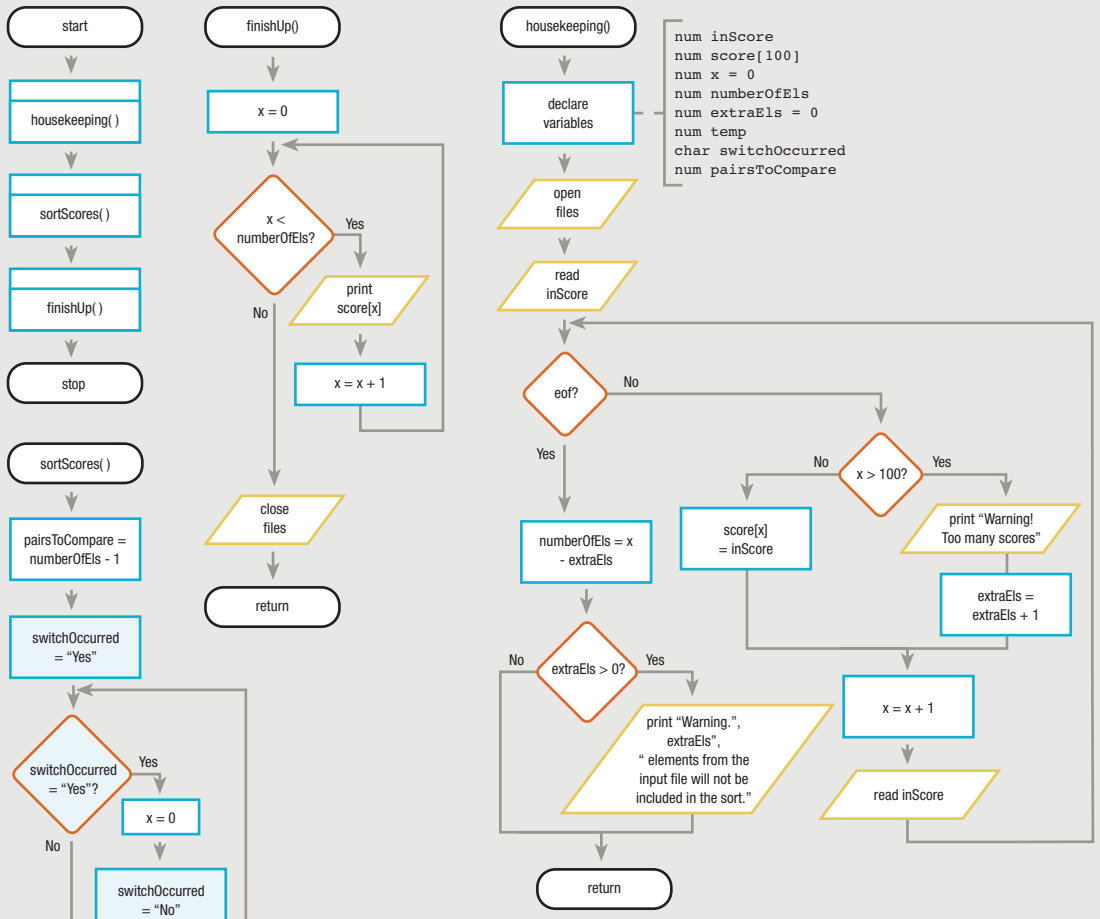
A possible remedy is to add a flag variable that you set to a "continue" value on any pass through the list in which any pair of elements is swapped (even if just one pair), and that holds a different "finished" value when no swaps are made—that is, all elements in the list are already in the correct order. For example, you can create a variable named `switchOccurred` and set it to "No" at the start of each pass through the list. You can change its value to "Yes" each time the `switchValues()` module is performed (that is, each time a switch is necessary).

If you ever "make it through" the entire list of pairs without making a switch, the `switchOccurred` flag will *not* have been set to "Yes", meaning that no switch has occurred and that the array elements must already be in the correct order. This *might* be on the first or second pass through the array list, or it might not be until a much later pass. If the array elements are already in the correct order at any point, there is no need to make more passes through the list. You can stop making passes through the list when `switchOccurred` is "No" after a complete trip through the array.

Figure 9-13 illustrates a module that sorts scores and uses a `switchOccurred` flag. At the beginning of the `sortScores()` module, initialize `switchOccurred` to "Yes" before entering the comparison loop the first time. Then, immediately set `switchOccurred` to "No". When a switch occurs—that is, when the `switchValues()` module executes—set `switchOccurred` to "Yes".

Figure 9-13 shows pseudocode for the `sortScores()` module only; pseudocode for the other modules has been shown in previous figures in this chapter.

FIGURE 9-13: BUBBLE SORT WITH `switchOccurred` FLAG




```
sortScores()
     pairsToCompare = numberOfEls - 1
     switchOccurred = "Yes"
     while switchOccurred = "Yes"
          x = 0
          switchOccurred = "No"
          while x < pairsToCompare
               if score[x] > score[x + 1] then
                    perform switchValues()
                    switchOccurred = "Yes"
               endif
               x = x + 1
          endwhile
          pairsToCompare = pairsToCompare - 1
     endwhile
return
```

TIP

With the addition of the flag variable in Figure 9-13, you no longer need the variable `y`, which was keeping track of the number of passes through the list. Instead, you just keep going through the list until you can make a complete pass without any switches. For a list that starts in perfect order, you go through the loop only once. For a list that starts in the *worst* possible order, you will make a switch with every pair each time through the loop until `pairsToCompare` has been reduced to 0. In this case, on the last pass through the loop, `x` is set to 1, `switchOccurred` is set to "No", `x` is no longer less than or equal to `pairsToCompare`, and the loop is exited.

USING AN INSERTION SORT

The bubble sort works well and is relatively easy for novice array users to understand and manipulate, but even with all the improvements you added to the original bubble sort in previous sections, it is actually one of the least efficient sorting methods available. An insertion sort provides an alternate method for sorting data, and it usually requires fewer comparison operations.

TIP

Although a sort (such as the bubble sort) might be inefficient, it is easy to understand. When programming, you frequently weigh the advantages of using simple solutions against writing more complicated ones that perform more efficiently.

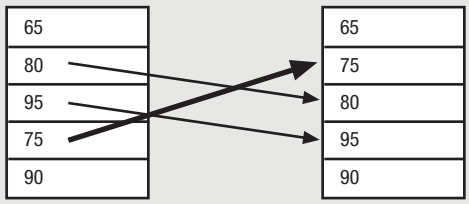
As with the bubble sort, when using an **insertion sort**, you also look at each pair of elements in an array. When you find an element that is smaller than the one before it (for an ascending sort), this element is "out of order." As soon as you locate such an element, search the array backward from that point to see where an element smaller than the out-of-order element is located. At that point, you open a new position for the out-of-order element by moving each subsequent element down one position. Then, you insert the out-of-order element into the newly opened position.

For example, consider these scores:

```
score[0] = 65
score[1] = 80
score[2] = 95
score[3] = 75
score[4] = 90
```

If you want to rearrange the scores in ascending order using an insertion sort, you begin by comparing `score[0]` and `score[1]`, which are 65 and 80, respectively. You determine that they are in order, and leave them alone. Then, you compare `score[1]` and `score[2]`, which are 80 and 95, and leave them alone. When you compare `score[2]`, 95, and `score[3]`, 75, you determine that the 75 is "out of order." Next, you look backward from the `score[3]` of 75. The value of `score[2]` is not smaller than `score[3]`, nor is `score[1]`; however, because `score[0]` is smaller than `score[3]`, `score[3]` should follow `score[0]`. So you store `score[3]` in a temporary variable, then move `score[1]` and `score[2]` "down" the list to higher subscripted positions. You move `score[2]`, 95, to the `score[3]` position. Then, you move `score[1]`, 80, to the `score[2]` position. Finally, you assign the value of the temporary variable, 75, to the `score[1]` position. Figure 9-14 diagrams the movements as 75 moves up to the second position and 80 and 95 move down.

FIGURE 9-14: MOVEMENT OF THE VALUE "75" TO A "BETTER" ARRAY POSITION IN AN INSERTION SORT



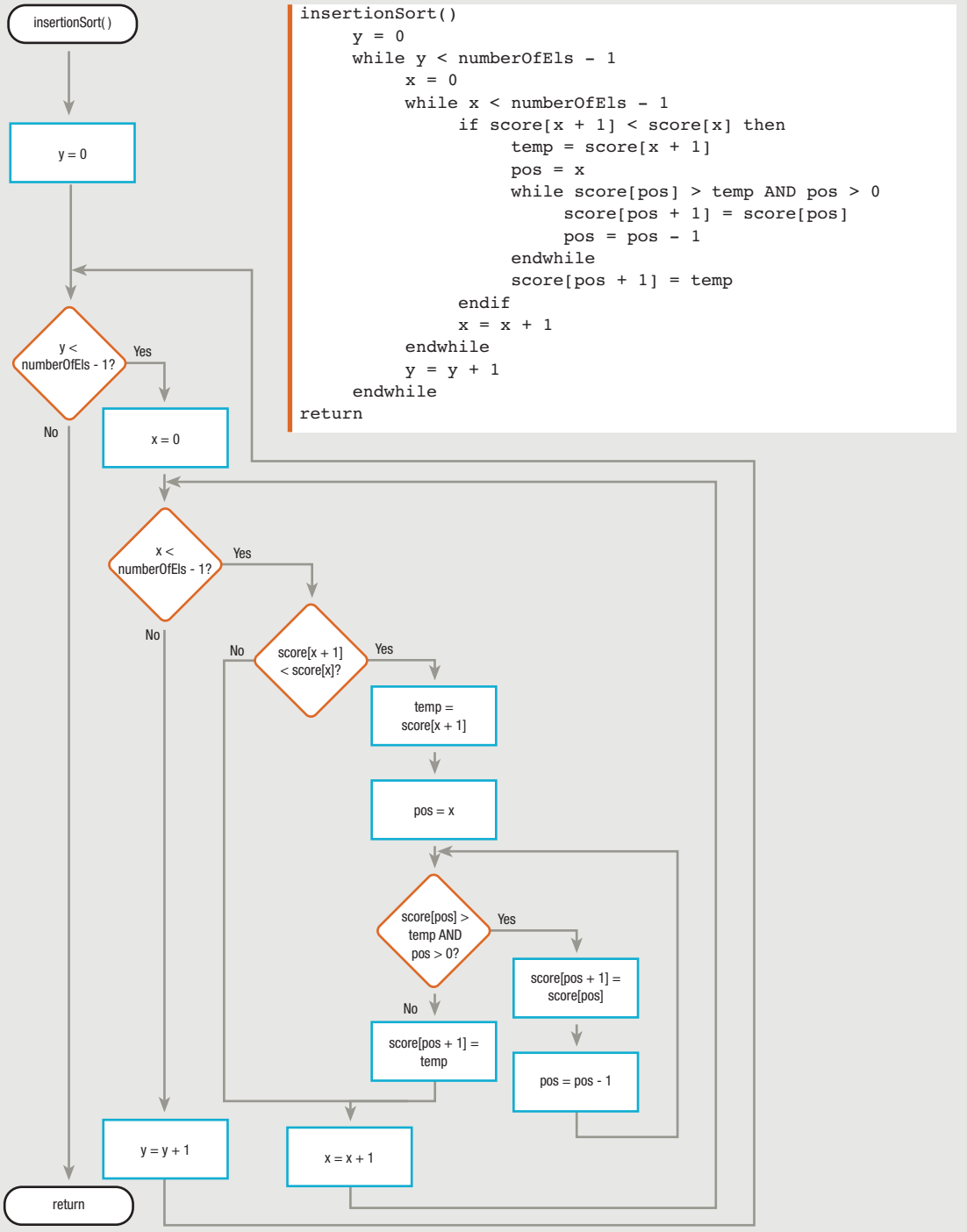
After the sort finds the first element that was out of order and inserts it in a "better" location, the results are:

```
score[0] = 65
score[1] = 75
score[2] = 80
score[3] = 95
score[4] = 90
```

You then continue down the list, comparing each pair of variables. A complete insertion sort module is shown in Figure 9-15.

The logic for the insertion sort is slightly more complicated than that for the bubble sort, but the insertion sort is more efficient because, for the average out-of-order list, it takes fewer "switches" to put the list in order.

FIGURE 9-15: SAMPLE INSERTION SORT MODULE



USING A SELECTION SORT

A selection sort provides another sorting option. In an ascending **selection sort**, the first element in the array is assumed to be the smallest. Its value is stored in a variable—for example, `smallest`—and its position in the array, 0, is stored in another variable—for example, `position`. Then, every subsequent element in the array is tested. If one with a smaller value than `smallest` is found, `smallest` is set to the new value, and `position` is set to that element's position. After the entire array has been searched, `smallest` holds the smallest value and `position` holds its position.

The element originally in `position[0]` is then switched with the `smallest` value, so at the end of the first pass through the array, the lowest value ends up in the first position, and the value that was in the first position is where the smallest value used to be.

For example, assume you have the following list of scores:

```
score[0] = 95
score[1] = 80
score[2] = 75
score[3] = 65
score[4] = 90
```

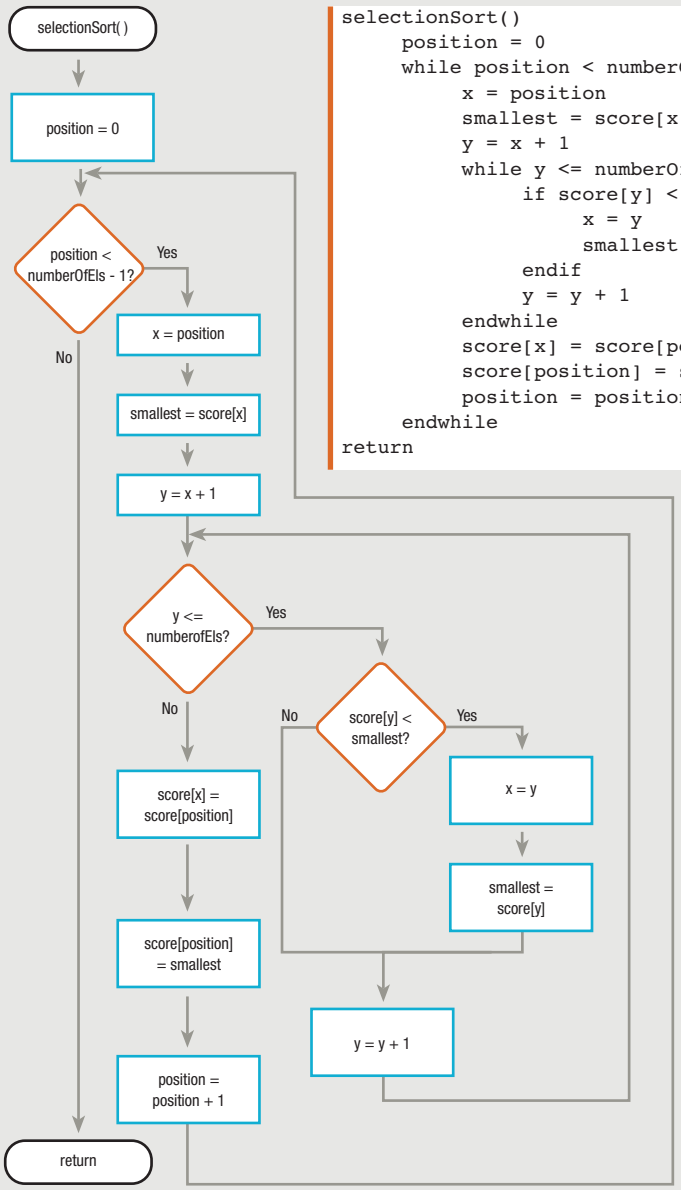
First, you place 95 in `smallest`. Then check `score[1]`; it's less than 95, so place 1 in `position` and 80 in `smallest`. Then test `score[2]`; it's smaller than `smallest`, so place 2 in `position` and 75 in `smallest`. Then test `score[3]`; because it is smaller than `smallest`, place 3 in `position` and 65 in `smallest`. Finally, check `score[4]`; it *isn't* smaller than `smallest`.

So at the end of the first pass through the list, `position` is 3 and `smallest` is 65. You move the value 95 to `score[position]`, or `score[3]`, and the value of `smallest`, 65, to `score[0]`. The list becomes:

```
score[0] = 65
score[1] = 80
score[2] = 75
score[3] = 95
score[4] = 90
```

Now that the smallest value is in the first position, you repeat the whole procedure starting with the second array element, `score[1]`. After you have passed through the list `numberOfEls - 1` times, all elements will be in the correct order. Walk through the logic shown in Figure 9-16.

FIGURE 9-16: SAMPLE SELECTION SORT MODULE




```
selectionSort()
     position = 0
     while position < numberOfEls - 1
          x = position
          smallest = score[x]
          y = x + 1
          while y <= numberOfEls
               if score[y] < smallest then
                    x = y
                    smallest = score[y]
               endif
               y = y + 1
          endwhile
          score[x] = score[position]
          score[position] = smallest
          position = position + 1
     endwhile
return
```

Like the insertion sort, the selection sort almost always requires fewer switches than the bubble sort, but the variables might be a little harder to keep track of, because the logic is a little more complex. Thoroughly understanding at least one of these sorting techniques provides you with a valuable tool for arranging data and increases your understanding of the capabilities of arrays.

USING INDEXED FILES

Sorting a list of five scores does not require significant computer resources. However, many data files contain thousands of records, and each record might contain dozens of data fields. Sorting large numbers of data records requires considerable time and computer memory. When a large data file needs to be processed in ascending or descending order based on some field, it is usually more efficient to store and access records based on their logical order than to sort and access them in their physical order. When records are stored, they are stored in some physical order. For example, if you write the names of 10 friends, each one on an index card, the stack of cards has a **physical order**—that is, a "real" order. You can arrange the cards alphabetically by the friends' last names, chronologically by age of the friendship, or randomly by throwing the cards in the air and picking them up as you find them. Whichever way you do it, the records still follow each other in *some* order. In addition to their current physical order, you can think of the cards as having a **logical order**; that is, a virtual order, based on any criterion you choose—from the tallest friend to the shortest, from the one who lives farthest away to the closest, and so on. Sorting the cards in a new physical order can take a lot of time; using the cards in their logical order without physically rearranging them is often more efficient.

A common method of accessing records in logical order is to use an index. Using an index involves identifying a key field for each record. A record's **key field** is the field whose contents make the record unique among all records in a file. For example, multiple employees can have the same last name, first name, salary, or street address, but each employee possesses a unique Social Security number, so a Social Security number field might make a good key field for a personnel file. (Because of security issues, a company-assigned employee ID number might make a better key field.) Similarly, a product number makes a good key field on an inventory file.

When you **index** records, you store a list of key fields paired with the storage address for the corresponding data record. When you use an index, you can store records on a **random-access storage device**, such as a disk, from which records can be accessed in any logical order. Each record can be placed in any physical location on the disk, and you can use the index as you would use the index in the back of a book. If you pick up a 600-page American history text because you need some facts about Betsy Ross, you do not want to start on page one and work your way through the text. Instead, you turn to the index, discover that Betsy Ross is discussed on page 418, and go directly to that page.

As pages in a book have numbers, computer memory and storage locations have **addresses**. In Chapter 1, you learned that every variable has a numeric address in computer memory; likewise, every data record on a disk has a numeric address where it is stored. You can store records in any physical order on the disk, but the index can find the records in order based on their addresses. For example, you might store a list of employees on a disk in the order in which they were hired. However, you often need to process the employees in Social Security number order. When adding a new employee to such a file, you can physically place the employee anywhere there is room available on the disk. Her Social Security number is inserted in proper order in the index, along with the physical address where her record is located.

TIP You do not need to determine a record's exact physical address in order to use it. A computer's operating system takes care of locating available storage for your records.

You can picture an index based on Social Security numbers by looking at Table 9-1.

TABLE 9-1: SAMPLE INDEX

Social Security number	Location
111-22-3456	6400
222-44-7654	4800
333-55-1234	2400
444-88-9812	5200

When you want to access the data for employee 333-55-1234, you tell your computer to look through the Social Security numbers in the index, find a match, and then proceed to the memory location specified. Similarly, when you want to process records in order based on Social Security number, you tell your system to retrieve records at the locations in the index in sequence. Thus, even though employee 111-22-3456 may have been hired last and the record is stored at the highest physical address on the disk, if the employee record has the lowest Social Security number, it will be accessed first during any ordered processing.

When a record is removed from an indexed file, it does not have to be physically removed. Its reference can simply be deleted from the index, and then it will not be part of any further processing.

USING LINKED LISTS

Another way to access records in a desired order, even though they might not be physically stored in that order, is to create a linked list. In its simplest form, creating a **linked list** involves creating one extra field in every record of stored data. This extra field holds the physical address of the next logical record. For example, a record that holds a customer's ID, name, and phone number might contain the fields:

```
custId
custName
custPhoneNum
custNextCustAddress
```

Every time you use a record, you access the next record based on the address held in the `custNextCustAddress` field.

Every time you add a new record to a linked list, you search through the list for the correct logical location for the new record. For example, assume that customer records are stored at the addresses shown in Table 9-2 and that they are linked in customer ID order. Notice that the addresses are not shown in sequential order. The records are shown in their logical order, with each one's `custNextCustAddress` field holding the address of the record shown in the following line.

TABLE 9-2: LINKED CUSTOMER LIST

Address of record	custId	custName	custPhoneNum	custNextCustAddress
0000	111	Baker	234-5676	7200
7200	222	Vincent	456-2345	4400
4400	333	Silvers	543-0912	6000
6000	444	Donovan	329-8744	eof

You can see from Table 9-2 that each customer's record contains a `custNextCustAddress` field that stores the address of the next customer who follows in customer ID number order (and not necessarily in address order). For any individual customer, the next logical customer's address might be physically distant. Each customer record, besides containing data about that customer, contains a `custNextCustAddress` field that associates the customer with the next customer who follows in `custId` value order.

Examine the file shown in Table 9-2, and suppose a new customer with number 245 and the name Newberg is acquired. Also suppose the computer operating system finds an available storage location for Newberg's data at address 8400. In this case, the procedure to add Newberg to the list is:

1. Create a variable named `currentAddress` to hold the address of the record in the list you are currently examining. Store the address of the first record in the list, 0000, in this variable.
2. Compare the new customer Newberg's ID, 245, with the current (first) record's ID, 111 (in other words, the ID at address 0000). The value 245 is higher than 111, so you save the first customer's address (the address you are currently examining), 0000, in a variable you can name `saveAddress`. The `saveAddress` variable always holds the address you just finished examining. The first customer's record contains a link to the address of the next logical customer—7200. Store the 7200 in the `currentAddress` variable.
3. Examine the second customer record, the one that physically exists at the address 7200, which is currently held in the `currentAddress` variable.
4. Compare Newberg's ID, 245, with the ID stored in the record at `currentAddress`, 222. The value 245 is higher, so save the current address, 7200, in `saveAddress` and store its `custNextCustAddress` address field, 4400, in the `currentAddress` variable.
5. Compare Newberg's ID, 245, with 333, which is the ID at `currentAddress` (4400). Up to this point, 245 had been higher than each ID tested, but this time the value 245 is lower, so that means customer 245 should logically precede customer 333. Set the `custNextCustAddress` field in Newberg's record (customer 245) to 4400, which is the address of customer 333 and the address currently stored in `currentAddress`. This means that in any future processing, Newberg's record will logically be followed by the record containing 333. Also set the `custNextCustAddress` field of the record located at `saveAddress` (7200, Vincent, customer 222, the customer who logically preceded Newberg) to the new customer Newberg's address, 8400. The updated list appears in Table 9-3.

TABLE 9-3: UPDATED CUSTOMER LIST

Address of record	custId	custName	custPhoneNum	custNextCustAddress
0000	111	Baker	234-5676	7200
7200	222	Vincent	456-2345	8400
8400	245	Newberg	222-9876	4400
4400	333	Silvers	543-0912	6000
6000	444	Donovan	329-8744	eof

As with indexing, when removing records from a linked list, the records do not need to be physically deleted from the medium on which they are stored. If you need to remove customer 333 from the preceding list, all you need to do is change Newberg's `custNextCustAddress` field to the value in Silvers' `custNextCustAddress` field, which is Donovan's address: 6000. In other words, the value of 6000 is obtained not by knowing who Newberg should point to, but by knowing who Silvers used to point to. When Newberg's record points to Donovan, Silvers' record is then bypassed during any further processing that uses the links to travel from one record to the next.

More sophisticated linked lists store *two* additional fields with each record. One field stores the address of the next record, and the other field stores the address of the *previous* record so that the list can be accessed either forward or backward.

USING MULTIDIMENSIONAL ARRAYS

An array that represents a single list of values is a **single-dimensional array** or **one-dimensional array**. For example, an array that holds five rent figures that apply to five floors of a building can be displayed in a single column, as in Figure 9-17.

FIGURE 9-17: A SINGLE-DIMENSIONAL `rent` ARRAY

```
rent[0] = 350
rent[1] = 400
rent[2] = 475
rent[3] = 600
rent[4] = 1000
```

TIP You used the single-dimensional `rent` array in Chapter 8.

The location of any `rent` value in Figure 9-17 depends on only a single variable—the floor of the building. Sometimes, however, locating a value in an array depends on more than one variable. If you must represent values in a table or grid that contains rows and columns instead of a single list, then you might want to use a **multidimensional array**—specifically in this case, a **two-dimensional array**.

Assume that the floor is not the only factor determining rent in your building, but that another variable, `numberOfBedrooms`, also needs to be taken into account. The rent schedule might be the one shown in Table 9-4.

TABLE 9-4: RENT SCHEDULE BASED ON FLOOR AND NUMBER OF BEDROOMS

Floor	Studio apartment	1-bedroom apartment	2-bedroom apartment
0	350	390	435
1	400	440	480
2	475	530	575
3	600	650	700
4	1000	1075	1150

Each element in a two-dimensional array requires two subscripts to reference it—one subscript to determine the row and a second to determine the column. Thus, the 15 separate `rent` values for a two-dimensional array based on the rent table in Table 9-4 would be those shown in Figure 9-18.

FIGURE 9-18: TWO-DIMENSIONAL `rent` ARRAY VALUES BASED ON FLOOR AND NUMBER OF BEDROOMS

```
rent[0][0] = 350
rent[0][1] = 390
rent[0][2] = 435
rent[1][0] = 400
rent[1][1] = 440
rent[1][2] = 480
.
.
.
rent[4][2] = 1150
```

Suppose you want to read records that store a floor and number of bedrooms in an apartment, and print the appropriate rent for that apartment. If you store tenant records that contain two fields named `floor` and `numberOfBedrooms`, then the correct rent can be printed with the statement: `print rent[floor][numberOfBedrooms]`. The first subscript represents the array row; the second subscript represents the array column.

TIP

Some languages access two-dimensional array elements with commas separating the subscript values; for example, the first-floor, two-bedroom rate might be written `rent[1,2]`. In every language, you provide a subscript for the row first and for the column second.

Just as within a one-dimensional array, each element in a multidimensional array must be the same data type.

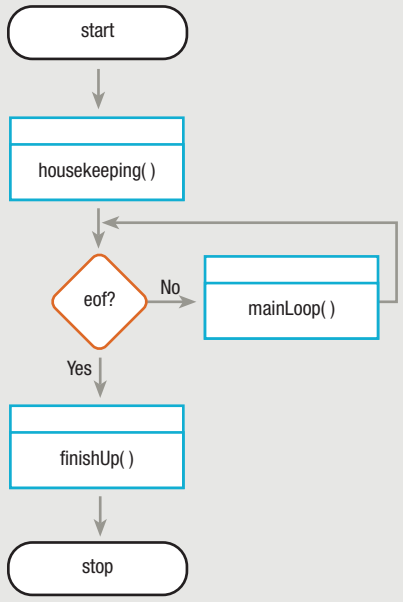
Two-dimensional arrays are never actually *required* in order to achieve a useful program. The same 15 categories of rent information could be stored in three separate single-dimensional arrays of five elements each. Of course, don't forget that even one-dimensional arrays are never *required* for you to be able to solve a problem. You could also declare 15 separate rent variables and make 15 separate decisions to determine the rent.

Figure 9-19 shows an entire program that produces a report that determines rent amounts for tenant records stored in a file. Notice that although significant setup is required to provide all the values for the rents, the `mainLoop()` module is extremely brief and easy to follow.

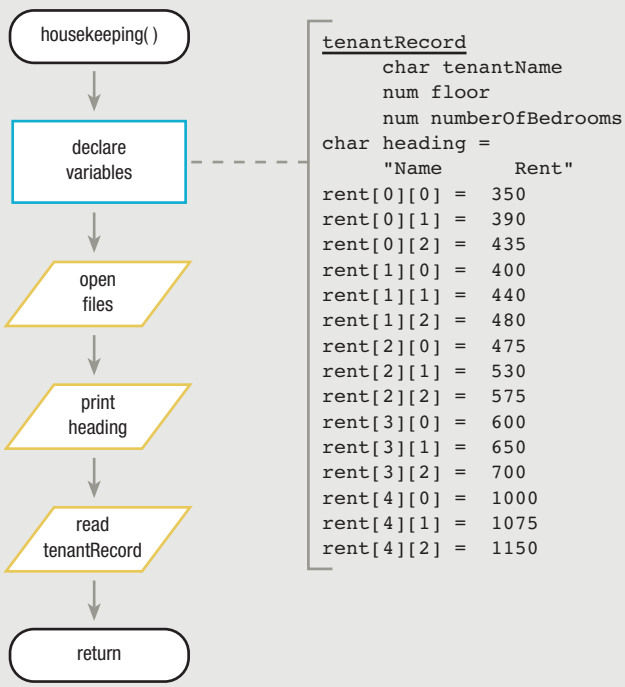
Some languages allow multidimensional arrays containing three levels, or **three-dimensional arrays**, in which you access array values using three subscripts. For example, rent might not only be determined by the two factors `floor` and `numberOfBedrooms`. There might also be 12 different buildings. The third dimension of a three-dimensional array to hold all these different rents would be a variable such as `buildingNumber`.

Some languages allow even more dimensions. It's usually hard for people to keep track of more than three dimensions, but if five variables determine rent—for example, floor number, number of bedrooms, building number, city number, and state number—you might want to try using a five-dimensional array.

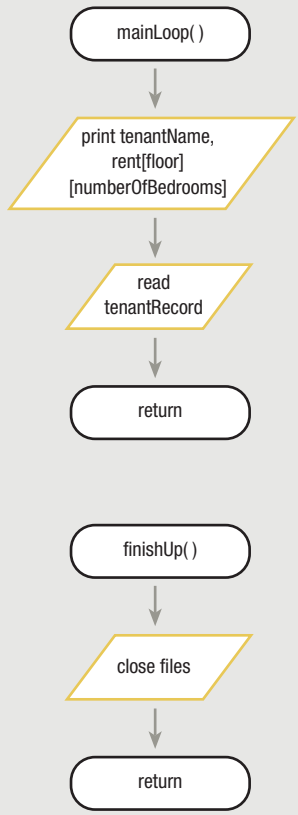
FIGURE 9-19: RENT-DETERMINING PROGRAM




```
start
     perform housekeeping()
     while not eof
          perform mainLoop()
     endwhile
     perform finishUp()
stop
housekeeping()
     declare variables
     open files
     print heading
     read tenantRecord
return
mainLoop()
     print tenantName, rent[floor][numberOfBedrooms]
     read tenantRecord
return
finishUp()
     close files
return
```




```
tenantRecord
     char tenantName
     num floor
     num numberOfBedrooms
char heading =
     "Name      Rent"
rent[0][0] =  350
rent[0][1] =  390
rent[0][2] =  435
rent[1][0] =  400
rent[1][1] =  440
rent[1][2] =  480
rent[2][0] =  475
rent[2][1] =  530
rent[2][2] =  575
rent[3][0] =  600
rent[3][1] =  650
rent[3][2] =  700
rent[4][0] =  1000
rent[4][1] =  1075
rent[4][2] =  1150
```



CHAPTER SUMMARY

- When the sequential order of data records is not the order desired for processing or viewing, the data needs to be sorted in ascending or descending order based on the contents of one or more fields.
- You can swap two values by creating a temporary variable to hold one of the values. Then, you can assign the second value to the temporary variable, assign the first value to the second, and assign the temporary value to the first variable.
- In a bubble sort, items in a list are compared in pairs, and when an item is out of order, it swaps with the item below it. With an ascending bubble sort, after each adjacent pair of items in a list has been compared once, the largest item in the list will have "sunk" to the bottom.
- When performing a bubble sort on an array, you compare two separate loop control variables with a value that equals the number of elements in the list. An advantage to using a variable instead of a constant to hold the number of elements is that if you modify the program array to accommodate more or fewer elements in the future, you can simply change the value in the variable once, where it is defined.
- On each pass through an array that is being sorted using a bubble sort, you can afford to stop your pair comparisons one element sooner than the time before.
- To avoid making unnecessary passes through a list while performing a bubble sort, you can add a flag that you test on every pass through the list, to determine when all elements are already in the correct order.
- When using an insertion sort, you look at each pair of elements in an array. When you find an element that is out of order, search the array backward from that point, find an element smaller than the out-of-order element, move each subsequent element down one position, and insert the out-of-order element into the list at the newly opened position.
- In an ascending selection sort, the first element in the array is assumed to be the smallest. Its value and position are stored. Then, every subsequent element in the array is tested, and if one has a smaller value, the new value and position are stored. After searching the entire array, you switch the original first value with the smallest value. Then you repeat the process with each subsequent list value.
- You can use an index to access data records in a logical order that differs from their physical order. Using an index involves identifying a key field for each record.
- Creating a linked list involves creating an extra field within every record, to hold the physical address of the next logical record.
- You use a multidimensional array whenever locating a value in an array depends on more than one variable.

KEY TERMS

When records are in **sequential order**, they are arranged one after another on the basis of the value in some field.

Sorted records are in order based on the contents of one or more fields.

Records in **ascending order** are arranged from lowest to highest, based on a value within a field.

Records in **descending order** are arranged from highest to lowest, based on a value within a field.

The **median** value in a list is the value in the middle position when the values are sorted.

The **mean** value in a list is the arithmetic average.

Swapping two values is the process of setting the first variable equal to the value of the second, and the second variable equal to the value of the first.

A **bubble sort** is a sort in which you arrange records in either ascending or descending order by comparing items in a list in pairs; when an item is out of order, it swaps values with the item below it.

A **sinking sort** is another name for a bubble sort.

When using an **insertion sort**, you look at each pair of elements in an array. For example, for an ascending insertion sort, when you find an element that is smaller than the one before it, you search the array backward from that point to see where an element smaller than the out-of-order element is located. At that point, you open a new position for the out-of-order element by moving each subsequent element down one position. Then, you insert the out-of-order element into the newly opened position.

In an ascending **selection sort**, you search for the smallest list value, and then swap it with the value in the first position. You then repeat the process with each subsequent list position.

A list's **physical order** is the order in which it is actually stored.

A list's **logical order** is the order in which you use it, even though it is not necessarily physically stored in that order.

A record's **key field** is the field whose contents make the record unique among all records in a file.

When you **index** records, you store a list of key fields paired with the storage address for the corresponding data record.

A **random-access storage device**, such as a disk, is one from which records can be accessed in any order.

Computer memory and storage locations have **addresses**.

Creating a **linked list** involves creating one extra field in every record of stored data. This extra field holds the physical address of the next logical record.

An array that represents a single list of values is a **single-dimensional array** or **one-dimensional array**.

An array that represents a table or grid containing rows and columns is a **multidimensional array**—for example, a **two-dimensional array**.

Some languages allow **three-dimensional arrays**, in which you access values using three subscripts.

REVIEW QUESTIONS

1. Employee records stored in order from highest-paid to lowest-paid have been sorted in _____ order.

a. ascending
b. descending
c. staggered
d. recursive

2. Student records stored in alphabetical order by last name have been sorted in _____ order.

a. ascending
b. descending
c. staggered
d. recursive

3. In the series of numbers 7, 5, 5, 5, 3, 2, and 1, what is the mean?

a. 3
b. 4
c. 5
d. 6

4. When computers sort data, they always _____.

a. place items in ascending order
b. use a bubble sort
c. begin the process by locating the position of the lowest value
d. use numeric values when making comparisons

5. Which of the following code segments correctly swaps the values of variables named `x` and `y`?

a.
```
x = y
y = temp
x = temp
```
b.
```
x = y
temp = x
y = temp
```
c.
```
temp = x
x = y
y = temp
```
d.
```
temp = x
y = x
x = temp
```

6. Which type of sort compares list items in pairs, swapping any two adjacent values that are out of order?

a. bubble sort
b. selection sort
c. insertion sort
d. indexed sort

7. Which type of sort compares pairs of values, looking for an out-of-order element, then searches the array backward from that point to see where an element smaller than the out-of-order element is located?

a. bubble sort
b. selection sort
c. insertion sort
d. indexed sort

8. Which type of sort tests each value in a list, looking for the smallest, then switches the element in the first list position with the smallest value?

a. bubble sort
b. selection sort
c. insertion sort
d. indexed sort

9. To sort a list of eight values using a bubble sort, the greatest number of times you would have to pass through the list making comparisons is _____.

a. six
b. seven
c. eight
d. nine

10. To sort a list of eight values using a bubble sort, the greatest number of pair comparisons you would have to make before the sort is complete is _____.

a. seven
b. eight
c. 49
d. 64

11. When you do not know how many items need to be sorted in a program, you create an array that has _____.

a. at least one element less than the number you predict you will need
b. at least as many elements as the number you predict you will need
c. variable-sized elements
d. a variable number of elements

12. In a bubble sort, on each pass through the list that must be sorted, you can stop making pair comparisons _____.

a. one comparison sooner
b. two comparisons sooner
c. one comparison later
d. two comparisons later

13. When performing a bubble sort on a list of 10 values, you can stop making passes through the list of values as soon as _____ on a single pass through the list.

a. no more than 10 swaps are made
b. no more than nine swaps are made
c. exactly one swap is made
d. no swaps are made

14. Student records are stored in ID number order, but accessed by grade point average for a report. Grade point average order is a(n) _____ order.

a. imaginary
b. physical
c. logical
d. illogical

15. With a linked list, every record _____.

a. is stored in sequential order
b. contains a field that holds the address of another record
c. contains a code that indicates the record's position in an imaginary list
d. is stored in a physical location that corresponds to a key field

16. Data stored in a table that can be accessed using row and column numbers is stored as a _____ array.

a. single-dimensional
b. two-dimensional
c. three-dimensional
d. nondimensional

17. The Funland Amusement Park charges entrance fees as shown in the following table. The table is stored as an array named `price` in a program that determines ticket price based on two factors—number of tickets purchased and month of the year. A clerk enters the `month` (5 through 9 for May through September), from which 5 is subtracted, so the month value becomes 0 through 4. A clerk also enters the number of `tickets` being purchased; if the number is over 6, it is forced to be 6. One is subtracted from the number of people, so the value is 0 through 5.

	Adjusted month number				
People in party	0	1	2	3	4
0	29.00	34.00	36.00	36.00	29.00
1	28.00	32.00	34.00	34.00	28.00
2	26.00	30.00	32.00	32.00	26.00
3	24.00	26.00	27.00	28.00	25.00
4	23.00	25.00	26.00	27.00	23.00
5	20.00	23.00	24.00	25.00	21.00

What is the price of a ticket for any party purchasing tickets?

a. `price[tickets][month]`
b. `price[month][tickets]`
c. `month[tickets][price]`
d. `tickets[price][month]`

18. Using the same table as in Question 17, where is the ticket price stored for a party of four purchasing tickets in September?

a. `price[4][9]`
b. `price[3][4]`
c. `price[4][3]`
d. `price[9][4]`

19. In a four-dimensional array, you would need to use _____ subscript(s) to access a single item.

a. one
b. two
c. three
d. four

20. In a two-dimensional array, the second subscript needed to access an item refers to the _____.

a. row
b. column
c. page
d. record

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **This application reads a file containing employee data, including salaries, for 1,000 employees. The salaries are sorted so the median salary in the organization can be displayed.**

```
start
     perform housekeeping()
     perform sortSalaries()
     perform finishUp()
stop

housekeeping()
     declare variables
        inRec
          char name
          num pay
          num x = 0
          num y = 0
          const num SIZE = 1000
          num salary[SIZE]
          num temp
          num midNum
     open files
     read inRec
     while not eof
          salary[SIZE] = pay
          x = x + 1
          read inRec
     endwhile
return

sortSalaries()
     y = 0
     while y > SIZE - 1
          x = 0
          while x < SIZE
               if salary[x] > salary[x] then
                    perform switchValues()
               endif
               x = x + 1
          endwhile
          y = y + 1
     endwhile
return
```

```
switchValues()
     temp = salary[x + 1]
     salary[x] = salary[x]
     salary[x] = temp
return

finishUp()
     midNum = SIZE / 2
     print "Median salary is ", salary[midNum]
     close files
return
```

2. **This application reads student typing test records. The records contain the student's ID number and name, the number of errors on the test, and the number of words typed per minute. Grades are assigned based on the following table:**

Speed	Errors 0	1	2 or more
0–30	C	D	F
31–50	C	C	F
51–80	B	C	D
81–100	A	B	C
101 and up	A	A	B

```
start
     perform housekeeping()
     while not eof
          perform mainLoop()
     endwhile
     perform finishUp()
stop

housekeeping()
     declare variables
          stuRecord
            num id
            char name
            num errors
            num speed
          num speedArray[0] = 0
          num speedArray[1] = 31
          num speedArray[2] = 51
```

```
          num speedArray[3] = 51
          num speedArray[4] = 101
          num x
          num speedCategory
          num grade[0][0] = "C"
          num grade[0][1] = "C"
          num grade[0][2] = "C"
          num grade[1][0] = "C"
          num grade[1][1] = "C"
          num grade[1][2] = "C"
          num grade[2][0] = "C"
          num grade[2][1] = "C"
          num grade[2][2] = "A"
          num grade[3][0] = "A"
          num grade[3][1] = "A"
          num grade[3][2] = "A"
          num grade[4][0] = "A"
          num grade[4][1] = "A"
          num grade[4][2] = "A"
     open files
     read stuRecord
return

mainLoop()
     if errors > 2 then
         errors = 2
     endif
     x = 4
     while x >= 0
       if speed = speedArray[speed]
          speedCategory = x
          x = 0
        endif
        x = x + 1
     endwhile
     print id, name, grade[speedCategory][errors]
     read stuRecord
return

finishUp()
     close files
return
```

EXERCISES

1. Professor Zak allows students to drop the two lowest scores on the ten 100-point quizzes she gives during the semester. Develop the logic for a program that reads student records that contain ID number, last name, first name, and 10 quiz scores. The output lists student ID, name, and total points for the eight highest-scoring quizzes.

2. The Hinner College Foundation holds an annual fundraiser for which the foundation director maintains records. Each record contains a donor name and contribution amount. Assume that there are never more than 300 donors. Develop the logic for a program that sorts the donation amounts in descending order. The output lists the highest five donation amounts.

3. A greeting-card store maintains customer records with data fields for first name, last name, address, and annual purchases in dollars. At the end of the year, the store manager invites the 100 customers with the highest annual purchases to an exclusive sale event. Develop the flowchart or pseudocode that sorts up to 1,000 customer records by annual purchase amount and prints the names and addresses for the top 100 customers.

4. The village of Ringwood has taken a special census. Every census record contains a household ID number, number of occupants, and income. Ringwood has exactly 75 households. Village statisticians are interested in the median household size and the median household income. Develop the logic for a program that determines these figures. (Remember, a list must be sorted before you can determine the median value.)

5. The village of Marengo has taken a special census and collected records that each contain a household ID number, number of occupants, and income. The exact number of household records has not yet been determined, but you know that there are fewer than 1,000 households in Marengo. Develop the logic for a program that determines the median household size and the median household income.

6. Create the flowchart or pseudocode that reads a file of 10 employee salaries and prints them from lowest to highest. Use an insertion sort.

7. Create the flowchart or pseudocode that reads a file of 10 employee salaries and prints them from highest to lowest. Use a selection sort.

8. The MidAmerica Bus Company charges fares to passengers based on the number of travel zones they cross. Additionally, discounts are provided for multiple passengers traveling together. Ticket fares are shown in the following table:

	Zones crossed			
Passengers	0	1	2	3
1	7.50	10.00	12.00	12.75
2	14.00	18.50	22.00	23.00
3	20.00	21.00	32.00	33.00
4	25.00	27.50	36.00	37.00

Develop the logic for a program that reads records containing number of passengers and zones crossed. The output is the ticket charge.

9. In golf, par represents a standard number of strokes a player will need to complete a hole. Instead of using an absolute score, players can compare their scores on a hole to the par figure and determine whether they are above or below par. Families can play nine holes of miniature golf at the Family Fun Miniature Golf Park. So that family members can compete fairly, the course provides a different par for each hole, based on the player's age. The par figures are shown in the following table:

	Holes								
Age	1	2	3	4	5	6	7	8	9
4 and under	8	8	9	7	5	7	8	5	8
5–7	7	7	8	6	5	6	7	5	6
8–11	6	5	6	5	4	5	5	4	5
12–15	5	4	4	4	3	4	3	3	4
16 and over	4	3	3	3	2	3	2	3	3

a. Develop the logic for a program that reads records containing a player's name, age, and nine-hole score. For each player, print a page that contains the player's name and score on each of the nine holes, with one of the phrases "Over par", "Par", or "Under par" next to each score.

b. Modify the program in Exercise 9a so that, at the end of each golfer's report, the golfer's total score is displayed. Include the figure indicating how many strokes over or under par the player is for the entire course.

10. Parker's Consulting Services pays its employees an hourly rate based on two criteria—number of years of service and last year's performance rating, which is a whole number, 0 through 5. Employee records contain ID number, last and first names, year hired, and performance score. The salary schedule follows:

	Performance score					
Years of service	0	1	2	3	4	5
0	8.50	9.00	9.75	10.30	12.00	13.00
1	9.50	10.25	10.95	11.30	13.50	15.25
2	10.50	11.00	12.00	13.00	15.00	17.60
3	11.50	12.25	14.00	14.25	15.70	18.90
4 or more	12.50	13.75	15.25	15.50	17.00	20.00

In addition to the pay rates shown in the table, an employee with more than 10 years of service receives an extra 5 percent per hour for each year over 10. Develop the logic for a program that prints each employee's ID number, name, and correct hourly salary for the current year.

11. The Roadmaster Driving School allows students to sign up for any number of driving lessons. The school allows up to four attempts to pass the driver's license test; if all the attempts are unsuccessful, then the student's tuition is returned. The school maintains an archive containing student records for those who have successfully passed the licensing test over the last 10 years. Each record contains a student ID number, name, number of driving lessons completed, and the number of the attempt on which the student passed the licensing test. The records are stored in alphabetical order by student name. The school administration is interested in examining the correlation between the number of lessons taken and the number of attempts required to pass the test. Develop the logic for a program that would produce a table for the school. Each row represents the number of lessons taken: 0–9, 10–19, 20–29, and 30 or more. Each column represents the number of test attempts in order to pass—1 through 4.

12. The Stevens College Testing Center creates a record each time a student takes a placement test. Students can take a test in any of 12 subject areas: English, Math, Biology, Chemistry, History, Sociology, Psychology, Art, Music, Spanish, German, or Computer Science. Each record contains the date the test was taken, the student's ID number, the test subject area, and a percent score on the test. Records are maintained in the order they are entered as the tests are taken. The college wants a report that lists each of the 12 tests along with a count of the number of students who have received scores in each of the following categories: at least 90 percent, 80 through 89 percent, 70 through 79 percent, and below 70 percent. Develop the logic that produces the report.

DETECTIVE WORK

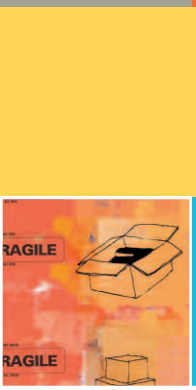
1. This chapter discussed the idea of using an employee's Social Security number as a key field. Is a Social Security number unique?

2. This chapter examines the bubble, insertion, and selection sorting algorithms. What other named sort processes can you find?

UP FOR DISCUSSION

1. Now that you are becoming comfortable with arrays, you can see that programming is a complex subject. Should all literate people understand how to program? If so, how much programming should they understand?

2. What are language standards? At this point in your study of programming, what do they mean to you?



10 USING MENUS AND VALIDATING INPUT

After studying Chapter 10, you should be able to:

- Understand the need for interactive, menu-driven programs
- Create a program that uses a single-level menu
- Code modules as black boxes
- Improve menu programs
- Use a case structure to manage a menu
- Create a program that uses a multilevel menu
- Validate input
- Understand types of data validation

USING INTERACTIVE PROGRAMS

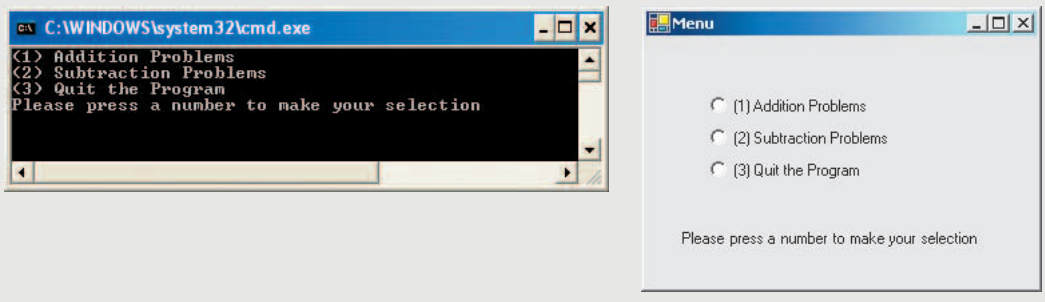
You can divide computer programs into two broad categories based on how they get their data. Programs for which all the data items are gathered prior to running use **batch processing**. Programs that depend on user input while the programs are running use **interactive processing**.

Many computer programs use batch processing with sequential files of data records that have been collected for processing. All standard billing, inventory, payroll, and similar programs work this way, and all the program logic you have developed while working through this text also works like this. Records used for batch processing are gathered over a period of time—hours, days, or even months. Programs that use batch processing typically read an input record, process it according to coded instructions, output the result, and then read another record. Batch processing gets its name because the data records are not processed at the time they are created; instead, they are "saved" and processed in a batch. For example, you do not receive a credit card bill immediately after every purchase, when the record is created. All purchases during a one-month period are gathered and processed at the end of that billing period.

Many computer programs cannot be run in batches. Instead, they must run interactively—that is, they must interact with a user while they are running. Ticket reservation programs for airlines and theaters must select tickets while you are interacting with them, not at the end of the month. A computerized library catalog system must respond to library patrons' requests immediately, while the patrons are searching, not at the end of every week. Interactive computer programs are often called **real-time applications**, because they run while a transaction is taking place, not at some later time. You also can refer to interactive processing as **online processing**, because the user's data or requests are gathered during the execution of the program, while the computer is operating. A batch processing system can be **offline**; that is, you can collect data such as time cards or purchase information well ahead of the actual computer processing of the paychecks or bills.

A **menu program** is a common type of interactive program in which the user sees a number of options on the screen and can select any one of them. For example, an educational program that drills you on elementary arithmetic skills might display three options, as shown in the two menus in Figure 10-1. The menu on the left is used in **console applications**, those that require the user to enter a choice using the keyboard; the menu style on the right is used in **graphical user interface applications**, those that allow the user to use a mouse or other pointing device to make selections. The style you use partly depends on the programming language you choose; with languages that allow either style, the program developer decides on the format based on considerations such as the preferences of users and the amount of time available for development.

FIGURE 10-1: ARITHMETIC DRILL MENUS



TIP You could include a title or further instructions on the menus shown in Figure 10-1, as well as on the other menus in this chapter. They are eliminated here to keep the examples as simple as possible.

The final option in each menu in Figure 10-1, *Quit the Program*, is very important; without it, there would be no elegant way for the program to terminate. A menu without a *Quit* option is very frustrating to the user.

Some menu programs require the user to enter a number to choose a menu option. For example, the user enters a *2* to perform a subtraction drill from the first menu shown in Figure 10-1. Other menu programs require the user to enter a letter of the alphabet—for example, *S* for a subtraction drill. Still other programs allow the user to use a pointing device such as a mouse to point to a choice on the screen, as with the menu on the right side of Figure 10-1. The most sophisticated programs allow users to employ the selection method that is most convenient at the time.

TIP Many organizations provide an audio menu to callers to handle routing of telephone calls. If you have ever called an organization and heard a message like "Press 1 for the Sales Department," then you have used an interactive menu.

USING A SINGLE-LEVEL MENU

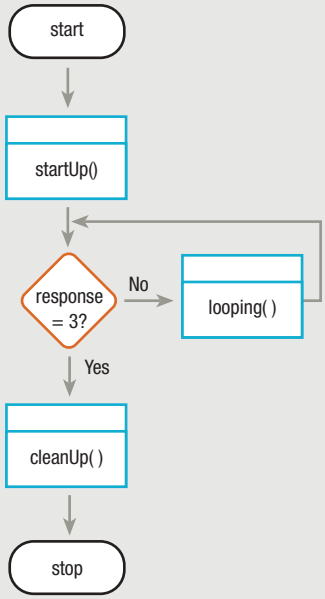
Suppose you want to write a program that displays a menu like the one shown in Figure 10-1. The program drills a student's arithmetic skills—if the student chooses the first option, four addition problems are displayed, and if the student chooses the second option, four subtraction problems are displayed. This program uses a **single-level menu**; that is, the user makes a selection from only one menu before using the program for its ultimate purpose—arithmetic practice. With more complicated programs, a user's choice from an initial menu often leads to other menus from which the user must make several selections before reaching the desired destination.

Suppose you want to write a program that requires the user to enter a digit to make a menu choice. The mainline logic for an interactive menu program is not substantially different from any of the other sequential file programs you've seen so far in this book. You can create `startUp()`, `looping()`, and `cleanUp()` modules, as shown in Figure 10-2.

The only difference between the mainline logic in Figure 10-2 and that of other programs you have worked with lies in the main loop control question. When a program's input data comes from a data file, asking whether the input file is at the end-of-file (`eof`) condition is appropriate. An interactive, menu-driven program is not controlled by an end-of-file condition, but by a user's menu response. The mainline logic, then, is more appropriately controlled by the user's response. For example, Figure 10-2 shows the mainline logic containing the question `response = 3?`.

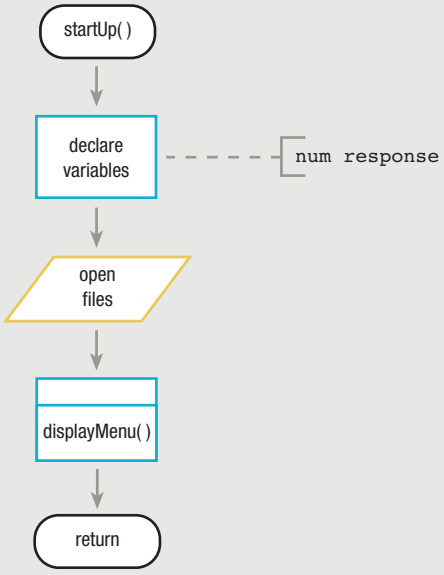
The `startUp()` module in the arithmetic drill program defines variables and opens files. The name of one of the variables is `response`; this is the numeric variable that will hold the user's menu choice. The `startUp()` module also displays the menu for the first time, so that the user can make a choice. See Figure 10-3.

FIGURE 10-2: MAINLINE LOGIC FOR THE ARITHMETIC DRILL MENU PROGRAM




```
start
     perform startUp()
     while response not = 3
          perform looping()
     endwhile
     perform cleanUp()
stop
```

FIGURE 10-3: THE `startUp()` MODULE FOR THE ARITHMETIC DRILL PROGRAM

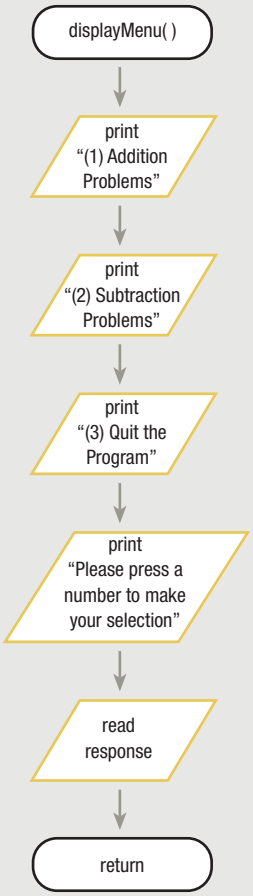



```
startUp()
     declare variables
     open files
     perform displayMenu()
return
```

TIP In many programming languages, if the keyboard is the default input device and the monitor is the default output device for an application, an explicit `open files` statement is frequently not needed.

You can include the set of instructions that displays the user menu directly in the `startUp()` module, or, as shown here, you can place the instructions in their own module. For example, Figure 10-4 shows the `displayMenu()` module that the `startUp()` module in Figure 10-3 calls. The `displayMenu()` module writes four menu lines on the screen, and then a `read response` statement reads the user's numeric choice from the keyboard.

FIGURE 10-4: THE `displayMenu()` MODULE FOR THE ARITHMETIC DRILL PROGRAM




```
displayMenu()
    print "(1) Addition Problems"
    print "(2) Subtraction Problems"
    print "(3) Quit the Program"
    print "Please press a number to make your selection"
    read response
return
```

TIP

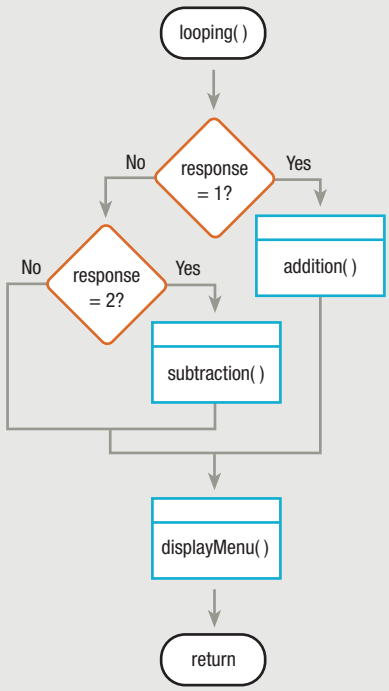
You might choose to add a command to clear the screen before printing any of the menu options. The precise syntax of the command differs from programming language to programming language. When you clear the screen, all previous messages and responses are removed, thus providing a cleaner look to the screen. Often, you clear a screen in the same circumstances when you start a new page in a printed report—at the beginning of the program or after a specified number of lines of output have been displayed.

By the time the logic of the arithmetic drill program leaves the `startUp()` module, the user has entered a value for `response`. In the mainline logic (Figure 10-2), if `response` is not *3* (for the *Quit the Program* option), then the program

enters the `looping()` module. The `looping()` module makes decisions about the user's input, and either performs one of two submodules, `addition()` or `subtraction()`; or, if the user has entered a number other than 1, 2, or 3, the module performs no submodule. Following the performance of the chosen arithmetic drill, the program calls the `displayMenu()` module again, and the user has the opportunity to select the same arithmetic drill, a different one, or the *Quit the Program* option. See Figure 10-5.

TIP In the `looping()` module in Figure 10-5, a user who has entered a value such as 4 or 5 receives no explanation, but is shown the menu again. You will improve this module later in this chapter.

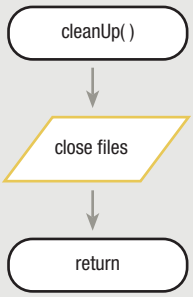
FIGURE 10-5: THE `looping()` MODULE FOR THE ARITHMETIC DRILL PROGRAM




```
looping()
     if response = 1 then
          perform addition()
     else
          if response = 2 then
               perform subtraction()
          endif
     endif
     perform displayMenu()
return
```

When the `looping()` module ends, control passes to the main program. If the user has entered a value of *3* to select the *Quit the Program* option during a `displayMenu()` module, the outcome of the question `response = 3?` sends the program to the `cleanUp()` module. That module simply closes the files, as shown in Figure 10-6.

FIGURE 10-6: THE `cleanUp()` MODULE FOR THE ARITHMETIC DRILL PROGRAM




```
cleanUp()
     close files
return
```

CODING MODULES AS BLACK BOXES

Any steps you want can occur within the `addition()` and `subtraction()` modules in the arithmetic drill program. The contents of these modules should not affect the main structure of the program in any way. You can write an `addition()` module that requires the user to solve simple addition problems, such as `3 + 4`, or you can write an `addition()` module that requires the user to solve more difficult, multidigit problems, such as `9267 + 3488`. You can write the module to contain a single problem for the user to solve, or dozens. As you will recall from Chapter 2, part of the advantage of modular, structured programs lies in your ability to break programs into modules that can be assigned to any number of programmers and then pieced back together at each module's single entry or exit point. Thus, any number of `addition()` or `subtraction()` modules can be used within the arithmetic drill program, and a new one can be substituted at any time.

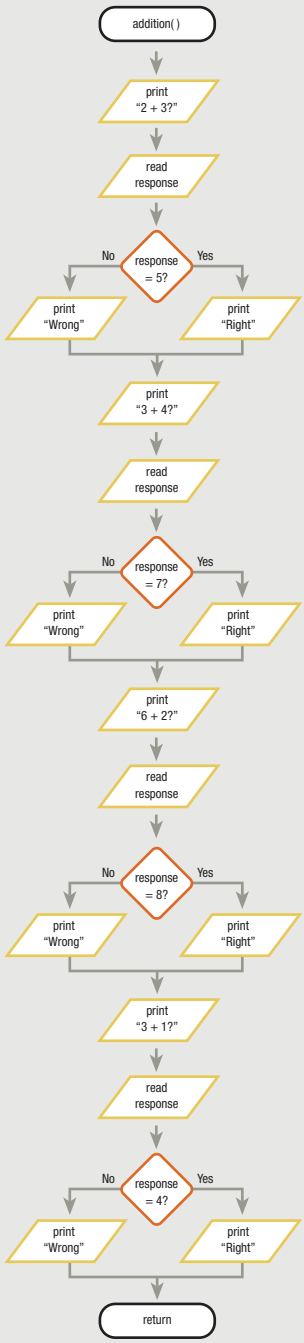
Programmers often refer to the code in modules such as `addition()` and `subtraction()` as existing within a **black box**, meaning that the module statements are encapsulated in a container that makes them "invisible" to the rest of the program. You probably own many real-life objects that are black boxes to you—a television or a stereo, for example. You might not know how these devices work internally, and if someone substituted new internal mechanisms in your devices, you might not know or care, so long as the devices continued to work properly. Similarly, many different `addition()` or `subtraction()` modules could be "plugged into" the arithmetic drill menu program and it would continue to function appropriately.

When first developing a program, programmers frequently don't bother with module details at all, because many versions of a module can substitute for one another. Instead, programmers concentrate on the mainline logic and on understanding what the called modules will do, not on how they will do it. When programmers develop systems containing many modules, they often code "empty" black box procedures, called **stubs**. That way, they can develop the overall project logic without worrying about the minor details. Later, they can code the details in the stub modules.

Figure 10-7 shows a possible `addition()` module. The module displays four addition problems one at a time, waits for the user's response, and displays a message indicating whether the user is correct.

TIP You can write a `subtraction()` module using a format that is almost identical to the `addition()` module. The only necessary change is the computation operation used in the actual problems.

FIGURE 10-7: THE `addition()` MODULE, VERSION 1




```
addition()
     print "2 + 3?"
     read response
     if response = 5 then
          print "Right"
     else
          print "Wrong"
     endif
     print "3 + 4?"
     read response
     if response = 7 then
          print "Right"
     else
          print "Wrong"
     endif
     print "6 + 2?"
     read response
     if response = 8 then
          print "Right"
     else
          print "Wrong"
     endif
     print "3 + 1?"
     read response
     if response = 4 then
          print "Right"
     else
          print "Wrong"
     endif
return
```

The `addition()` module shown in Figure 10-7 works, but it is repetitious; a basic set of statements repeats four times, changing only the actual problem values that the user should add, and the correct answer to which the user's response is compared. A more elegant solution involves storing the problem values in arrays and using a loop. For example, if you declare two arrays, as shown in Figure 10-8, then the loop in Figure 10-9 displays and checks four problems. The power of using an array allows you to alter a subscript in order to display four separate addition problems.

FIGURE 10-8: ARRAYS FOR ADDITION PROBLEMS

```
num probValFirst[0] = 2
num probValFirst[1] = 3
num probValFirst[2] = 6
num probValFirst[3] = 3

num probValSecond[0] = 3
num probValSecond[1] = 4
num probValSecond[2] = 2
num probValSecond[3] = 1
```

TIP To use the `addition()` module shown in Figure 10-9, besides the problem value arrays, you also have to declare the numeric variable count.

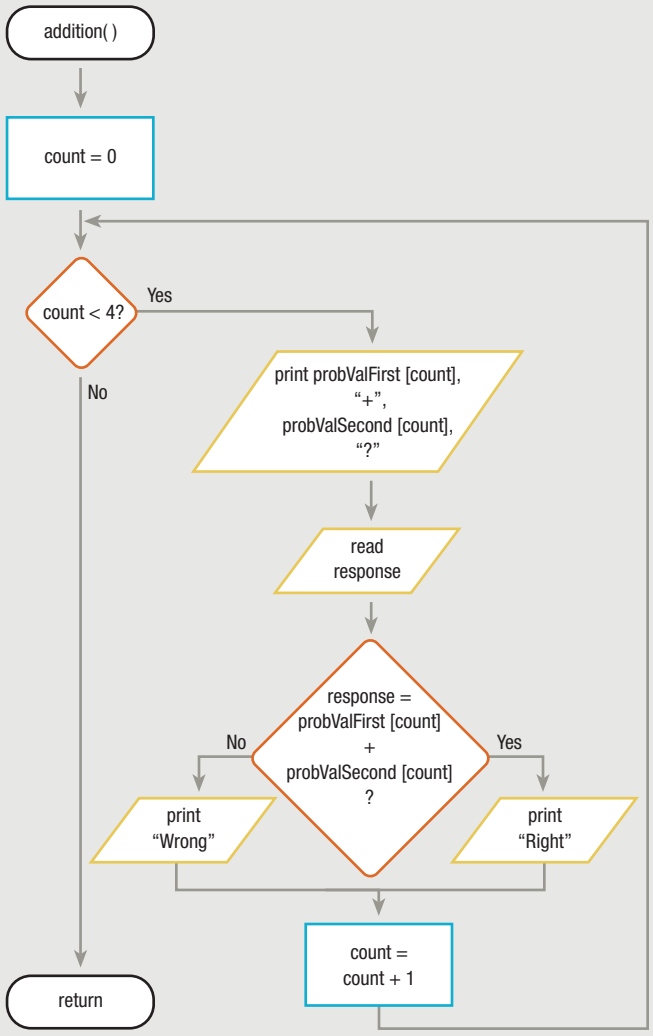
In Figure 10-9, the `addition()` module sets a `count` variable to 0. Then, because `count` remains less than 4, a problem is displayed for the student. The problem display is constructed in four parts—the first `probValFirst` element, a plus sign, the first `probValSecond` element, and a question mark. The module reads the user's answer and compares it to the calculated sum of the two operands in the addition problem, printing either "Right" or "Wrong".

Calculating the correct answer is an improvement over the original version of the program for two reasons. First, a hard-coded answer might be typed incorrectly by the programmer, whereas a calculated answer will always be correct. Second, if the programmer decides to alter the values used in the arithmetic problem, the calculated answer will be recomputed automatically.

After the user receives feedback on the arithmetic problem, `count` is increased, and if it remains in range, the arithmetic drill proceeds with the next addition problem.

The `addition()` module in Figure 10-9 is more compact and efficient than the module shown in Figure 10-7. However, it still contains flaws. A student will not want to use the `addition()` module more than two or three times. Every time a user executes the program, the same four addition problems are displayed. Once students have solved all the addition problems, they probably will be able to provide memorized answers without practicing arithmetic skills at all. Fortunately, most programming languages provide you with built-in modules, or **functions**, that automatically provide a mathematical value such as a square root, absolute value, or random number. Functions that generate a random number usually take a form similar to `random(x)`, where `x` is a value you provide for the maximum random number you want. Different computer systems use different formulas for generating a random number; for example, many use part of the current clock time when the random number function is called. However, a programming language's built-in functions can operate as black boxes, just as your program modules do, so you need not know exactly how the functions do their jobs. You can use the random number function without knowing how it determines the specific random number.

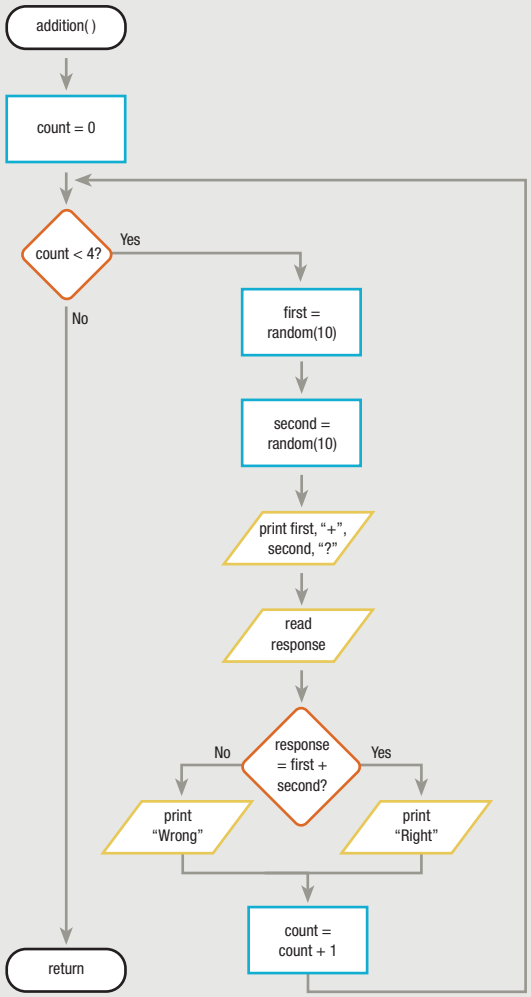
FIGURE 10-9: THE `addition()` MODULE, VERSION 2, USING ARRAYS




```
addition()
     count = 0
     while count < 4
          print probValFirst[count], "+", probValSecond[count], "?"
          read response
          if response = probValFirst[count] + probValSecond[count] then
               print "Right"
          else
               print "Wrong"
          endif
          count = count + 1
     endwhile
return
```

Figure 10-10 shows an `addition()` module in which two random numbers, each 10 or less, are generated for each of four arithmetic problems. Using this technique, you do not have to store values in an array, and users encounter different addition problems every time they use the program.

FIGURE 10-10: THE `addition()` MODULE, VERSION 3, USING RANDOM VALUES




```
addition()
     count = 0
     while count < 4
          first = random(10)
          second = random(10)
          print first, "+", second, "?"
          read response
          if response = first + second then
               print "Right"
          else
               print "Wrong"
          endif
          count = count + 1
     endwhile
return
```

TIP The module in Figure 10-10 would require two new variable declarations in the `startUp()` module in Figure 10-3: `num first` and `num second`.

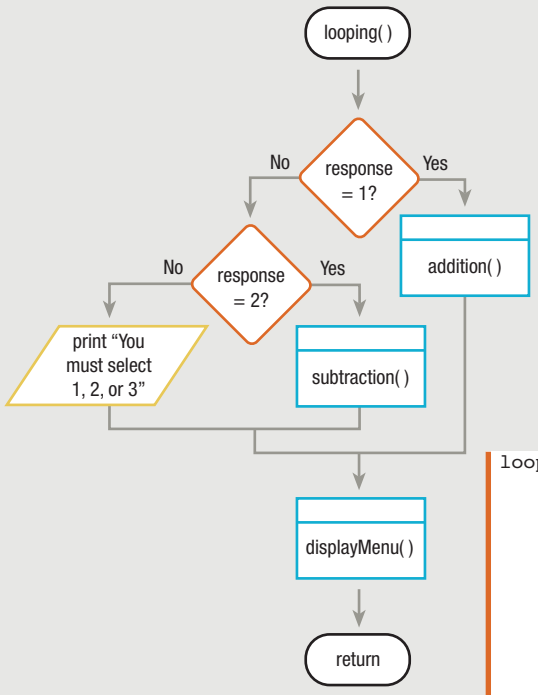
TIP Popular spreadsheet programs also contain functions. As in programming, they are built-in modules that return requested values such as square root or absolute value. Most spreadsheets also contain dozens of specialized functions to support financial applications, such as computing the future value of an investment and calculating a loan payment.

You can make many additional improvements to any of the `addition()` modules shown in Figures 10-7, 10-9, and 10-10. For example, you might want to give the user several chances to calculate the correct answer, or you might want to vary the messages displayed in response to correct and incorrect answers. However you change the `addition()` or `subtraction()` modules in the future, the main structure of the menu program does not have to change; modularization has made your program easily modifiable to meet changing needs and user preferences.

MAKING IMPROVEMENTS TO A MENU PROGRAM

When the menu appears at the end of the `looping()` module of the arithmetic drill program, if the user selects anything other than 3, the `looping()` module is entered again. Note that if the user chooses *4* or *9* or any other invalid menu item, the menu simply reappears. Unfortunately, the repeated display of the menu can confuse the user. Perhaps the user is familiar with another program in which option *9* has always meant *Quit*. When using the arithmetic drill program, the user who does not read the menu carefully might press *9*, get the menu back, press *9*, and get the menu back again. The programmer can assist the user by displaying a message when the selected `response` value is not one of the allowable menu options, as shown in Figure 10-11.

FIGURE 10-11: ADDING AN ERROR MESSAGE TO THE `looping()` MODULE OF THE ARITHMETIC DRILL PROGRAM




```
looping()
     if response = 1 then
          perform addition()
     else
          if response = 2 then
               perform subtraction()
          else
               print "You must select 1, 2, or 3"
          endif
     endif
     perform displayMenu()
return
```

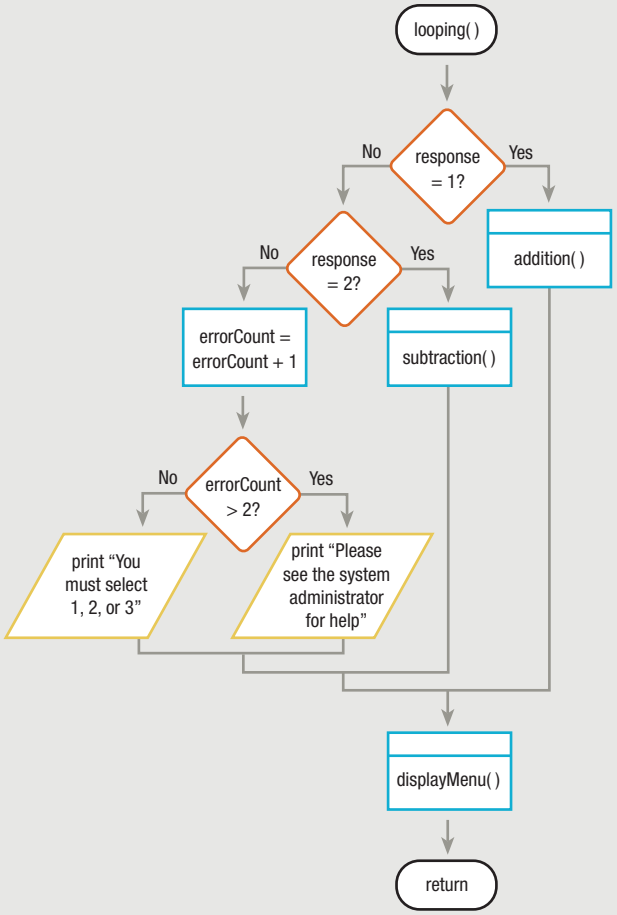
TIP

When you code the `displayMenu()` module in a programming language, you might choose to write it so that it clears the screen of all old output before showing the menu options. If so, then in the `looping()` module in Figure 10-11, you would be required to place a statement that pauses the program—for example, requiring the user to press a key or using a built-in function available in many languages that waits for a number of specified seconds before continuing. Without such a pause, the message "You must select 1, 2, or 3" would be displayed on the screen, then be replaced by the menu almost instantaneously, denying the user enough time to read the message.

Among programmers, there is a saying that no program is ever really completed. You always can continue to make improvements. For example, the `looping()` module in Figure 10-11 shows that a helpful message ("You must select 1, 2, or 3") appears when the user selects an inappropriate option. However, if users do not understand the message, or simply do not stop to read the message, they might keep entering invalid data. As a user-friendly improvement to your program, you can add a counter that keeps track of a user's invalid responses. For example, you can decide that after three invalid entries, you will issue a stronger message, such as "Please see the system administrator for help." Figure 10-12 shows this logic. Of course, to use this module, you must remember to declare `errorCount` in your variable list in the `startUp()` module, and initialize it to 0. Then, each time the user chooses an invalid response and you display the message "You must select 1, 2, or 3", you can add 1 to `errorCount`. When `errorCount` exceeds 2, you display the stronger message.

You can make an additional improvement to the `looping()` module in Figure 10-12. Suppose the user starts the program and enters a *5*. The value of `response` is not 1, 2, or 3, so you add 1 to `errorCount`, display the message "You must select 1, 2, or 3", and display the menu. Suppose the user enters a *5* again. Once again the response is not 1, 2, or 3, so you add 1 to `errorCount`, which is now 2, display the message "You must select 1, 2, or 3", and display the menu. If the user enters a *5* again, `errorCount` exceeds 2 and the user receives the message "Please see the system administrator for help." Assume the user gets help and figures out that he or she must type 1, 2, or 3. The user then might successfully use the program for several more minutes. However, the next time the user makes a selection error, `errorCount` will increase to 4 and the stronger "system administrator" message appears immediately, even though this is only the user's first "new" mistake. If you want to give the user three more chances before the stronger message appears again, then you should reset `errorCount` to 0 every time the user makes a valid choice. This technique allows the user to make three bad selections after any good selection before the stronger message appears. See Figure 10-13 for a flowchart and pseudocode of a complete program containing all the improvements.

FIGURE 10-12: THE `looping()` MODULE WITH A STRONGER ERROR MESSAGE AFTER THREE ERRORS




```
looping()
     if response = 1 then
          perform addition()
     else
          if response = 2 then
               perform subtraction()
          else
               errorCount = errorCount + 1
               if errorCount > 2 then
                    print "Please see the system administrator for help"
               else
                    print "You must select 1, 2, or 3"
               endif
          endif
     endif
     perform displayMenu()
return
```

FIGURE 10-13: COMPLETE PROGRAM ALLOWING THREE ATTEMPTS AT SUCCESSFUL MENU SELECTION BEFORE STRONGER MESSAGE APPEARS

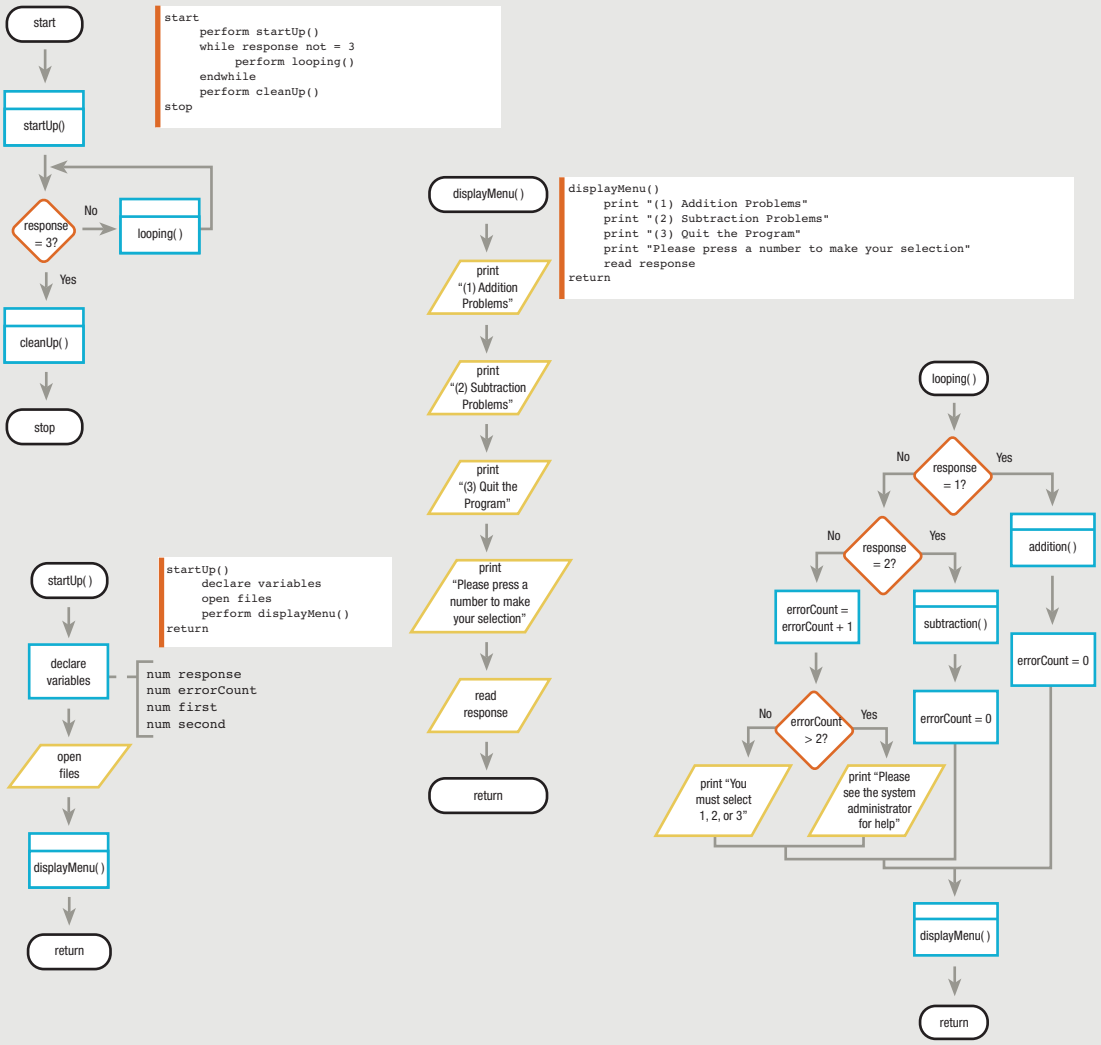
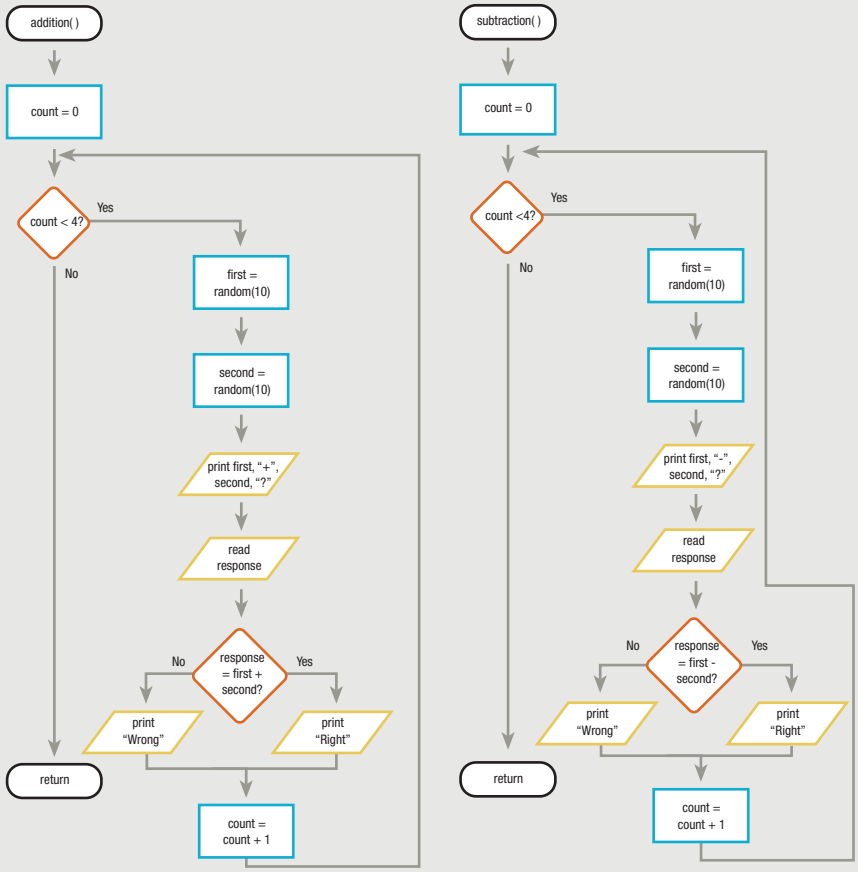
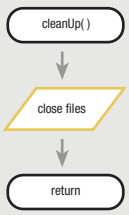


FIGURE 10-13: COMPLETE PROGRAM ALLOWING THREE ATTEMPTS AT SUCCESSFUL MENU SELECTION BEFORE STRONGER MESSAGE APPEARS (CONTINUED)




```
addition()
     count = 0
     while count < 4
          first = random(10)
          second = random(10)
          print first, "+", second, "?"
          read response
          if response = first + second then
              print "Right"
          else
              print "Wrong"
          endif
          count = count + 1
     endwhile
return
```

```
subtraction()
     count = 0
     while count < 4
          first = random(10)
          second = random(10)
          print first, "-", second, "?"
          read response
          if response = first - second then
              print "Right"
          else
              print "Wrong"
          endif
          count = count + 1
     endwhile
return
```




```
cleanUp()
     close files
return
```

USING THE CASE STRUCTURE TO MANAGE A MENU

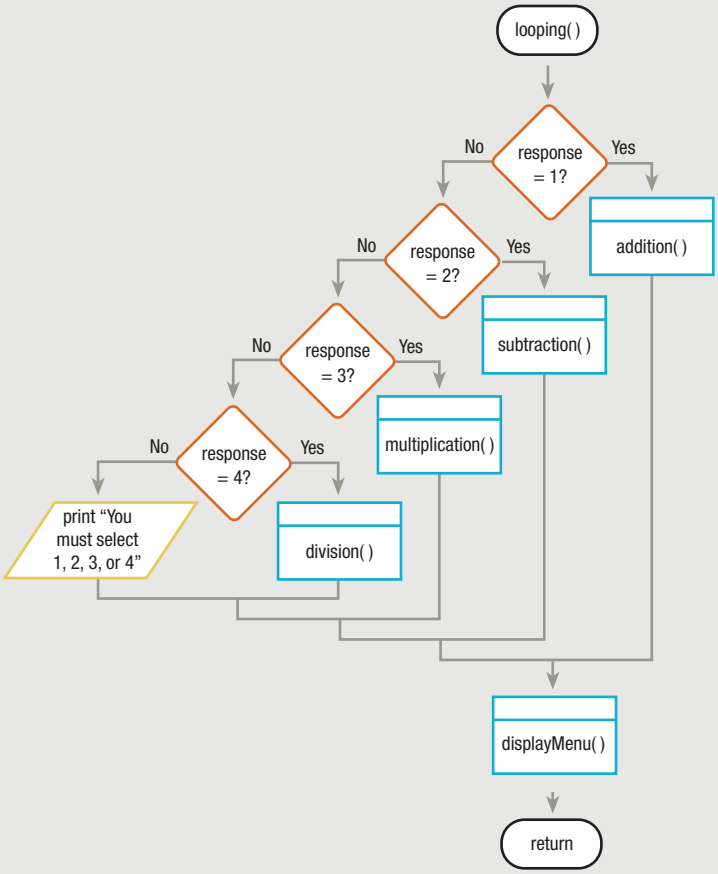
The arithmetic drill program contains just three valid user options: numeric entries that represent addition, subtraction, or quitting the program. Many menus include more than three options, but the main logic of such programs is not substantially different from that in programs with only three. You just include more decisions that lead to additional submodules. For example, Figure 10-14 shows the main logic for a menu program with four optional arithmetic drills.

In Chapter 2 and again in Chapter 5, you learned about the case structure. You can use the case structure to make decisions when you need to test a single variable against several possible values. The case structure is particularly convenient to use in menu-driven programs, because you decide from among several courses of action based on the value in the user's `response` variable. The case structure often is a more convenient way to express a series of individual decisions.

As you have learned, the syntax of case structures in most programming languages allows you to make a series of comparisons, and if none is true, an *Other* or *Default* option executes. Using a default option is a great convenience in a menu-driven program, because a user usually can enter many more invalid responses than valid ones. Figure 10-15 shows the logic of a four-option arithmetic drill program that uses the case structure.

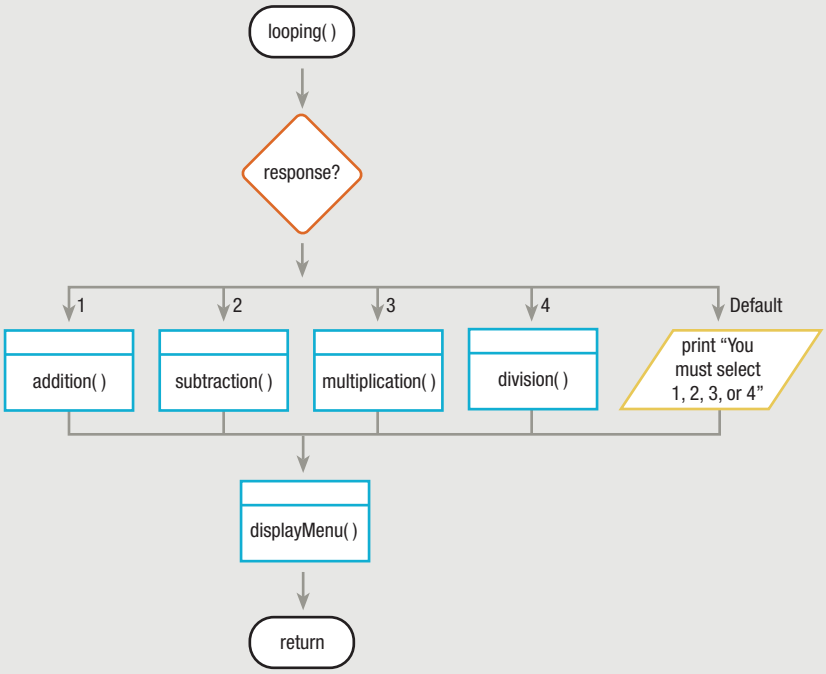
All menu-driven programs should be **user-friendly**, meaning that they should make it easy for the user to make desired choices. Instead of requiring a user to type numbers to select an arithmetic drill, you can improve the menu program by allowing the user the additional option of typing the first letter of the desired option—for example, *A* for addition. To enable the menu program to accept alphabetic characters as a variable named `response`, you must make sure you declare `response` as a character variable in the `startUp()` module. Numeric variables can hold only numbers, but character variables can hold alphabetic characters (such as *A*) as well as numbers.

FIGURE 10-14: MAIN LOGIC OF PROGRAM CONTAINING FOUR OPTIONAL ARITHMETIC DRILLS




```
looping()
     if response = 1 then
          perform addition()
     else
          if response = 2 then
               perform subtraction()
          else
               if response = 3 then
                    perform multiplication()
               else
                    if response = 4 then
                         perform division()
                    else
                         print "You must select 1, 2, 3, or 4"
                    endif
               endif
          endif
     endif
     perform displayMenu()
return
```

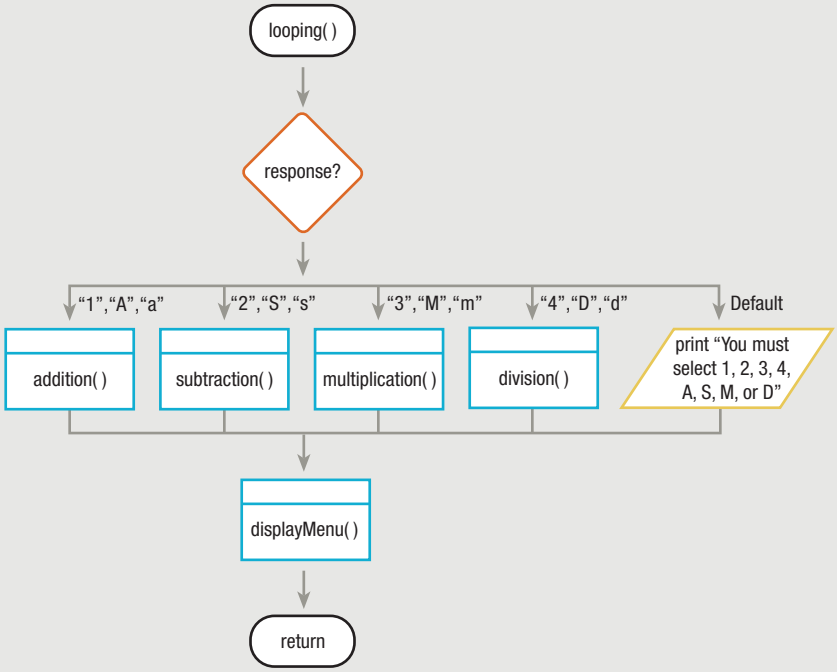
FIGURE 10-15: MENU PROGRAM USING THE CASE STRUCTURE




```
looping()
     case based on response
          case 1
               perform addition()
          case 2
               perform subtraction()
          case 3
               perform multiplication()
          case 4
               perform division()
          default
               print "You must select 1, 2, 3, or 4"
     endcase
     perform displayMenu()
return
```

Programmers sometimes overlook the fact that computers recognize uppercase letters as being different from their lowercase counterparts. Thus, a response of *A* is different from a response of *a*. A good menu-driven program probably would allow any of three responses for the first option of *(1) Addition—1, A,* or *a*. Figure 10-16 shows the case structure that performs the menu option selection when the user can enter a variety of responses for each menu choice.

FIGURE 10-16: MENU PROGRAM USING THE CASE STRUCTURE WITH MULTIPLE ALLOWED RESPONSES




```
looping()
     case based on response
          case "1", "A", "a"
               perform addition()
          case "2", "S", "s"
               perform subtraction()
          case "3", "M", "m"
               perform multiplication()
          case "4", "D", "d"
               perform division()
          default
               print "You must select 1, 2, 3, 4,
                     A, S, M, or D"
     endcase
     perform displayMenu()
return
```

USING MULTILEVEL MENUS

Sometimes, a program requires more options than can easily fit in one menu. When you need to present the user with a large number of options, you invite several potential problems:

- If there are too many options to fit on the display at one time, the user might not realize that additional options are available.
- The screen is too crowded to be visually pleasing when you try to force all the options to fit on the screen.
- Users become confused and frustrated when you present them with too many choices.

When you have many menu options to present, using a multilevel menu might be more effective than using a single-level menu. With a **multilevel menu**, the selection of a menu option leads to another menu from which the user can make further, more refined selections.

For example, an arithmetic drill program might contain three difficulty levels for each type of problem. After the user sees a menu like the one shown in Figure 10-17, he or she can choose to quit the program immediately, without selecting an arithmetic drill. You refer to a menu that controls whether the program will continue as the **main menu** of a program. Alternatively, the user can choose to continue the program, selecting an Addition, Subtraction, Multiplication, or Division arithmetic drill. No matter which drill the user chooses, you can display a second menu like the one shown in Figure 10-18. A second-level (or later-level) menu is a **submenu**.

FIGURE 10-17: FIRST OR MAIN MENU FOR ARITHMETIC DRILL PROGRAM

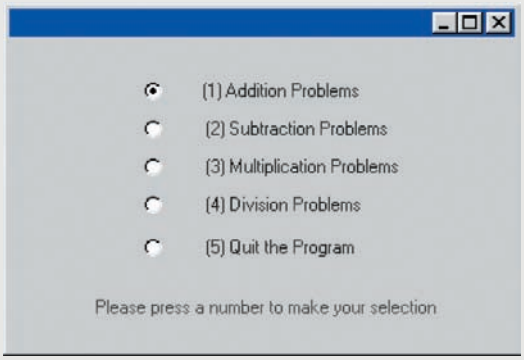
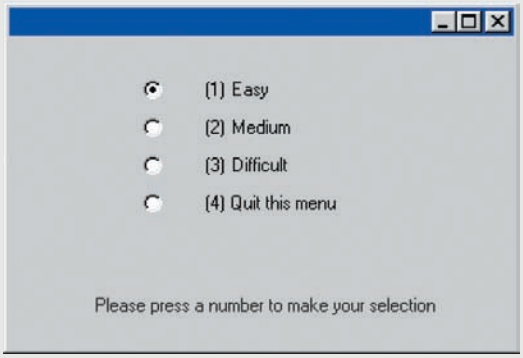
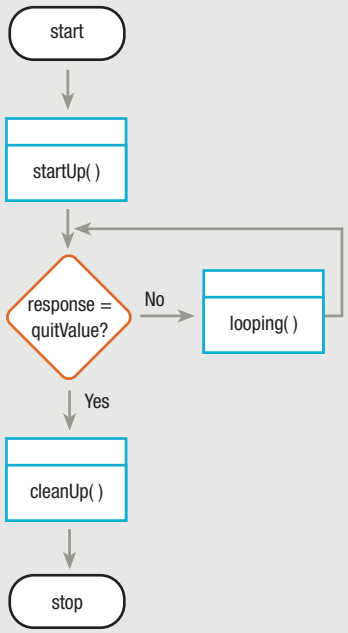


FIGURE 10-18: SECOND OR SUBMENU FOR ARITHMETIC DRILL PROGRAM



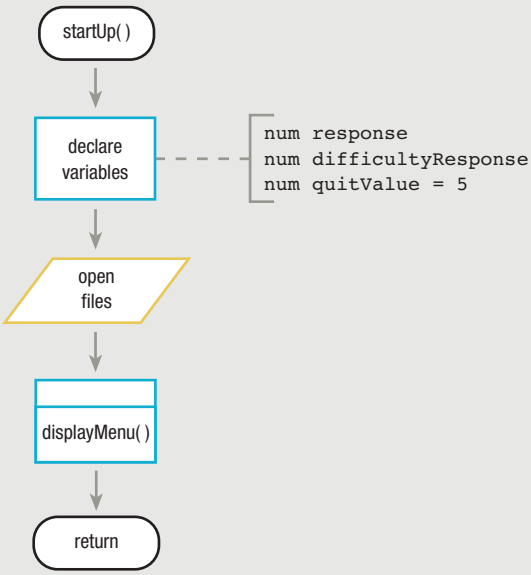
The mainline logic of this multilevel menu arithmetic program calls a `startUp()` module in which the first menu presents options for the four types of arithmetic problems—*Addition, Subtraction, Multiplication,* and *Division*—as well as an option to quit. When the user makes a selection—for example, *Addition*—the mainline logic determines that `response` is not the quit option, so the `looping()` module executes. Figures 10-19, 10-20, and 10-21 show flowcharts and pseudocode for the mainline logic, `startUp()` module, and `displayMenu()` module, respectively.

FIGURE 10-19: FLOWCHART AND PSEUDOCODE FOR MAINLINE LOGIC FOR MULTILEVEL MENU PROGRAM




```
start
     perform startUp()
     while response not equal to quitValue
            perform looping()
     endwhile
     perform cleanUp()
stop
```

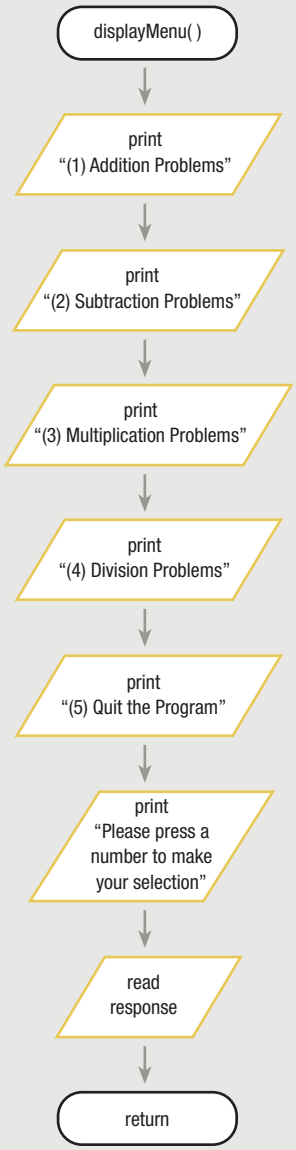
FIGURE 10-20: FLOWCHART AND PSEUDOCODE FOR `startUp()` MODULE FOR MULTILEVEL MENU PROGRAM




```
startUp()
    declare variables
    open files
    perform displayMenu()
return
```

When the program begins, unless the user chooses to quit by entering the `quitValue` (*5*) for the `response` in the `startUp()` module, the `looping()` module executes. The `looping()` module uses a case structure to select one of five actions. Either the user has entered the correct `response` to select addition, subtraction, multiplication, or division problems, or the user has selected an invalid option. If the user selects an invalid option, an error message "Sorry. Invalid entry." appears. Whether or not the user selects an entry that performs one of the four arithmetic drill modules, the final step in the `looping()` module displays the menu again and waits for the next `response`. Back in the mainline logic, the new `response` value is tested, and if the user has entered anything other than the *quitValue*, the `looping()` module executes again. Figure 10-22 shows the flowchart and pseudocode for this version of the `looping()` module.

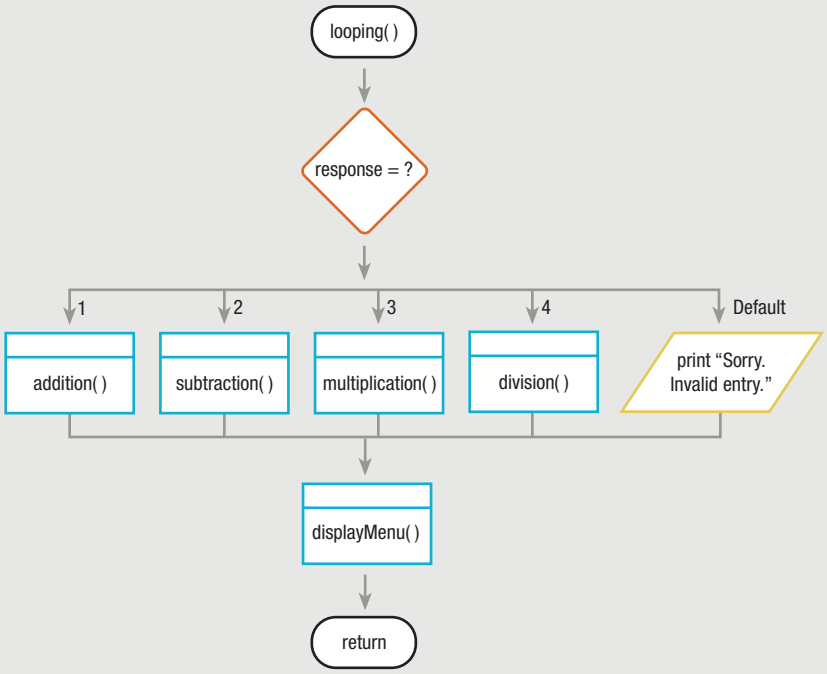
FIGURE 10-21: FLOWCHART AND PSEUDOCODE FOR `displayMenu()` MODULE FOR MULTILEVEL MENU PROGRAM




```
displayMenu()
    print "(1) Addition Problems"
    print "(2) Subtraction Problems"
    print "(3) Multiplication Problems"
    print "(4) Division Problems"
    print "(5) Quit the Program"
    print "Please press a number to make your selection"
    read response
return
```

In the `looping()` module in Figure 10-22, if the user selects a valid option, then the module executes one of the four arithmetic drill modules. For example, if the user selects *1* for *Addition Problems*, then the `addition()` module executes.

FIGURE 10-22: FLOWCHART AND PSEUDOCODE FOR `looping()` MODULE FOR MULTILEVEL MENU PROGRAM

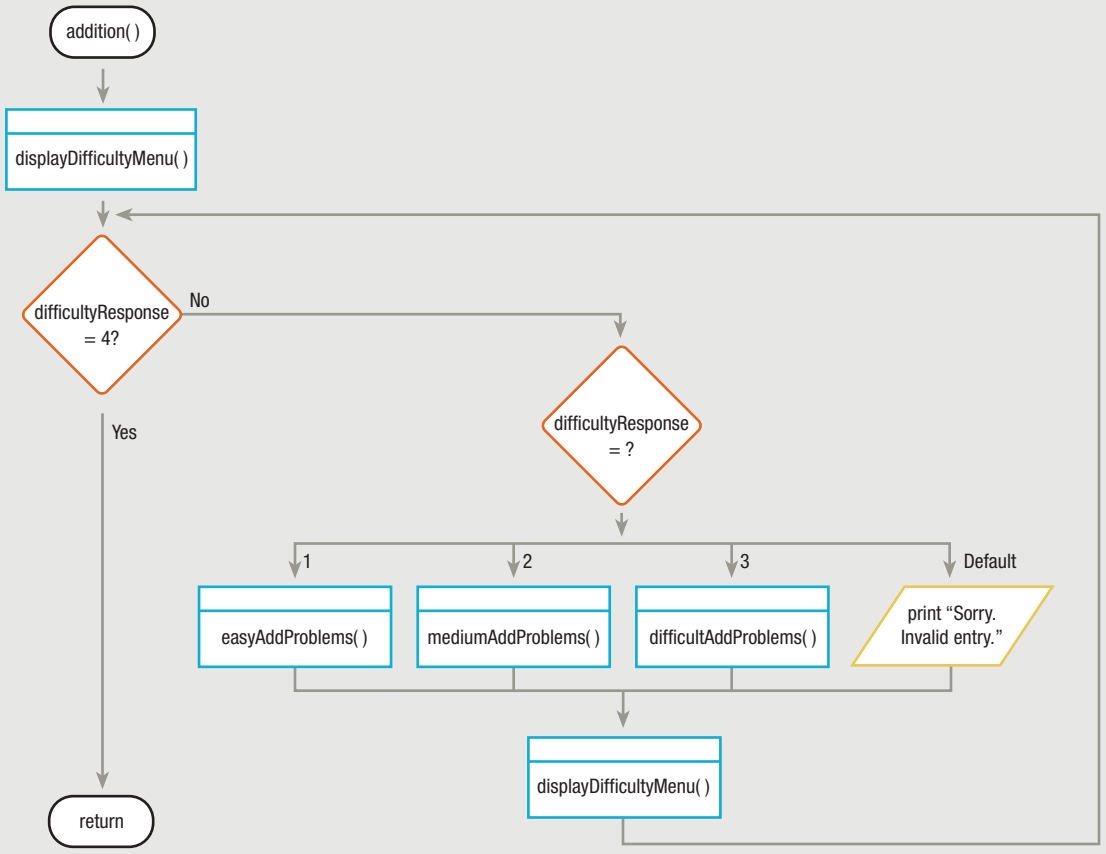



```
looping()
    case based on response
           case 1
                 perform addition()
           case 2
                 perform subtraction()
           case 3
                 perform multiplication()
           case 4
                 perform division()
           default
                 print "Sorry. Invalid entry."
    endcase
    perform displayMenu()
return
```

Within the `addition()` module, the first task is to allow the user to select a problem-difficulty level from a submenu like the one shown in Figure 10-18. Figure 10-23 shows the flowchart and pseudocode for the `addition()` module. Within the `addition()` module, you call another module to display the difficulty level. Shown in Figure 10-24, this module allows the user to choose easy, medium, or difficult addition problems. If the user selects to quit this menu by entering a *4*, then the user will leave the `addition()` module and return to the main menu to choose a different type of arithmetic problem, choose addition again, or quit the program. In the `displayDifficultyMenu()` module, if the user makes a selection other than *4*, the case structure in the `addition()` module determines one of four actions: either one of three addition problem modules executes, or the user is informed that the choice is invalid. In any

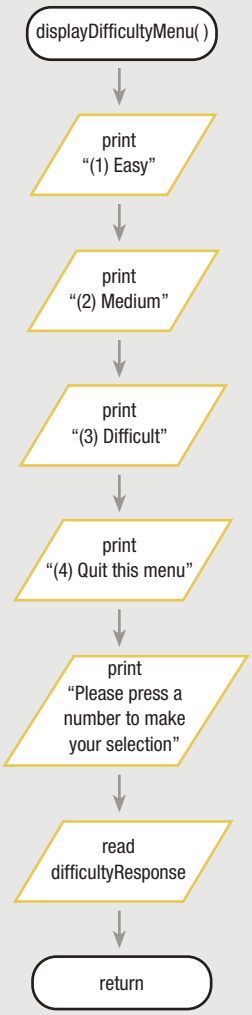
case, the last action of the `addition()` module is to display the difficulty level menu again. As long as users choose options other than *4*, they can continue to select addition problem drills at any of the three difficulty levels.

FIGURE 10-23: FLOWCHART AND PSEUDOCODE FOR `addition()` MODULE FOR MULTILEVEL MENU PROGRAM




```
addition()
    perform displayDifficultyMenu()
    while difficultyResponse is not equal to 4
          case based on difficultyResponse
              case 1
                   perform easyAddProblems()
              case 2
                   perform mediumAddProblems()
              case 3
                   perform difficultAddProblems()
              default
                   print "Sorry. Invalid entry."
          endcase
          perform displayDifficultyMenu()
    endwhile
return
```

FIGURE 10-24: FLOWCHART AND PSEUDOCODE FOR `displayDifficultyMenu()` MODULE FOR MULTILEVEL MENU PROGRAM

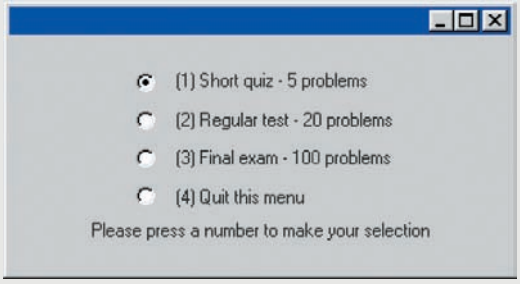



```
displayDifficultyMenu()
    print "(1) Easy"
    print "(2) Medium"
    print "(3) Difficult"
    print "(4) Quit this menu"
    print "Please press a number to make your selection"
    read difficultyResponse
return
```

The `subtraction()`, `multiplication()`, and `division()` modules can contain code similar to that in the `addition()` module. That is, each module can display a submenu of difficulty levels. The actual arithmetic problems do not execute until the user reaches the `easyAddProblems()` module or one of its counterparts.

Many programs have multiple menu levels. For example, you might want the `easyAddProblems()` module to display a new menu asking the user for the number of problems to attempt. Figure 10-25 shows a possible menu.

FIGURE 10-25: THIRD MENU FOR ARITHMETIC DRILL PROGRAM



You would not need to learn any new techniques to create as many levels of menus as the application warrants. The module that controls each new level can:

- Display a menu.
- Accept a response.
- Perform another module based on the selection (or inform the user of an error) while the user does not select the *Quit* option for the specific menu level.
- Display the menu and accept a response again.

VALIDATING INPUT

Menu programs rely on a user's input to select one of several paths of action. Other types of programs also require a user to enter data. Unfortunately, you cannot count on users to enter valid data, whether they are using a menu or supplying information to a program. Users will make incorrect choices because they don't understand the valid choices, or simply because they make typographical errors. Therefore, the programs you write will be improved if you employ **defensive programming**, which means trying to prepare for all possible errors before they occur. Incorrect user entries are by far the most common source of computer errors.

You can circumvent potential problems caused by a user's invalid data entries by validating the user's input. **Validating input** involves checking the user's responses to ensure they fall within acceptable bounds. Validating input does not eliminate all program errors. For example, if a user can choose option *1* or option *2* from a menu, validating the input means you check to make sure the user response is *1* or *2*. If the user enters a *3*, you can issue an error message. However, if the user enters a *2* when she really wants a *1*, there is no way you can validate the response. Similarly, if a user must enter his birth date, you can validate that the month falls between 1 and 12; you usually cannot verify that the user has typed his true birth date.

TIP Validating input is also called *editing* data.

TIP Programmers employ the acronym GIGO to mean "garbage in, garbage out." It means that if your input is incorrect, your output is worthless.

The correct action to take when you find invalid data depends on the application. Within an interactive program, you might require the user to reenter the data. If your program uses a data file, you might print a message so someone can correct the invalid data. Alternatively, you can force the invalid data to a default value. **Forcing** a field to a value means you override incorrect data by setting the field to a specific value. For example, you might decide that if a month value does not fall between 1 and 12, you will force the field to 0 or 99. This indicates to those who use the data that no valid value exists.

New programmers often make the following two kinds of mistakes when validating data:

- They use incorrect logic to check for valid responses when there is more than one possible correct entry.
- They fail to account for the user making multiple invalid entries.

For example, assume a user is required to respond with a *Y* or *N* to a yes-or-no question. The pseudocode in Figure 10-26 appears to check for valid responses.

FIGURE 10-26: INVALID METHOD FOR VALIDATING USER RESPONSE

```
print "Do you want to continue? Enter Y or N."
read userAnswer
if userAnswer not equal to "Y" OR userAnswer not equal to "N" then
       print "Invalid response. Please type Y or N"
       read userAnswer
endif
```

The logic shown in Figure 10-26 intends to make sure that the user enters a *Y* or an *N*. However, if you use the logic shown in Figure 10-26, all users will see the "Invalid response" error message, no matter what they type. Remember, when you use OR logic, only one of the two expressions used in each half of the OR expression must be true for the whole expression to be true. For example, if the user types a *B*, then `userAnswer` is not equal to *Y*. Therefore, `userAnswer not equal to "Y"` is true, and the "Invalid response" message is displayed. However, if the user types an *N*, `userAnswer` also is not equal to *Y*. Again, the condition in the `if` statement is true, and the "Invalid response" message prints, even though the response is actually valid. Similarly, if the user types a *Y*, `userAnswer not equal to "Y"` is false, but `userAnswer not equal to "N"` is true, so again "Invalid response" prints. Every character that exists is either not Y or not N, even "Y" and "N". The correct logic prints the "Invalid response" message when `userAnswer` is not Y *and it is also not N*. See Figure 10-27.

FIGURE 10-27: IMPROVED METHOD FOR VALIDATING USER RESPONSE

```
print "Do you want to continue? Enter Y or N."
read userAnswer
if userAnswer not equal to "Y" AND userAnswer not equal to "N" then
       print "Invalid response. Please type Y or N"
       read userAnswer
endif
```

TIP You first learned about OR decision logic in Chapter 5.

If you use the logic shown in Figure 10-27, when the user types an invalid response, you will correctly display the error message and get a new `userAnswer`. However, you have not made allowance for the user typing an invalid response a second time. Instead of using a decision statement to check for a valid response, you can use a loop to continue to issue error messages and get new input as long as the user continues to make invalid selections. Figure 10-28 shows the logic for the best method for validating user input.

FIGURE 10-28: BEST METHOD FOR VALIDATING USER RESPONSE

```
print "Do you want to continue? Enter Y or N."
read userAnswer
while userAnswer not equal to "Y" AND userAnswer not equal to "N"
      print "Invalid response. Please type Y or N"
      read userAnswer
endwhile
```

UNDERSTANDING TYPES OF DATA VALIDATION

The data you use within computer programs is varied. It stands to reason that validating data requires a variety of methods. In the last section, you learned to check for an exact match of a user response to the character "Y" or "N". In addition, some of the techniques you want to master include validating:

- Data type
- Range
- Reasonableness and consistency of data
- Presence of data

VALIDATING A DATA TYPE

Some programming languages allow you to check data items to make sure they are the correct data type. Although this technique varies from language to language, you can often make a statement like the one shown in Figure 10-29. In this program segment, `isNumeric()` represents a method call; it is used to check whether the entered `employeeSalary` falls within the category of numeric data. A method such as `isNumeric()` is most often provided with the language translator you use to write your programs. Such a method operates as a black box; you can use its results without understanding its internal statements.

FIGURE 10-29: METHOD FOR CHECKING DATA FOR CORRECT TYPE

```
print "Enter salary."
read employeeSalary
while employeeSalary not isNumeric()
       print "Salary not numeric. Please reenter."
       read employeeSalary
endwhile
```

TIP Some languages require you to check data against the actual machine codes (such as ASCII or EBCDIC) used to store the data, to determine if the data is the appropriate type.

Besides allowing you to check whether a value is numeric, some languages contain methods with names like `isChar()` (for "is the value a character data type?"), `isWhitespace()` (meaning "is the value a nonprinting character such as a space, a tab, or the Enter key?"), `isUpper()` (meaning "is the value a capital letter?"), and `isLower()` (meaning "is the value a lowercase letter?").

In many languages, you accept all user data as a string of characters, and then use built-in methods to attempt to convert the characters to the correct data type for your application. When the conversion methods succeed, you have useful data; when the conversion methods fail because the user has entered the wrong data type, you can take appropriate action, such as issuing an error message, reprompting the user, or forcing the data to a default value.

VALIDATING A DATA RANGE

Sometimes, a user response or other data must fall within a range of values. For example, when the user enters a month, you typically require it to fall between 1 and 12, inclusive. The method you use to check for a valid range is similar to one you use to check for an exact match; you continue to prompt for and receive responses while the user's response is out of range. See Figure 10-30.

FIGURE 10-30: METHOD FOR VALIDATING USER RESPONSE WITHIN RANGE

```
print "Enter month."
read userAnswer
while userAnswer < 1 OR userAnswer > 12
       print "Invalid response. Please enter month 1 through 12."
       read userAnswer
endwhile
```

VALIDATING REASONABLENESS AND CONSISTENCY OF DATA

Data items can be the correct type and within range, but still be incorrect. You have experienced this phenomenon yourself if anyone has ever misspelled your name or overbilled you. The data might have been the correct type—that is, alphabetic letters were used in your name—but the name itself was incorrect. There are many data items that you cannot check for reasonableness; it is just as reasonable that your name is Catherine as it is that your name is Katherine or Kathryn.

However, there are many data items that you can check for reasonableness. If you make a purchase on May 3, 2007, then the payment cannot possibly be due prior to that date. Perhaps within your organization, if you work in Department 12, you cannot possibly make more than $20.00 per hour. If your zip code is 90201, your state of residence cannot be New York. If your pet's breed is stored as "Great Dane," then its species cannot be "bird." Each of these examples involves comparing two data fields for reasonableness and consistency. You should consider making as many such comparisons as possible when writing your own programs.

TIP Frequently, testing for reasonableness and consistency involves using additional data files. For example, to check that a user has entered a valid county of residence for a state, you might use a file that contains every county name within every state in the United States, and check the user's county against those contained in the file.

VALIDATING PRESENCE OF DATA

Sometimes, data is missing from a file, either for a reason or by accident. A job applicant might fail to submit an entry for the `salaryAtPreviousJob` field, or a client might have no entry for the `emailAddress` field. A data-entry clerk might accidentally skip a field when typing records. Many programming languages allow you to check for missing data and take appropriate action with a statement similar to `if emailAddress is blank perform noEmailModule()`. You can place any instructions you like within `noEmailModule()`, including forcing the field to a default value or issuing an error message.

Good defensive programs try to foresee all possible inconsistencies and errors. The more accurate your data, the more useful information you will produce as output from your programs.

CHAPTER SUMMARY

- Programs for which all the data items are gathered prior to running use batch processing. Programs that depend on user input while they are running use interactive, real-time, online processing. A menu program is a common type of interactive program in which the user sees a number of options on the screen and can select any one of them.
- When you create a single-level menu, the user makes a selection from only one menu before using the program for its ultimate purpose. The user's response controls the mainline logic of a menu program.
- When you code a module as a black box, the module statements are invisible to the rest of the program. Many versions of a module can substitute for one another. When programmers develop systems containing many modules, they often code "empty" black box procedures, called stubs; later they can code the details in the stub modules. In addition, most programming languages provide you with built-in black box functions.
- A programmer can improve a menu program and assist the user by displaying a message when the selected response is not one of the allowable menu options. Another user-friendly improvement to a program adds a counter that keeps track of a user's invalid responses and issues a stronger message after a specific number of invalid responses.
- You can use the case structure to make decisions when you need to test a single variable against several possible values. The case structure is particularly convenient to use in menu-driven programs, because you decide from among several courses of action based on the value in the user's response variable.
- When a program requires more options than can easily fit in one menu, you can use a multilevel menu. With a multilevel menu, the selection of an option from a main menu leads to a submenu from which the user can make further, more refined selections. With multilevel menus, the module that controls each new level can display a menu, accept a response, and—while the user does not select the quit option for that menu level—perform another module based on the selection (or inform the user of an error). Finally, the module for each menu level displays the menu and accepts a response again.
- You can circumvent potential problems caused by a user's invalid data entries by validating the user's input. Validating input involves checking the user's responses to ensure they fall within acceptable bounds, and taking one of several possible actions. Common mistakes when validating data include using incorrect logic and failing to account for the user making multiple invalid entries.
- Some of the techniques you want to master include validating data type, range, reasonableness and consistency of data, and presence of data.

KEY TERMS

Programs for which all the data items are gathered prior to running use **batch processing**.

Programs that depend on user input while the programs are running use **interactive processing**.

Interactive computer programs are often called **real-time applications**, because they run while a transaction is taking place, not at some later time.

You also can refer to interactive processing as **online processing**, because the user's data or requests are gathered during the execution of the program, while the computer is operating.

A batch processing system can be **offline**; that is, you can collect data such as time cards or purchase information well ahead of the actual computer processing of the paychecks or bills.

A **menu program** is a common type of interactive program in which the user sees a number of options on the screen and can select any one of them.

Console applications are programs that require the user to enter choices using the keyboard.

Graphical user interface applications allow the user to use a mouse or other pointing device to enter choices.

A **single-level menu** is one from which a user makes a selection that results in the program's ultimate purpose, as opposed to displaying additional menus.

When code exists in a **black box**, module statements are "invisible" to the rest of the program.

Stubs are empty procedures, intended to be coded later.

Functions are modules that automatically provide a mathematical value such as a square root, absolute value, or random number.

User-friendly programs are those that make it easy for the user to make desired choices.

With a **multilevel menu**, the selection of a menu option leads to another menu from which the user can make further, more refined selections.

The **main menu** of a program is the menu that determines whether execution of the program will continue.

A second-level, or later-level, menu is a **submenu**.

Defensive programming involves trying to prepare for all possible errors before they occur.

Validating input involves checking the user's responses to ensure they fall within acceptable bounds.

Forcing a field to a value means you override incorrect data by setting the field to a specific value.

REVIEW QUESTIONS

1. Programs for which all the data items are gathered prior to running use _____ processing.

a. batch
b. interactive
c. online
d. real-time

2. Programs that depend on user input while the programs are running use _____ processing.

a. artificial
b. delayed
c. batch
d. interactive

3. Which of the following means the same as interactive processing?

a. query processing
b. virtual processing
c. real-time processing
d. batch processing

4. A menu program is a common type of _____ program.

a. batch
b. interactive
c. control break
d. offline

5. If a user makes a selection from only one menu before using the program for its ultimate purpose, then the menu is a _____ menu.

a. primary
b. single-level
c. focal
d. batch

6. When module statements are invisible to the rest of a program, they are said to exist within a _____.

a. black hole
b. magic hat
c. mirror
d. black box

7. Modules containing no code that are used as temporary placeholders are called _____.

a. black boxes
b. stubs
c. fill-ins
d. padded

8. **Most programming languages provide you with built-in modules called _____ that automatically provide a mathematical value such as a square root, absolute value, or random number.**
   a. functions
   b. formulas
   c. stubs
   d. black boxes

9. **Writing a program that provides a user with increasingly detailed help messages as the user continues to make data-entry errors requires that the program contain a _____.**
   a. loop
   b. counter
   c. both of these
   d. neither a nor b

10. **The structure that provides a more convenient way to express a series of decisions that are based on the value of a single variable is the _____ structure.**
    a. loop
    b. do until
    c. case
    d. sequence

11. **A program that makes it easy for a user to accomplish tasks is said to be _____.**
    a. simplex
    b. user-friendly
    c. structured
    d. accommodating

12. **You might need to create a multilevel menu from a single-level one if _____.**
    a. you do not have enough options to fill the screen
    b. users are allowed only true-false choices
    c. the screen appears too crowded
    d. all of the above

13. **Where is the user selection that ends a program most likely to appear?**
    a. in a program's main menu
    b. in a program's first submenu
    c. in a program's last submenu
    d. in every menu in a program

14. **Writing programs that try to prepare for all possible user errors is known as _____ programming.**
    a. proactive
    b. cautious
    c. aggressive
    d. defensive

15. Checking to ensure that data values fall within acceptable bounds is known as _____ data.

a. forcing
b. defending
c. classifying
d. validating

16. Which value for `deptNumber` would be considered valid using the following code?

```
if deptNumber not = 1 OR deptNumber not = 2 then
     print "Invalid number"
else
     print "Valid number"
endif
```

a. 1
b. 2
c. Both 1 and 2 are valid.
d. Neither 1 nor 2 is valid.

17. Which value for `deptNumber` would be considered valid using the following code?

```
if deptNumber not = 5 AND deptNumber not = 6 then
     print "Invalid number"
else
     print "Valid number"
endif
```

a. 5
b. 6
c. Both 5 and 6 are valid.
d. Neither 5 nor 6 is valid.

18. Which of the following student data items could most easily be validated by a program used by a college?

a. The name of the high school the student attended is spelled correctly.
b. The student's middle name is correct.
c. The student's grade point average is between 0.0 and 4.0, inclusive.
d. The student's last tuition payment is for the correct amount.

19. Which of the following data items could least easily be validated by a program used by a grocery store?

a. The Universal Product Code for an item contains the correct number of digits (12).
b. The product name is alphabetic.
c. The date the product was last ordered from the manufacturer is a valid date and no more than two years old.
d. The product price is no more than any other store in the state is charging this week.

20. Good defensive programs _____.

a. catch all errors
b. catch all range errors, but not necessarily other error types
c. catch many errors
d. seldom catch errors until the data is visually verified by clerical employees

FIND THE BUGS

The following pseudocode contains one or more bugs that you must find and correct.

1. **Head Gear, Inc. sells customized baseball caps embroidered with your team name or company logo. This application allows a user to enter the phrase to be imprinted on a cap and a quantity. The application then displays a menu from which a user can choose the color for the caps ordered. The total amount due is displayed when the order is complete.**

```
start
     perform firstTasks()
     while phrase not = QUIT
          perform userChoices()
     endwhile
     perform finishUp()
stop

firstTasks()
     declare variables
         char phrase
         num quantity
         num colorChoice
         const num QUIT = "XXX"
         const num LOWAMOUNT = 1
         const num HIGHAMOUNT = 500
         const num DISCOUNTPRICE = 6.99
         const num REGPRICE = 8.99
         const num CUTOFF = 100
         const num CAMO_PREMIUM = 1.50
         num price
     open files
     print "Enter phrase you want embroidered on caps
     print " or enter ", QUIT, " to quit"
     read phrase
return

userChoices()
     display "Enter quantity"
     while quantity < LOWAMOUNT OR quantity > HIGHAMOUNT
        print "Invalid amount. Please re-enter quantity"
        read quantity
     endwhile
     perform displayMenu()
     perform computePrice()
     print "Enter phrase you want embroidered on caps
```

```
     print " or enter ", QUIT, " to quit"
return

displayMenu()
    colorChoice = 0
    whileColorChoice < 1 OR colorChoice > 6
      print "Choose a color from the following menu"
      print "(1) Black"
      print "(2) Red"
      print "(3) Blue"
      print "(4) Green"
      print "(5) White"
      print "(6) Camouflage"
    endwhile
return

computePrice()
    if quantity < = CUTOFF then
        price = REGPRICE * quantity
    else
        price = DISCOUNTPRICE
    endif
    if colorChoice = 6 then
         price = price + CAMO_PREMIUM * quantity
    endif
    print "Total is $ ", price
return

finishUp()
    close files
return
```

2. The Good Thoughts Web site lets users select whether they are in the mood for an inspirational, motivational, or empathetic message. A message is randomly selected from a database of quotes and displayed. (Assume that a random number can be obtained by passing a numeric argument to a built-in `rand()` function that returns a value from 0 through one less than the argument.)

```
start
     perform getReady()
     while entry not = QUIT
          perform displayMessage()
     endwhile
     perform finishUp()
stop
```

```
getReady()
     declare variables
          num entry
          const num QUIT = 4
     open files
     perform menuSelect()
stop

menuSelect()
    userInput = 1
    whileUserInput < 1 OR userInput > QUIT
      print "Choose a type of message for the day"
      print "(1) Inspirational message"
      print "(2) Motivational message"
      print "(3) Empathetic message"
      print "(4) Quit"
    endwhile
return

displayMessage()
   num SZ = 3
   char inspirationMessages[SZ]
   char motiveMessages[SZ]
   char empathyMessages[SZ]
   inspirationMessages message[0] =
       "This is the first day of the rest of your life"
   inspirationMessages [SZ] =
       "The sun will come out tomorrow"
   inspirationMessages [NUM] =
       "The journey is the destination"
   motiveMessages[SZ] = "Go the extra mile"
   motiveMessages[2] = "Rome wasn't built in a day"
   motiveMessages[3] =
       "If at first you don't succeed, try, try again"
   empathyMess [0] = "Poor baby"
   empathyMess[1] = "I feel your pain"
   empathyMess[2] = "I know where you are coming from"

   randNum = rand(SZ)
        // A prewritten function that returns 0, 1 or 2
   if user = 1 then
     print inspireMessage[SZ]
   else
```

```
        if userInput = 2 then
            print motiveMessage[5]
        else
            print empMess[randNum]
        endif
    endif
    perform menuSelect()
return

finishUp()
    close files
return
```

EXERCISES

1. **Develop the logic for a program that gives you the following options for a trivia quiz:**
   (1) Movies
   (2) Television
   (3) Sports
   (4) Quit

   When the user selects an option, display a question that falls under the category. After the user responds, display whether the answer is correct.
   a. Draw the hierarchy chart.
   b. Draw the flowchart.
   c. Write the pseudocode.

2. **Modify the program in Exercise 1 so that when the user selects a trivia quiz topic option, you display five questions in the category instead of just one.**

3. **Develop the logic for a program that presents you with the following options for a banking machine:**
   (1) Deposit
   (2) Withdrawal
   (3) Quit

   After you select an option, the program asks you for the amount of money to deposit or withdraw, then displays your balance and allows you to make another selection. When the user selects *Quit*, display the final balance.
   a. Draw the hierarchy chart.
   b. Draw the flowchart.
   c. Write the pseudocode.

4. **Develop the logic for a program that gives you the following options:**
   (1) Hot dog 1.50
   (2) Fries 1.00
   (3) Lemonade .75
   (4) End order

You should be allowed to keep ordering from the menu until you press *4* for *End order*, at which point you should see a total amount due for your entire order.

a. Draw the hierarchy chart.
b. Draw the flowchart.
c. Write the pseudocode.

5. **Develop the logic for a program that gives you the following options when registering for college classes:**

(1) English 101 3
(2) Math 260 5
(3) History 100 3
(4) Sociology 151 4
(5) Quit

You should be allowed to select as many classes as you want before you choose the *Quit* option, but you should not be allowed to register for the same class twice. The program accumulates the hours for which you have registered and displays your tuition bill at $50 per credit hour.

a. Draw the hierarchy chart.
b. Draw the flowchart.
c. Write the pseudocode.

6. **Suggest two subsequent levels of menus for each of the first two options in this main menu:**

(1) Print records from file
(2) Delete records from file
(3) Quit

7. **Develop the logic for a program that displays the rules for a sport or a game. The user can select from the following menu:**

(1) Sports
(2) Games
(3) Quit

If the user chooses *1* for *Sports*, then display options for four different sports of your choice (for example, soccer or basketball).

If the user chooses *2* for *Games*, display options for:

(1) Card games
(2) Board games
(3) Quit

Display options for at least two card games (for example, Hearts) and two board games (for example, checkers) of your choice. Then display a one- or two-sentence summary of the game rules.

a. Draw the hierarchy chart.
b. Draw the flowchart.
c. Write the pseudocode.

8. **Draw the menus and then develop the logic for a program that displays United States travel and tourism facts. The main menu should allow the user to choose a region of the country. The next level should allow the user to select a state in that region. The final level should allow the user to select a city, at which point the user can view facts such as the city's population and average temperature. Write the complete module for only one region, one state, and one city.**
   a. Draw the hierarchy chart.
   b. Draw the flowchart.
   c. Write the pseudocode.

9. **Design the menus and then develop the logic for an interactive program for a florist. The first screen asks the user to choose indoor plants, outdoor plants, nonplant items, or quit. When the user chooses indoor or outdoor plants, list at least three appropriate plants of your choice. When the user chooses a plant, display its correct price. If the user chooses the nonplant option, offer a choice of gardening tools, gift items, or quit. Depending on the user selection, display at least three gardening tools or gift items. When the user chooses one, display its price.**
   a. Draw the hierarchy chart.
   b. Draw the flowchart.
   c. Write the pseudocode.

10. **Design the menus and then develop the logic for an interactive program for a company's customer database. Store the customers' ID numbers in a 20-element array; store their balances due in a parallel 20-element array. The menu options include: add customers to the database, find a customer in the database, print the database, and quit. If the user chooses to add customers, allow the user to enter a customer ID and balance to the current list, but do not let the list exceed 20 customers. If the user chooses to print, then print all existing IDs and balances; if there are none, issue a message. If the user chooses to find a customer, issue a message if there are none; otherwise, provide a second menu with three options—find by number, find by balance, or quit. Assume that every customer has a unique ID number, but that there might be several customers with the same balance.**
   a. Draw the hierarchy chart.
   b. Draw the flowchart.
   c. Write the pseudocode.

11. **Design the logic for a program that creates job applicant records, including all input data and starting salary. The program asks users for their first name, middle initial, last name, birth date (month, day, and year), current age, date of application (month, day, and year), and the job title for which they are applying. Available jobs and starting salaries appear in the following table:**

JOB TITLE	SALARY
Clerk I	26,000
Clerk II	30,000
Administrative assistant	37,500
Technical writer	39,000
Programmer I	42,500
Programmer II	50,000

Perform as many validation checks as you can think of to make sure that complete and accurate records are created.

a. Draw the hierarchy chart.
b. Draw the flowchart.
c. Write the pseudocode.

12. **Design the logic for a program that creates student records for Creighton Technical College and assigns an advisor and a dormitory to each student. The program asks users for their first name, last name, birth date (month, day, and year), and intended major. Advisors are assigned based on major, as follows:**

MAJOR	ADVISOR LAST NAME
Business	Brown for the first 100 students, then Davis
Computer Information Systems	Cunningham for the first 100 students, then Lee
Heating and Air Conditioning	Parke
Hospitality	Hunter
Undeclared	Ulster

Dormitories are assigned based on both major and age, as follows:

MAJOR	AGE	DORMITORY
Business	under 21	Washington
Business	21 and over	Adams
Computer Information Systems	under 21	Jefferson
Computer Information Systems	21 and over	Lincoln
Heating and Air Conditioning	any	Grant
Hospitality or Undeclared	any	Wilson

Perform as many validation checks as you can think of to make sure that complete and accurate records are created.

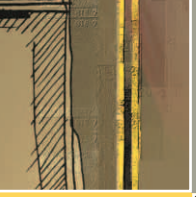
a. Draw the hierarchy chart.
b. Draw the flowchart.
c. Write the pseudocode.

DETECTIVE WORK

1. **Many programming languages make a distinction between the terms "function" and "procedure." To most programmers, what is the difference?**
2. **What is black box testing? What are the advantages and disadvantages of this type of testing?**
3. **What is defensive programming? What is Murphy's law? What do the two have to do with each other?**

UP FOR DISCUSSION

1. **Obviously, you use a menu in a restaurant. Where else?**
2. **Have you ever used a telephone menu system that was inconvenient or frustrating? Describe the problems you encountered. Can you develop a set of recommendations for telephone menu systems?**




11 SEQUENTIAL FILE MERGING, MATCHING, AND UPDATING

After studying Chapter 11, you should be able to:

- Understand sequential files and the need for merging them
- Create the mainline and `housekeeping()` logic for a merge program
- Create the `mergeFiles()` and `finishUp()` modules for a merge program
- Modify the `housekeeping()` module to check for `eof`
- Understand master and transaction file processing
- Match files to update master file fields
- Allow multiple transactions for a single master file record
- Update records in sequential files

UNDERSTANDING SEQUENTIAL DATA FILES AND THE NEED FOR MERGING FILES

A **sequential file** is a file in which records are stored one after another in some order. One option is to store records in a sequential file in the order in which the records are created. For example, if you maintain records of your friends, you might store the records as you make the friends; you could say the records are stored in **temporal order**—that is, in order based on time. At any point in time, the records of your friends will be stored in sequential order based on how long you have known them—the data stored about your best friend from kindergarten is record 1, and the data about the friend you just made last week could be record 30.

Instead of temporal order, records in a sequential file are more frequently stored based on the contents of one or more fields within each record. Perhaps it is most useful for you to store your friends' records sequentially in alphabetical order by last name, or maybe in order by birthday.

Other examples of sequential files include:

- A file of employees stored in order by Social Security number
- A file of parts for a manufacturing company stored in order by part number
- A file of customers for a business stored in alphabetical order by last name

TIP

Recall from Chapter 9 that the field that makes a record unique from all records in a file is the key field. Frequently, though not always, records are most conveniently stored in order by their key fields.

Businesses often need to merge two or more sequential files. **Merging files** involves combining two or more files while maintaining the sequential order. For example:

- Suppose you have a file of current employees in Social Security number order and a file of newly hired employees, also in Social Security number order. You need to merge these two files into one combined file before running this week's payroll program.
- Suppose you have a file of parts manufactured in the Northside factory in part-number order and a file of parts manufactured in the Southside factory, also in part-number order. You need to merge these two files into one combined file, creating a master list of available parts.
- Suppose you have a file that lists last year's customers in alphabetical order and another file that lists this year's customers in alphabetical order. You want to create a mailing list of all customers in order by last name.

Before you can easily merge files, two conditions must be met:

- Each file must contain the same record layout.
- Each file used in the merge must be sorted in the same order (ascending or descending) based on the same field.

For example, suppose your business has two locations, one on the East Coast and one on the West Coast, and each location maintains a customer file in alphabetical order by customer name. Each file contains fields for name and customer balance. You can call the fields in the East Coast file `eastName` and `eastBalance`, and the fields in the West Coast file `westName` and `westBalance`. You want to merge the two files, creating one master file containing records for all customers. Figure 11-1 shows some sample data for the files; you want to create a merged file like the one shown in Figure 11-2.

FIGURE 11-1: SAMPLE DATA CONTAINED IN TWO CUSTOMER FILES

East Coast File		West Coast File	
eastName	eastBalance	westName	westBalance
Able	100.00	Chen	200.00
Brown	50.00	Edgar	125.00
Dougherty	25.00	Fell	75.00
Hanson	300.00	Grand	100.00
Ingram	400.00		
Johnson	30.00		

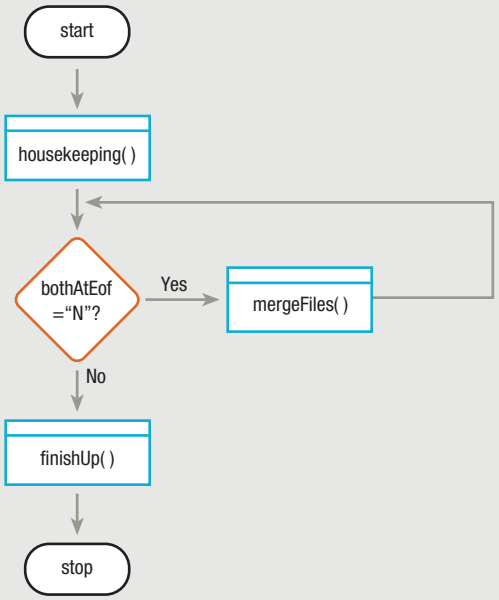
FIGURE 11-2: MERGED CUSTOMER FILE

mergedName	mergedBalance
Able	100.00
Brown	50.00
Chen	200.00
Dougherty	25.00
Edgar	125.00
Fell	75.00
Grand	100.00
Hanson	300.00
Ingram	400.00
Johnson	30.00

CREATING THE MAINLINE AND housekeeping() LOGIC FOR A MERGE PROGRAM

The mainline logic for a program that merges two files is similar to the main logic you've used before in other programs: it contains a `housekeeping()` module, a `mergeFiles()` module that repeats until the end of the program, and a `finishUp()` module. Most programs you have written would repeat the main, central module (in this program, the `mergeFiles()` module) until the `eof` condition occurs. In a program that merges files, there are two input files, so checking for `eof` on one of them is insufficient. Instead, the mainline logic will check a flag variable that you create with a name such as `bothAtEof`. You will set the `bothAtEof` flag to "Y" after you have encountered `eof` in both input files. Figure 11-3 shows the mainline logic.

FIGURE 11-3: FLOWCHART AND PSEUDOCODE FOR MAINLINE LOGIC OF THE MERGE PROGRAM




```
start
  perform housekeeping()
  while bothAtEof = "N"
        perform mergeFiles()
  endwhile
  perform finishUp()
stop
```

TIP You first used flag variables in Chapter 8. A flag is a variable that keeps track of whether an event has occurred.

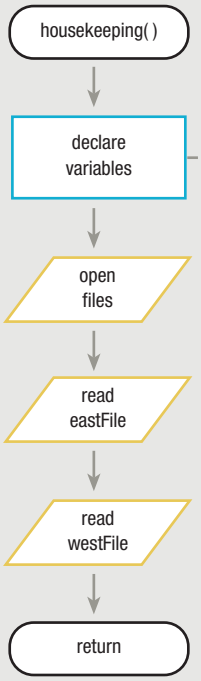
When you declare variables within the `housekeeping()` module, you must declare the `bothAtEof` flag and initialize it to "N" to indicate that the input files have not yet reached the end-of-file condition. In addition, you need to define two input files, one for the file from the East Coast office and one for the file from the West Coast office. Figure 11-4 shows that the files are called `eastFile` and `westFile`. Their variable fields are `eastName`, `eastBalance`, `westName`, and `westBalance`, respectively.

TIP You will modify the `housekeeping()` module in Figure 11-4 later in this chapter, after you learn about the special techniques needed to handle the `eof` conditions in this program.

At the end of a `housekeeping()` module, typically you read the first file input record into memory. In this file-merging program with two input files, you will read one record from *each* input file into memory at the end of the `housekeeping()` module.

The output from the merge program is a new, merged file containing all records from the two original input files. Logically, writing to a file and writing a printed report are very similar—each involves sending data to an output device. The major difference is that when you write a data file, typically you do not include headings or other formatting for people to read, as you do when creating a printed report. A **data file** contains only data for another computer program to read.

FIGURE 11-4: FLOWCHART AND PSEUDOCODE FOR THE **housekeeping()** MODULE IN THE MERGE PROGRAM, VERSION 1




```
eastFile
   char eastName
   num eastBalance
westFile
   char westName
   num westBalance
char bothAtEof = "N"
```

```
housekeeping()
     declare variables
     open files
     read eastFile
     read westFile
return
```

TIP Logically, the verbs "print," "write," and "display" mean the same thing—all produce output. However, in conversations, programmers usually reserve the word "print" for situations in which they mean "produce hard copy output," and are more likely to use "write" when talking about sending records to a data file and "display" when sending records to a monitor. In some programming languages, there is no difference in the verb you use for output, no matter what type of hardware you use; you simply assign different output devices (such as printers, monitors, and disk drives) as needed to programmer-named objects that represent them.

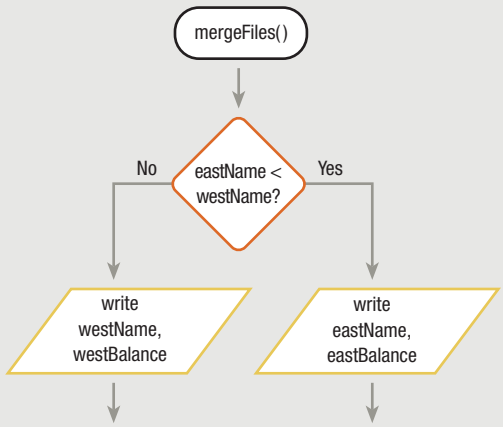
TIP In some programming languages, you might assign each input field to a named variable designed specifically for output before writing. In many languages, such as Java, C++, and C#, you can use the same variable as an input field and an output field—a convention that is followed in this book.

TIP In many organizations, both data files and printed report files are sent to disk storage devices when they are created. Later, as time becomes available on the organization's busy printers (often after business hours), the report disk files are copied to paper.

CREATING THE `mergeFiles()` AND `finishUp()` MODULES FOR A MERGE PROGRAM

When you begin the `mergeFiles()` module, two records—one from `eastFile` and one from `westFile`—are sitting in the memory of the computer. One of these records needs to be written to the new output file first. Which one? Because the two input files contain records stored in alphabetical order, and you want the new file to store records in alphabetical value, you first output the input record that has the lower alphabetical value in the name field. Therefore, the `mergeFiles()` module begins as shown in Figure 11-5.

FIGURE 11-5: BEGINNING OF THE `mergeFiles()` MODULE OF THE MERGE PROGRAM




```
mergeFiles()
     if eastName < westName then
          write eastName, eastBalance
          …
     else
          write westName, westBalance
          …
```

TIP Don't be confused by a statement such as `write eastName, eastBalance`. Even though `eastName` and `eastBalance` are input fields, *writing* them sends their contents to a new output file, just as printing them sends them to a piece of paper. In some older programming languages, you had to move input fields such as `eastName` and `eastBalance` to an output area before you could write them to a file.

Using the sample data from Figure 11-1, you can see that the record from the East Coast file containing "Able" should be written to the output file, while Chen's record from the West Coast file waits in memory because the `eastName` value "Able" is alphabetically lower than the `westName` value "Chen".

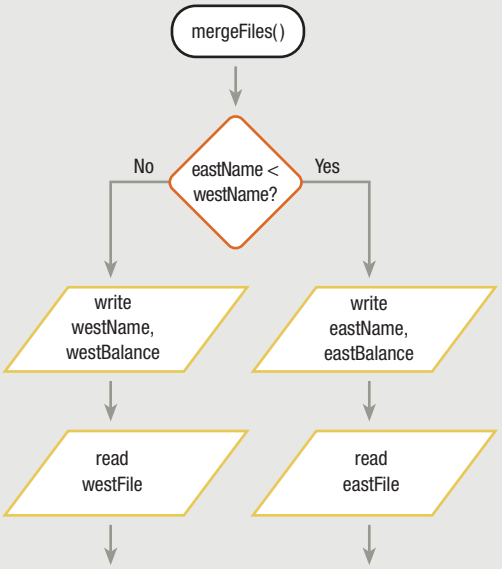
After you write Able's record, should Chen's record be written to the output file next? Not necessarily. It depends on the next `eastName` following Able's record in `eastFile`. When data records are read into memory from a file, a program typically does not "look ahead" to determine the values stored in the next record. Instead, a program usually reads the record into memory before making decisions about its contents. In this program, you need to read the next `eastFile` record into memory and compare it to "Chen". Because in this case the next record in `eastFile` contains the name "Brown", another `eastFile` record is written; no `westFile` records are written yet.

After the first two `eastFile` records, is it Chen's turn to be written now? You really don't know until you read another record from `eastFile` and compare its name value to "Chen". Because this record contains the name "Dougherty",

it is indeed time to write Chen's record. After Chen's record is written to output, should you now write Dougherty's record? Until you read the next record from **westFile**, you don't know whether that record should be placed before or after Dougherty's record.

Therefore, the **mergeFiles()** module proceeds like this: compare two records, write the record with the lower alphabetical name, and read another record from the *same* input file. See Figure 11-6.

FIGURE 11-6: CONTINUATION OF THE **mergeFiles()** MODULE FOR THE MERGE PROGRAM




```
mergeFiles()
     if eastName < westName then
          write eastName, eastBalance
          read eastFile
          …
     else
          write westName, westBalance
          read westFile
          …
```

Recall the names from the two original files (see Figure 11-7) and walk through the processing steps.

FIGURE 11-7: NAMES FROM TWO FILES TO MERGE

eastName	westName
Able	Chen
Brown	Edgar
Dougherty	Fell
Hanson	Grand
Ingram	
Johnson	

1. Compare "Able" and "Chen". Write Able's record. Read Brown's record from **eastFile**.
2. Compare "Brown" and "Chen". Write Brown's record. Read Dougherty's record from **eastFile**.
3. Compare "Dougherty" and "Chen". Write Chen's record. Read Edgar's record from **westFile**.
4. Compare "Dougherty" and "Edgar". Write Dougherty's record. Read Hanson's record from **eastFile**.

5. Compare “Hanson” and “Edgar”. Write Edgar’s record. Read Fell’s record from `westFile`.
6. Compare “Hanson” and “Fell”. Write Fell’s record. Read Grand’s record from `westFile`.
7. Compare “Hanson” and “Grand”. Write Grand’s record. Read from `westFile`, encountering `eof`.

What happens when you reach the end of the West Coast file? Is the program over? It shouldn’t be, because records for Hanson, Ingram, and Johnson all need to be included in the new output file, and none of them is written yet. You need to find a way to write the Hanson record as well as read and write all the remaining `eastFile` records. And you can’t just write statements to read and write from `eastFile`; sometimes, when you run this program, records in `eastFile` will finish first alphabetically, and in that case you need to continue reading from `westFile`.

An elegant solution to this problem involves setting the field on which the merge is based to a “high” value when the end of the file is encountered. A **high value** is one that is greater than any possible value in a field. Programmers often use all 9s in a numeric field and all Zs in a character field to indicate a high value. Every time you read from `westFile` you can check for `eof`, and when it occurs, set `westName` to “ZZZZZ”. Similarly, when reading `eastFile`, set `eastName` to “ZZZZZ” when `eof` occurs. When both `eastName` and `westName` are “ZZZZZ”, then you set the `bothAtEof` variable to “Y”. Figure 11-8 shows the complete `mergeFiles()` logic.

TIP

At the end of the file, you might choose to use 10 or 20 Zs in the `eastName` and `westName` fields instead of using only five. Although it is unlikely that a person will have the last name ZZZZZ, you should make sure that the value you choose for a high value is actually a higher value than any legitimate value.

TIP

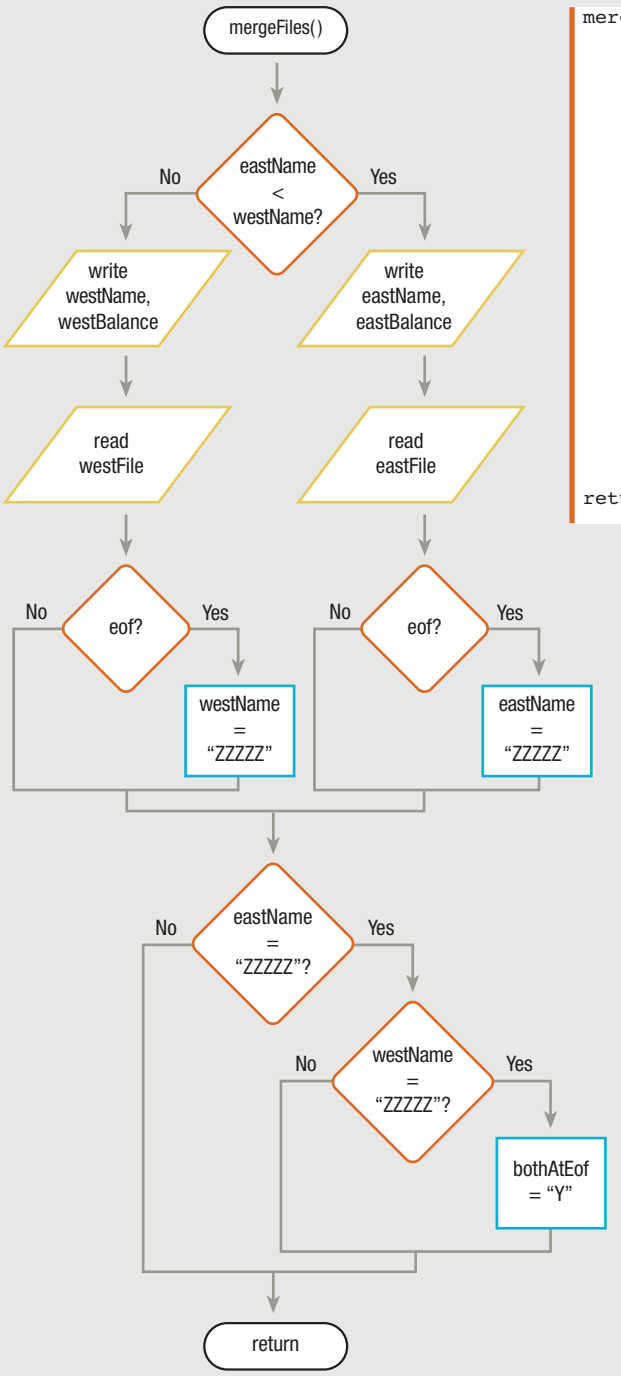
Several programming languages contain a name you can use for a value that occurs when every bit in a byte is an “on” bit, creating a value that is even higher than all Zs or all 9s. For example, in COBOL this value is called HIGH-VALUES, and in RPG it is called HIVAL.

Using the sample data in Figure 11-7, after Grand’s record is processed, `westFile` is read and `eof` is encountered, so `westName` gets set to “ZZZZZ”. Now, when you enter the `mergeFiles()` module again, `eastName` and `westName` are compared, and `eastName` is still “Hanson”. The `eastName` value (Hanson) is lower than the `westName` value (ZZZZZ), so the data for `eastName`’s record writes to the output file, and another `eastFile` record (Ingram) is read.

The complete run of the file-merging program now executes the first six of the seven steps as listed previously, and then proceeds as shown in Figure 11-8 and as follows, starting with a modified Step 7:

7. Compare “Hanson” and “Grand”. Write Grand’s record. Read from `westFile`, encountering `eof` and setting `westName` to “ZZZZZ”.
8. Compare “Hanson” and “ZZZZZ”. Write Hanson’s record. Read Ingram’s record.
9. Compare “Ingram” and “ZZZZZ”. Write Ingram’s record. Read Johnson’s record.
10. Compare “Johnson” and “ZZZZZ”. Write Johnson’s record. Read from the `eastFile`, encountering `eof` and setting `eastName` to “ZZZZZ”.
11. Now that both names are “ZZZZZ”, set the flag `bothAtEof` equal to “Y”.

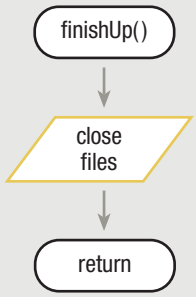
FIGURE 11-8: THE `mergeFiles()` MODULE FOR THE MERGE PROGRAM, COMPLETED




```
mergeFiles()
     if eastName < westName then
          write eastName, eastBalance
          read eastFile
          if eof then
               eastName = "ZZZZZ"
          endif
     else
          write westName, westBalance
          read westFile
          if eof then
               westName = "ZZZZZ"
          endif
     endif
     if eastName = "ZZZZZ" then
          if westName = "ZZZZZ" then
               bothAtEof = "Y"
          endif
     endif
return
```

When the `bothAtEof` flag variable equals "Y" at the end of the `mergeFiles()` module, the mainline logic then proceeds to the `finishUp()` module. See Figure 11-9.

FIGURE 11-9: THE `finishUp()` MODULE FOR THE MERGE PROGRAM




```
finishUp()
     close files
return
```

TIP

Notice that if two names are equal during the merge process—for example, when there is a "Hanson" record in each file—then both Hansons will be included in the final file. When `eastName` and `westName` match, `eastName` is not lower than `westName`, so you write the `westFile` "Hanson" record. After you read the next `westFile` record, `eastName` will be lower than the next `westName`, and the `eastFile` "Hanson" record will be output. A more complicated merge program could check another field, such as first name, when last-name values match.

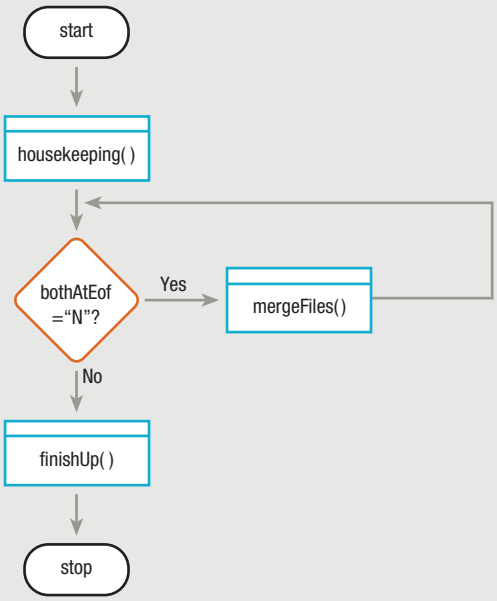
TIP

You can merge any number of files. To merge more than two files, the logic is only slightly more complicated; you must compare the key fields from all three files before deciding which file is the next candidate for output.

MODIFYING THE housekeeping() MODULE IN THE MERGE PROGRAM TO CHECK FOR eof

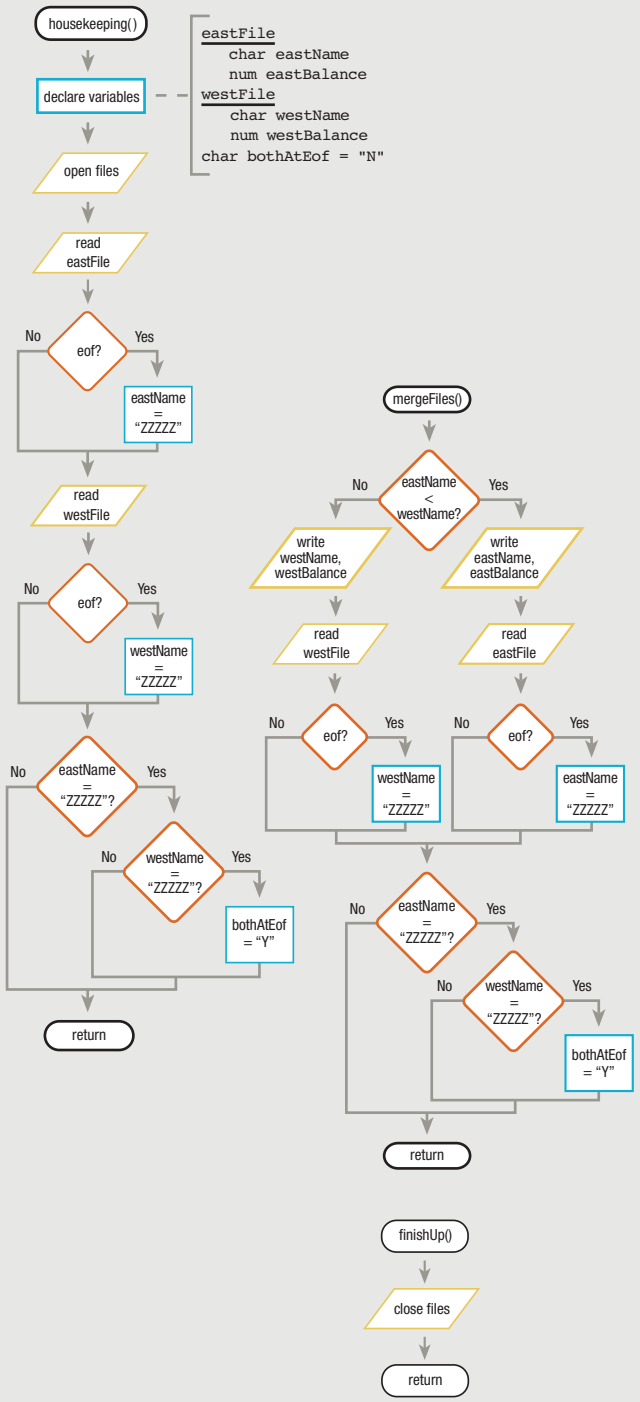
Recall that in the **housekeeping()** module for the merge program that combines East Coast and West Coast customer files, you read one record from each of the two input files. Although it is unlikely that you will reach the end of the file after attempting to read the first record in a file, it is good practice to check for **eof** every time you read. In the **housekeeping()** module, you first read from one of the input files. Whether you encounter **eof** or not, you then read from the second input file. If both files are at **eof**, then both name fields are set to "ZZZZZ", and you can set the **bothAtEof** flag to "Y". Then, when the **housekeeping()** module ends, if the value of **bothAtEof** is "Y", it means that there are no records to merge, and the mainline logic will immediately send the program to the **finishUp()** module. Figure 11-10 shows the complete merge program, including the newly modified **housekeeping()** module that checks for the end of each input file.

FIGURE 11-10: THE COMPLETE FILE MERGE PROGRAM




```
start
     perform housekeeping()
     while bothAtEof = "N"
          perform mergeFiles()
     endwhile
     perform finishUp()
stop
```

FIGURE 11-10: THE COMPLETE FILE MERGE PROGRAM (CONTINUED)




```
housekeeping()
     declare variables
     open files
     read eastFile
     if eof then
          eastName = "ZZZZZ"
     endif
     read westFile
     if eof then
          westName = "ZZZZZ"
     endif
     if eastName = "ZZZZZ" then
          if westName = "ZZZZZ" then
               bothAtEof = "Y"
          endif
     endif
return
```

```
mergeFiles()
     if eastName < westName then
          write eastName, eastBalance
          read eastFile
          if eof then
               eastName = "ZZZZZ"
          endif
     else
          write westName, westBalance
          read westFile
          if eof then
               westName = "ZZZZZ"
          endif
     endif
     if eastName = "ZZZZZ" then
          if westName = "ZZZZZ" then
               bothAtEof = "Y"
          endif
     endif
return
```

```
finishUp()
     close files
return
```

MASTER AND TRANSACTION FILE PROCESSING

When two related sequential files seem "equal," in that they hold the same *type* of information—for example, when one holds customers from the East Coast and one holds customers from the West Coast—you often need to merge the files to use them as a single unit. When you merge records from two or more files, the records (almost) always contain the same fields in the same order; in other words, every record in the merged file has the same format.

Some related sequential files, however, are unequal and you do not want to merge them. For example, you might have a file containing records for all your customers, in which each record holds a customer ID number, name, address, and balance due. You might have another file that contains data for every purchase made, containing the customer ID number and other purchase information such as a dollar amount. Although both files contain a customer ID number, the file with the customer names and addresses is an example of a master file. You use a **master file** to hold relatively permanent data, such as customers' names. The file containing customer purchases is a **transaction file**, a file that holds more temporary data generated by the actions of the customers. You may maintain certain customers' names and addresses for years, but the transaction file will contain new data daily, weekly, or monthly, depending on your organization's billing cycle. Commonly, you periodically use a transaction file to find a **matching record** in a master file—one that contains data about the same customer. Sometimes, you match records so you can **update the master file** by making changes to the values in its fields. For example, the file containing transaction purchase data might be used to update each master file record's balance due field. At other times, you might match a transaction file's records to its master file counterpart, creating an entity that draws information from both files—an invoice, for example. This type of program requires matching, but no updating. Whether a program simply matches records in master and transaction files, or updates the master file, depending on the application, there might be none, one, or many transaction records corresponding to each master file record.

Here are a few other examples of files that have a master-transaction relationship:

- A library maintains a master file of all patrons and a transaction file with information about each book or other items checked out.
- A college maintains a master file of all students and a transaction file for each course registration.
- A telephone company maintains a master file for every telephone line (number) and a transaction file with information about every call.

When you update a master file, you can take two approaches:

- You can actually change the information in the master file. When you use this approach, the information that existed in the master file prior to the transaction processing is lost.
- You can create a copy of the master file, making the changes in the new version. Then, you can store the previous version of the master file for a period of time, in case there are questions or discrepancies regarding the update process. The saved version of a master file is the **parent file**; the updated version is the **child file**. This approach is used later in this chapter.

TIP When a child file is updated, it becomes a parent, and its parent becomes a grandparent. Individual organizations create policies concerning the number of generations of backup files they will save before discarding them.

TIP The terms "parent" and "child" refer to file backup generations, but they also are used in object-oriented programming. When you base a class on another using inheritance, the original class is the parent and the derived class is the child. You will learn about these concepts in Chapter 13.

MATCHING FILES TO UPDATE FIELDS IN MASTER FILE RECORDS

The logic you use to perform a match between master and transaction file records is similar to the logic you use to perform a merge. As with a merge, you must begin with both files sorted in the same order on the same field.

Assume you have a master file with the fields shown in Figure 11-11.

FIGURE 11-11: MASTER CUSTOMER FILE DESCRIPTION

```
MASTER CUSTOMER FILE DESCRIPTION
File name: CUSTOMERS
FIELD DESCRIPTION       DATA TYPE      COMMENTS
Customer number         Numeric        3 digits
Name                    Character
Address                 Character
Phone number            Character
Total sales             Numeric        2 decimal places
```

The `custTotalSales` field holds the total dollar amount of all purchases the customer has made previously; in other words, it holds the total amount the customer has spent prior to the current week. At the end of each week, you want to update this field with any new sales transaction that occurred during the week. Assume a transaction file contains one record for every transaction that has occurred and that each record holds a transaction number, the number of the customer who made the transaction, the transaction date, and the amount of the transaction. The fields in the transaction file are shown in Figure 11-12.

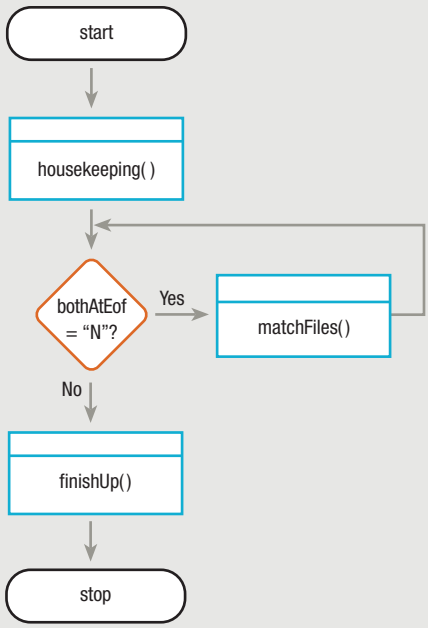
FIGURE 11-12: TRANSACTION FILE DESCRIPTION

```
TRANSACTION FILE DESCRIPTION
File name: TRANSACTIONS
FIELD DESCRIPTION       DATA TYPE      COMMENTS
Transaction number      Numeric        7 digits
Customer number         Numeric        3 digits
Transaction date        Numeric        8 digits YYYYMMDD
Transaction amount      Numeric        2 decimal places
```

You want to create a new master file in which almost all information is the same as in the original file, but the `custTotalSales` field increases to reflect the most recent transaction. The process involves going through the old master file, one record at a time, and determining whether there is a new transaction for that customer. If there is no transaction for a customer, the new customer record will contain exactly the same information as the old customer record. However, if there is a transaction for a customer, the `transAmount` value adds to the `custTotalSales` field before you write the updated master file record to output. Imagine you were going to update master file records by hand instead of using a computer program, and imagine each master and transaction record was stored on a separate piece of paper. The easiest way to accomplish the update would be to sort all the master records by customer number and place them in a stack, and then sort all the transactions by customer number (not transaction number) and place them in another stack. You then would examine the first transaction, and look through the master records until you found a match. You would then correct the matching master record and examine the next transaction. The computer program you write to perform the update works exactly the same way.

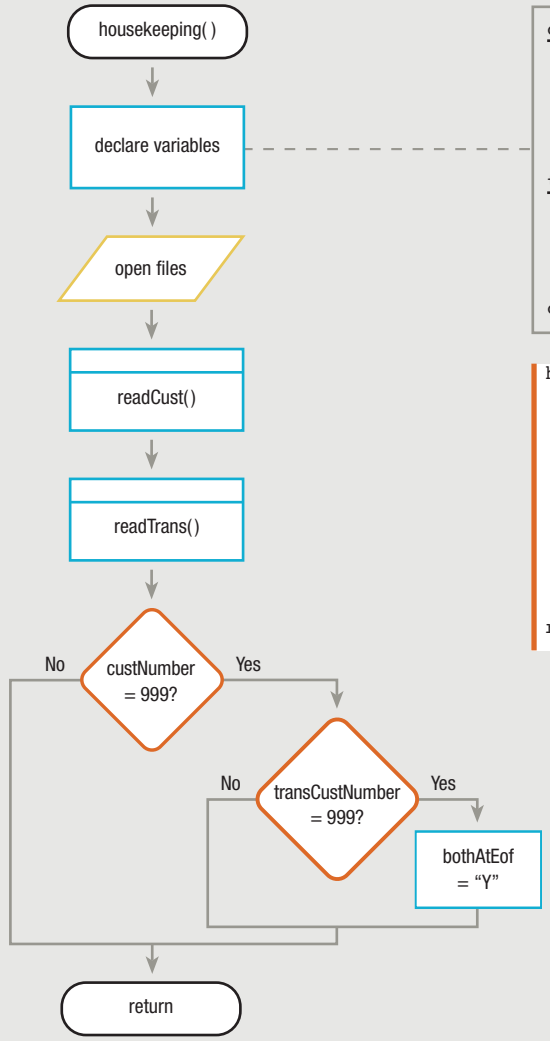
The mainline logic (see Figure 11-13) and `housekeeping()` module (see Figure 11-14) for this matching program look similar to their counterparts in a file-merging program. Two records are read, one from the master file and one from the transaction file. When you encounter `eof` for either file, store a high value (999) in the customer number field. Using the `readCust()` and `readTrans()` modules moves the reading of files and checking for `eof` off into their individual modules, as shown in Figure 11-15.

FIGURE 11-13: MAINLINE LOGIC FOR THE FILE-MATCHING PROGRAM




```
start
     perform housekeeping()
     while bothAtEof = "N"
            perform matchFiles()
     endwhile
     perform finishUp()
stop
```

FIGURE 11-14: THE `housekeeping()` MODULE FOR THE FILE-MATCHING PROGRAM

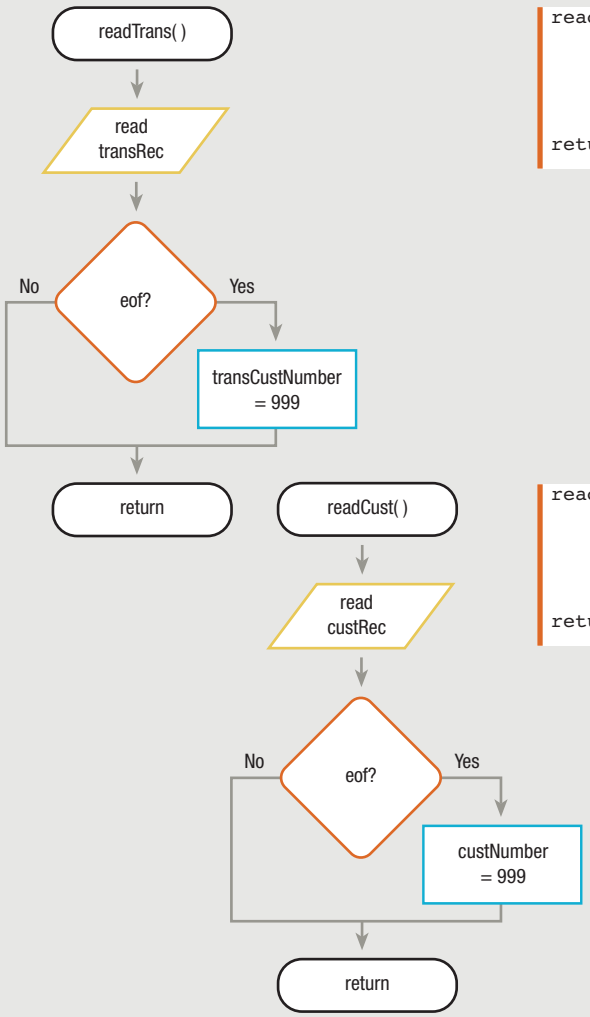



```
custRec
   num custNumber
   char custName
   char custAddress
   char custPhone
   num custTotalSales
transRec
   num transNumber
   num transCustNumber
   num transDate
   num transAmount
char bothAtEof = "N"
```

```
housekeeping()
     declare variables
     open files
     perform readCust()
     perform readTrans()
     if custNumber = 999 then
           if transCustNumber = 999 then
                 bothAtEof = "Y"
           endif
     endif
return
```

TIP In the file-merging program earlier in this chapter, you placed “ZZZZZ” in the customer name field at the end of the file because character fields were being compared. In this example, because you are using numeric fields (customer numbers), you can store 999 in them at the end of the file. The value 999 is the highest possible numeric value for a three-digit number in the customer number field.

FIGURE 11-15: THE `readTrans()` AND `readCust()` MODULES FOR THE FILE-MATCHING PROGRAM




```
readTrans()
    read transRec
    if eof then
       transCustNumber = 999
    endif
return
```

```
readCust()
    read custRec
    if eof then
       custNumber = 999
    endif
return
```

In the file-merging program, your first action in the mainline `mergeFiles()` module was to determine which file held the record with the lower value; then, you wrote that file to output. In a main module within a matching program, you need to determine more than whether one file's comparison field is larger than another's; it's also important to know if they are *equal*. In this example, you want to update the master file record's `custTotalSales` field only if the transaction record `transCustNumber` field contains an exact match for the customer number in the master

file record. Therefore, in the file-matching module (called `matchFiles()` in this example), you compare `custNumber` from `custRec` and `transCustNumber` from `transRec`. Three possibilities exist:

- The `transCustNumber` value equals `custNumber`.
- The `transCustNumber` value is higher than `custNumber`.
- The `transCustNumber` value is lower than `custNumber`.

When you compare records from the two input files, if `custNumber` and `transCustNumber` are equal, you add `transAmount` to `custTotalSales`, and then write the updated master record to the output file. Then, you read in both a new master record and a new transaction record.

TIP The logic used here assumes there can be only one transaction per customer. Later in this chapter, you will develop the logic for a program in which the customer can have multiple transactions.

If `transCustNumber` is higher than `custNumber`, there wasn't a sale for that customer. That's all right; not every customer makes a transaction every period. If `transCustNumber` is higher than `custNumber` when you compare records, you simply write the original customer record to output with exactly the same information it contained when input; then, you get the next customer record to see if this customer made the transaction currently under examination.

Finally, when you compare records from the master and transaction files, if `transCustNumber` is lower than `custNumber` in the master file, you are trying to record a transaction for which no master record exists. That means there must be an error, because a transaction should always have a master record. You can handle this error in a variety of ways; here, you will write an error message to an output device before reading the next transaction record. A human operator can then read the message and take appropriate action.

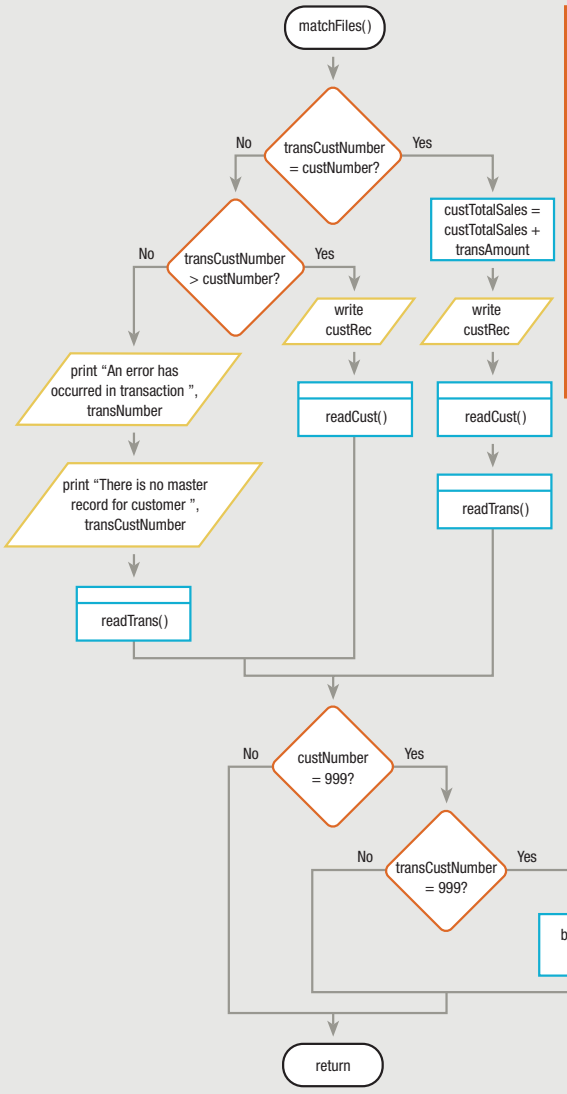
Whether `transCustNumber` was higher than, lower than, or equal to `custNumber`, at the bottom of the `matchFiles()` module you check whether both `custNumber` and `transCustNumber` are 999; when they are, you set the `bothAtEof` flag to "Y".

Figure 11-16 shows some sample data you can use to walk through the logic for this program, and Figure 11-17 shows the pseudocode and flowchart.

FIGURE 11-16: SAMPLE DATA FOR THE FILE-MATCHING PROGRAM

```
Master File                          Transaction File
custNumber   custTotalSales          transCustNumber  transAmount
100          1000.00                 100              400.00
102            50.00                 105              700.00
103           500.00                 108              100.00
105            75.00                 110              400.00
106          5000.00
109          4000.00
110           500.00
```

FIGURE 11-17: THE `matchFiles()` MODULE LOGIC FOR THE FILE-MATCHING PROGRAM




```
matchFiles()
    if transCustNumber = custNumber then
          custTotalSales = custTotalSales + transAmount
          write custRec
          perform readCust()
          perform readTrans()
    else
          if transCustNumber > custNumber then
                write custRec
                perform readCust()
          else
                print "An error has occurred in transaction ",
                   transNumber
                print "There is no master record for customer ",
                   transCustNumber
                perform readTrans()
          endif
    endif
    if custNumber = 999 then
          if transCustNumber = 999 then
                bothAtEof = "Y"
          endif
    endif
return
```

The program proceeds as follows:

1. Read customer 100 from the master file and customer 100 from the transaction file. Customer numbers are equal, so 400.00 from the transaction file is added to 1000.00 in the master file, and a new master file record is written with a 1400.00 total sales figure. Then, read a new record from each input file.

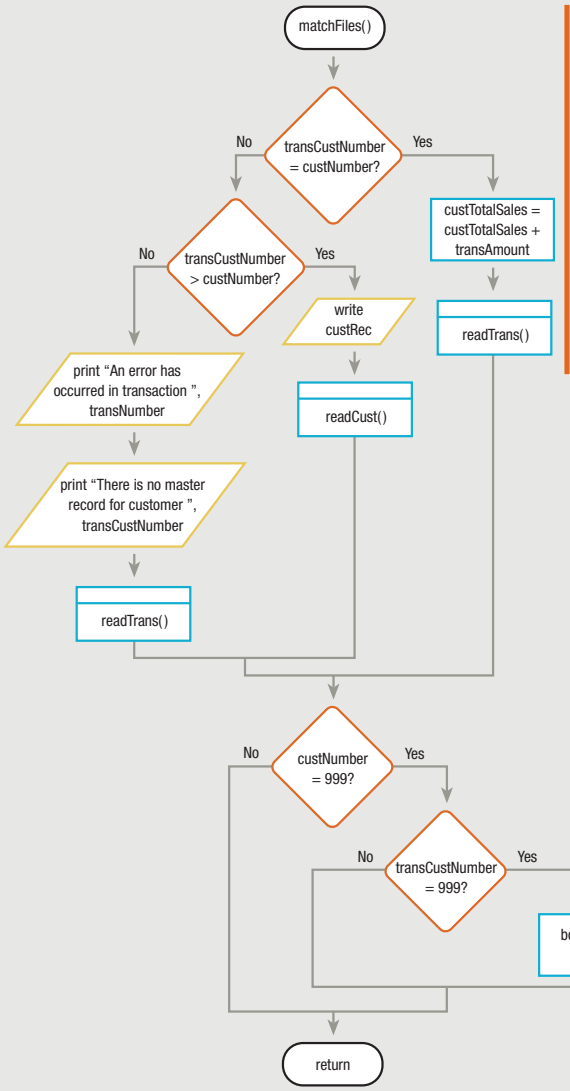
2. The customer number in the master file is 102 and the customer number in the transaction file is 105, so there are no transactions today for customer 102. Write the master record exactly the way it came in, and read a new master record.
3. Now, the master customer number is 103 and the transaction customer number is still 105. This means customer 103 has no transactions, so you write the master record as is and read a new one.
4. Now, the master customer number is 105 and the transaction number is 105. Because customer 105 had a 75.00 balance and now has a 700.00 transaction, the new total sales figure is 775.00, and a new master record is written. Read one record from each file.
5. Now, the master number is 106 and the transaction number is 108. Write customer record 106 as is, and read another master.
6. Now, the master number is 109 and the transaction number is 108. An error has occurred. The transaction record indicates that you made a sale to customer 108, but there is no master record for customer number 108. Either there is an error in the transaction's customer number or the transaction is correct but you have failed to create a master record. Either way, write an error message so that a clerk is notified and can handle the problem. Then, get a new transaction record.
7. Now, the master number is 109 and the transaction number is 110. Write master record 109 with no changes and read a new one.
8. Now, the master number is 110 and the transaction number is 110. Add the 400.00 transaction to the previous 500.00 figure, and write a new record with a 900.00 value in the `custTotalSales` field. Read one record from each file.
9. Because both files are finished, end the job. The result is a new master file in which some records contain exactly the same data they contained going in, but others (for which a transaction has occurred) have been updated with a new total sales figure.

ALLOWING MULTIPLE TRANSACTIONS FOR A SINGLE MASTER FILE RECORD

In the last example, the logic provided for, at most, one transaction record per master customer record. You would use very similar logic if you wanted to allow multiple transactions for a single customer. Figure 11-18 shows the new logic. A small but important difference exists between logic that allows multiple transactions and logic that allows only a single transaction per master file record. If a customer can have multiple transactions, whenever a transaction matches a customer, you add the transaction amount to the master total sales field. Then, you read *only* from the transaction file. After you exit `mainLoop()` and reenter it, the next transaction might also pertain to the same master customer. (Compare the first "Yes" branch in Figure 11-18 with the one in Figure 11-17; the `readCust()`

module is removed in Figure 11-18.) Only when a transaction number is greater than a master file customer number do you write the customer master record.

FIGURE 11-18: THE `matchFiles()` LOGIC ALLOWING MULTIPLE TRANSACTIONS FOR EACH MASTER FILE RECORD




```
matchFiles()
    if transCustNumber = custNumber then
          custTotalSales = custTotalSales + transAmount
          perform readTrans()
    else
          if transCustNumber > custNumber then
                write custRec
                perform readCust()
          else
                print "An error has occurred in transaction ",
                      transNumber
                print "There is no master record for customer ",
                      transCustNumber
                perform readTrans()
          endif
    endif
    if custNumber = 999 then
          if transCustNumber = 999 then
                bothAtEof = "Y"
          endif
    endif
return
```

UPDATING RECORDS IN SEQUENTIAL FILES

In the example in the preceding section, you needed to update a field in some of the records in a master file with new data. A more sophisticated update program allows you not only to make changes to data in a master file record, but also to update a master file either by adding new records or by eliminating the ones you no longer want.

Assume you have a master employee file, as shown on the left side of Figure 11-19. Sometimes, a new employee is hired and a record must be added to this file, or an employee quits and the employee's record must be removed from the file. Sometimes, you need to change an employee record by recording a raise in salary, for example, or a change of department.

For this kind of update program, it's common to have a transaction file in which each record contains all the same fields as the master file records do, with one exception. The transaction file has one extra field to indicate whether this transaction is meant to be an addition, a deletion, or a change—for example, a one-letter code of "A", "D", or "C". Figure 11-19 shows the master and transaction file layouts.

FIGURE 11-19: MASTER AND TRANSACTION FILES FOR THE UPDATE PROGRAM

MASTER AND TRANSACTION FILES FOR THE UPDATE PROGRAM

File name: EMPREC		File name: TRANSREC	
FIELD DESCRIPTION	DATA TYPE	FIELD DESCRIPTION	DATA TYPE
Employee number	Numeric	Employee number	Numeric
Name	Character	Name	Character
Salary	Numeric	Salary	Numeric
Department	Numeric	Department	Numeric
		Transaction code	Character

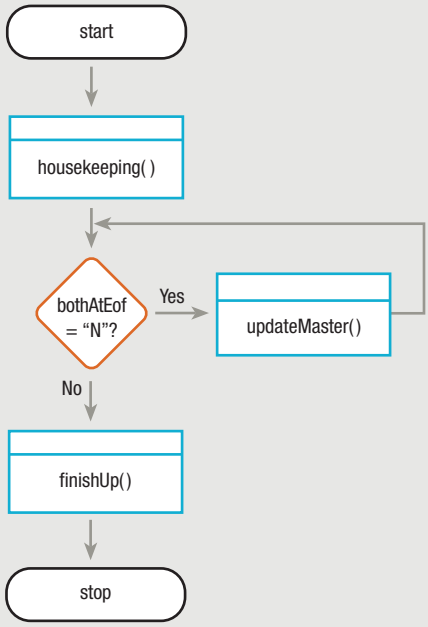
The master file records contain data in each of the fields shown in Figure 11-19—an employee number, name, salary, and department number. The three types of transaction records stored in the transaction file would differ as follows:

- An **addition record** in a transaction file actually represents a new master file record. An addition record would contain data in each of the fields—the employee number, name, salary, and department; because an addition record represents a new employee, data for all the fields must be captured for the first time. Also, in this example, such a record contains an "A" for "Addition" in the transaction code field.
- A **deletion record** in a transaction file flags a master file record that should be removed from the file. In this example, a deletion record really needs data in only two fields—a "D" for "Deletion" in the transaction code field and a number in the employee number field. If a "D" transaction record's employee number matches an employee number on a master record, then you have identified a record you want to delete. You do not need data indicating the salary, department, or anything else for a record you are deleting.

- A **change record** indicates an alteration that should be made to a master file record. In this case, it contains a "C" code for "Change" and needs data only in the employee number field and any fields that are going to be changed. In other words, if an employee's salary is not changing, the salary field in the transaction record will be blank; but if the employee is transferring to Department 28, then the department field of the transaction record will hold a 28.

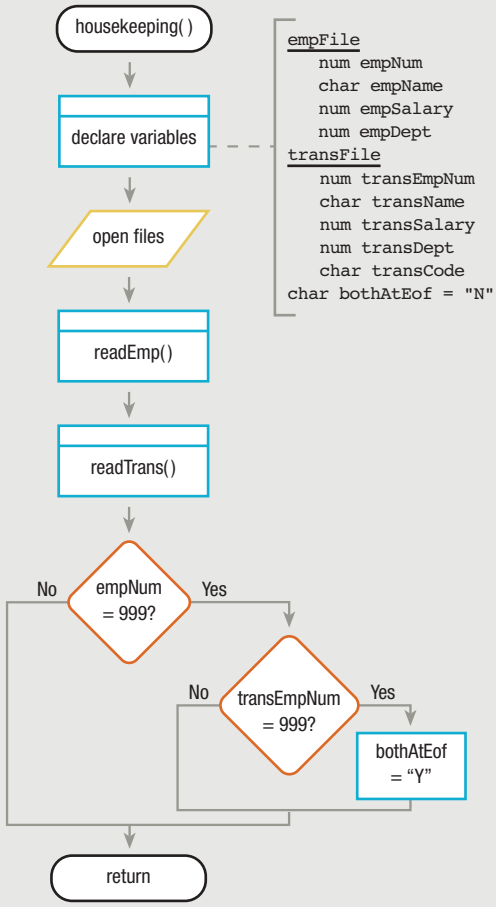
The mainline logic for an update program is very similar to the merging and matching programs shown in Figures 11-3 and 11-13, respectively. After `housekeeping()` and before `finishUp()`, the module that does the real work of the program executes repeatedly. Within the `housekeeping()` module, you declare the variables, open the files, and read the first record from each file. You can use the `readEmp()` and `readTrans()` modules to set the key fields `empNum` and `transEmpNum` to high values at `eof`. See Figures 11-20, 11-21, and 11-22.

FIGURE 11-20: THE MAINLINE LOGIC FOR THE UPDATE PROGRAM



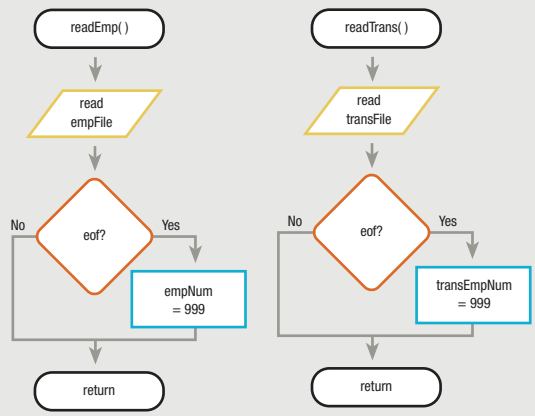

```
start
     perform housekeeping()
     while bothAtEof = "N"
            perform updateMaster()
     endwhile
     perform finishUp()
stop
```

FIGURE 11-21: THE `housekeeping()` MODULE FOR THE UPDATE PROGRAM




```
housekeeping()
     declare variables
     open files
     perform readEmp()
     perform readTrans()
     if empNum = 999 then
          if transEmpNum = 999 then
               bothAtEof = "Y"
          endif
     endif
return
```

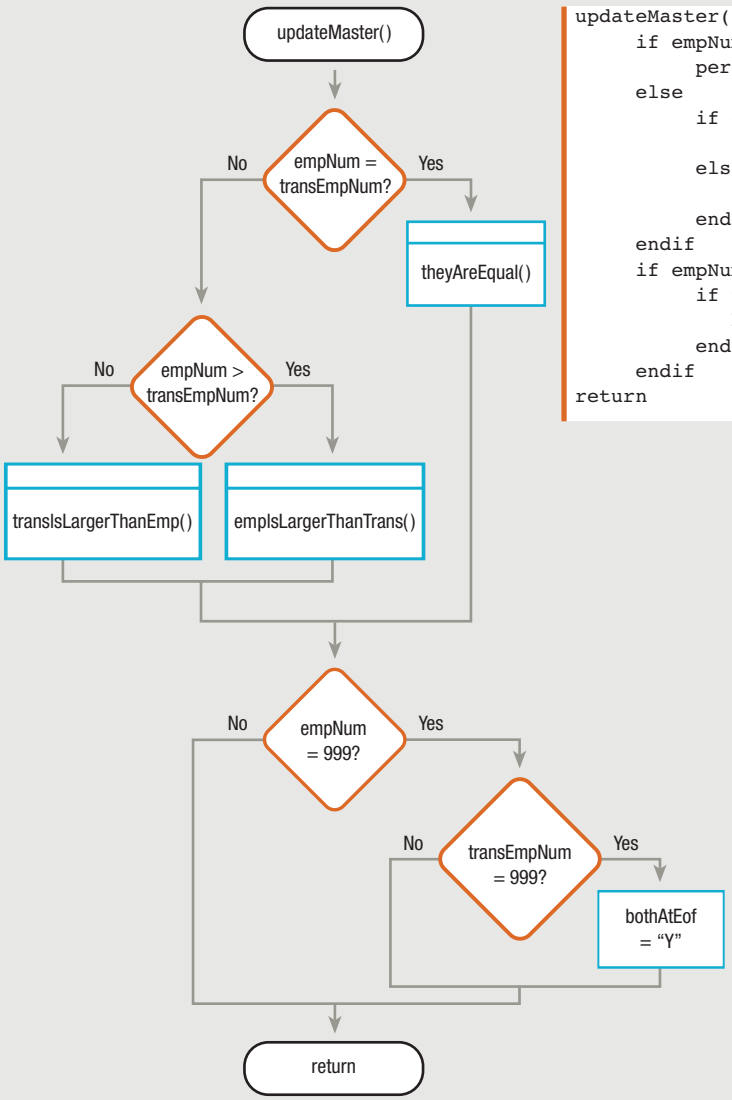
FIGURE 11-22: THE `readEmp()` AND `readTrans()` MODULES FOR THE UPDATE PROGRAM




```
readEmp()
     read empFile
     if eof then
          empNum = 999
     endif
return
readTrans()
     read transFile
     if eof then
          transEmpNum = 999
     endif
return
```

The `updateMaster()` module of the update program begins like the `matchFiles()` module in the matching program. You need to know whether `empNum` in the master file and `transEmpNum` in the transaction file are equal, or, if not, then you need to know which value is higher. To keep the `updateMaster()` module simple, you can create modules for each of the three possible scenarios: `theyAreEqual()`, `empIsLargerThanTrans()`, and `transIsLargerThanEmp()`. (Of course, you might choose shorter module names; the long names used here are intended to help you remember what condition preceded the execution of each module.) At the end of the `updateMaster()` module, after one of the three submodules has finished, you can set the `bothAtEof` flag variable to "Y" if both files have completed. Figure 11-23 shows the `updateMaster()` module.

FIGURE 11-23: THE `updateMaster()` MODULE OF THE UPDATE PROGRAM




```
updateMaster()
     if empNum = transEmpNum then
          perform theyAreEqual()
     else
          if empNum > transEmpNum then
             perform empIsLargerThanTrans()
          else
             perform transIsLargerThanEmp()
          endif
     endif
     if empNum = 999 then
          if transEmpNum = 999 then
             bothAtEof = "Y"
          endif
     endif
return
```

You perform the `theyAreEqual()` module only if a record in the master file and a record in the transaction file contain the same employee number. This should be the situation when a change is made to a record (for example, a change in salary) or when a record is to be deleted. If the master file and the transaction file records are equal, but the `transCode` value in the transaction record is an "A", then an error has occurred. You should not attempt to add a full employee record when the employee already exists in the master file.

As shown in Figure 11-24, within the `theyAreEqual()` module, you check `transCode` and perform one of three actions:

- If the code is an "A", print an error message. But what is the error? (Is the code wrong? Was this meant to be a change or a deletion of an existing employee? Is the employee number wrong—was this meant to be the addition of some new employee?) Because you're not completely sure, you can only print an error message to let an employee know that an error has occurred; then, the employee can handle the error. You should also write the existing master record to output exactly the same way it came in, without making any changes.
- If the code is a "C", you need to make changes. You must check each field in the transaction record. If any field is blank, the data in the new master record should come from the old master record. If, however, a field in the transaction record contains data, this data is intended to constitute a change, and the corresponding field in the new master record should be created from the transaction record. Then, for each changed field, you replace the contents of the old field in the master file with the new value in the corresponding field in the transaction file, and then write the master file record.
- If the code is not an "A" or a "C", it must be a "D" and the record should be deleted. How do you delete a record from a new master file? Just don't write it out to the new master file! In other words, as Figure 11-24 shows, no action is necessary when a record is deleted.

TIP

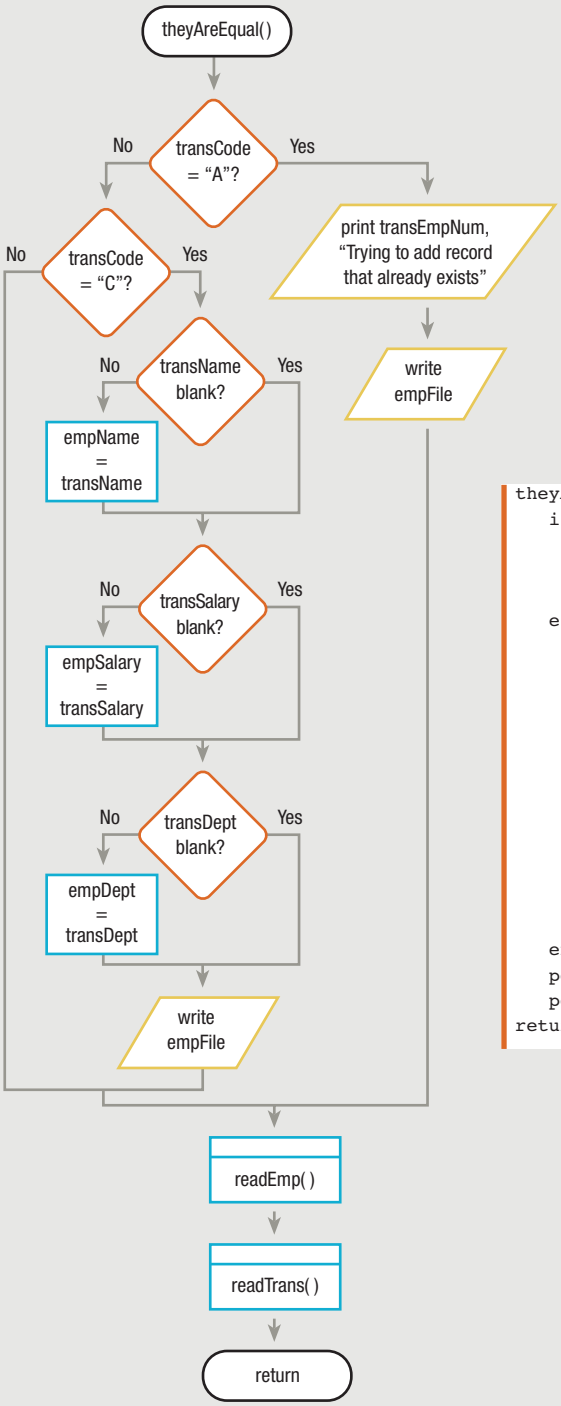
Various programming languages have different ways of checking a field to determine if it is blank. In some languages, you compare the field to an empty string, as in `transName = ""`. The quotation marks with nothing between them indicate an empty or null string. In some systems, you might need to compare the field to a space character, as in `transName = " "`, in which a literal space is inserted between the quotation marks. In other languages, you can use a predefined language-specific constant such as `BLANK`, as in `transName = BLANK`.

TIP

To keep the illustration simple here, you can assume that all the transaction records have been checked by a previous program, and all `transCode` values are "A", "C", or "D". If this were not the case, you could simply add one more decision to the `theyAreEqual()` module. If `transCode` is not "C", instead of assuming it is "D", ask if it is "D". If so, delete the record (by not writing it); if not, it must be something other than "A", "C", or "D", so print an error message.

Finally, at the end of the `theyAreEqual()` module, after the appropriate action has been taken with the matching master and transaction file records, you read one new record from each of the two input files.

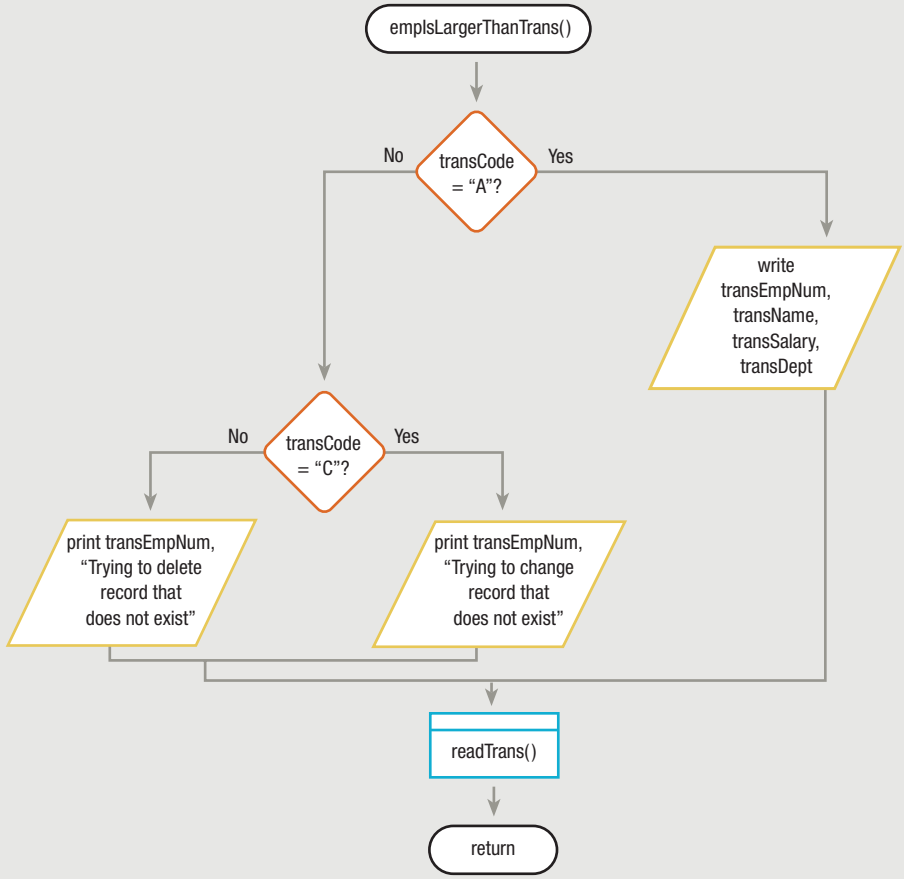
FIGURE 11-24: THE `theyAreEqual()` MODULE FOR THE UPDATE PROGRAM




```
theyAreEqual()
   if transCode = "A" then
         print transEmpNum, "Trying to add
              record that already exists"
         write empFile
   else
        if transCode = "C" then
             if transName not blank then
                  empName = transName
             endif
             if transSalary not blank then
                  empSalary = transSalary
             endif
             if transDept not blank then
                  empDept = transDept
             endif
             write empFile
        endif
   endif
   perform readEmp()
   perform readTrans()
return
```

Suppose that within the `updateMaster()` module in Figure 11-23, the master file record and the transaction file record do *not* match. If the master file record has a higher number than the transaction file record, this means you have read a transaction record for which there is no master file record, so you execute the `empIsLargerThanTrans()` module. See Figure 11-25.

FIGURE 11-25: THE `empIsLargerThanTrans()` MODULE




```
empIsLargerThanTrans()
   if transCode = "A" then
      write transEmpNum, transName, transSalary, transDept
   else
      if transCode = "C" then
         print transEmpNum, "Trying to change record that does not exist"
      else
         print transEmpNum, "Trying to delete record that does not exist"
      endif
   endif
   perform readTrans()
return
```

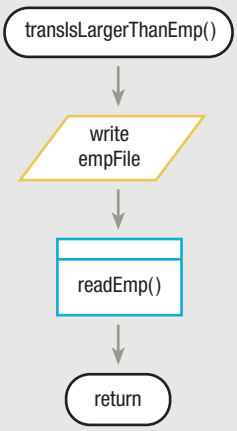
Within the `empIsLargerThanTrans()` module, if the transaction record contains code "A", that's fine because an addition transaction shouldn't have a master record. The transaction record data simply become the data for the new master record, so each of its fields is written to the new output file.

However, if the transaction code is "C" or "D" in the `empIsLargerThanTrans()` module, an error has occurred. Either you are attempting to make a change to a record that does not exist or you are attempting to delete a record that does not exist. Either way, a mistake has been made, and you must print an error message.

At the end of the `empIsLargerThanTrans()` module, you should not read another master file record. After all, there could be several more transactions that represent new additions to the master file. You want to keep reading transactions until a transaction matches or is greater than a master record. Therefore, only a transaction record should be read.

The final possibility in the `updateMaster()` module in Figure 11-23 is that a master file record's `empNum` field is smaller than the transaction file record's `transEmpNum` field in memory. If there is no transaction for a given master file record, it just means that the master file record has no changes or deletions; therefore, when you perform the `transIsLargerThanEmp()` module, you simply write the new master record out exactly like the old master record and read another master record. See Figure 11-26.

FIGURE 11-26: THE `transIsLargerThanEmp()` MODULE




```
transIsLargerThanEmp()
     write empFile
     perform readEmp()
return
```

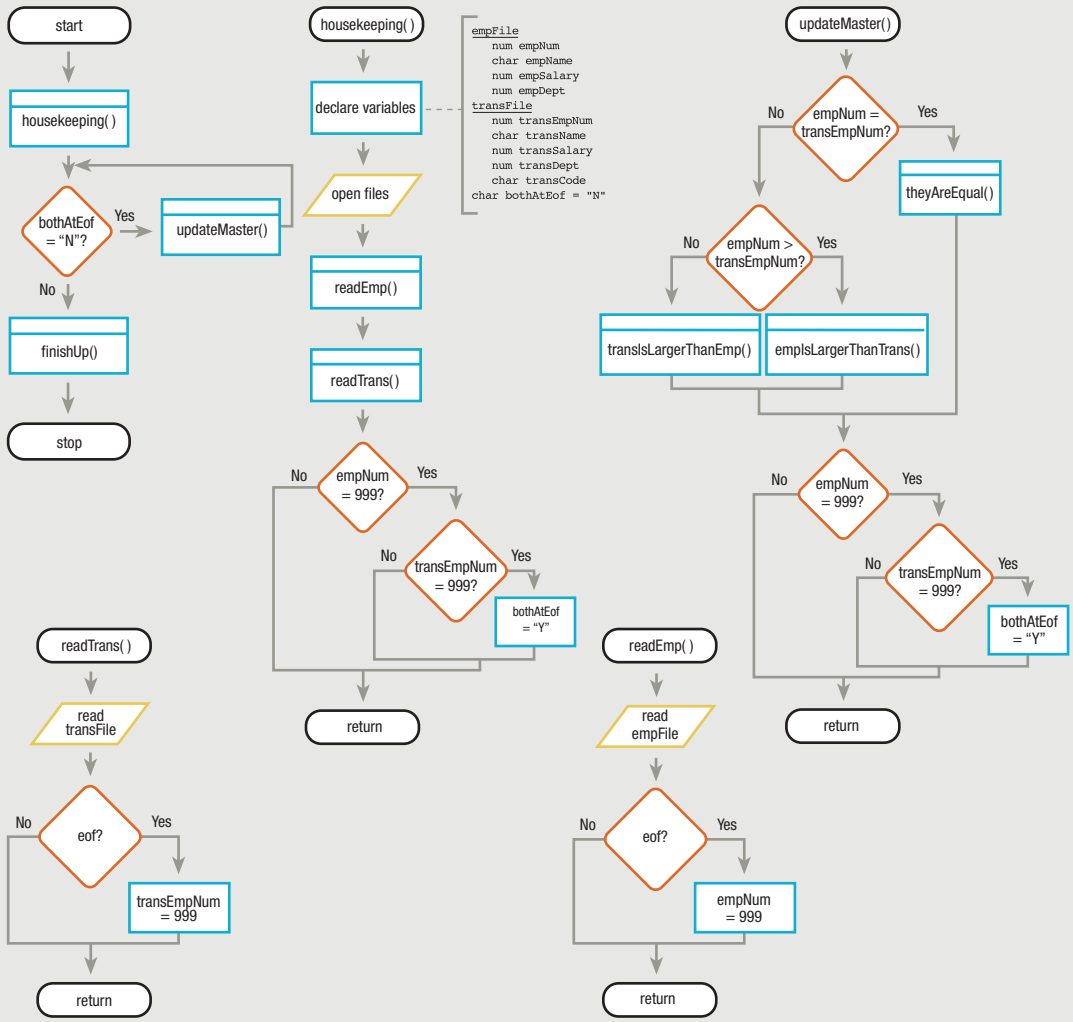
At some point, one of the files will reach `eof`. If the transaction file reaches the end first, `transEmpNum` is set to 999 in the `readTrans()` module. Each time the `updateMaster()` module is entered after `transEmpNum` is set to 999, `empNum` will be lower than `transEmpNum` and the `transIsLargerThanEmp()` module will execute. That module writes records from the master file without alteration, and this is exactly what you want to happen. Obviously, there were no transactions for these final records in the master file, because all the records in the transaction file were used to apply to earlier master file records.

On the other hand, if the master file reaches its end first, `empNum` is set to 999 in the `readEmp()` module. Now, each time the program enters the `updateMaster()` module, `transEmpNum` will be lower than `empNum`. The `empIsLargerThanTrans()` module will execute for all remaining transaction records. In turn, each remaining transaction will be compared to the possible code values. If any remaining transaction records are additions, they will write to the new master as new records. However, if the remaining transaction records represent changes or deletions, a mistake has been made, because there are no corresponding master file records. In other words, error messages will then be printed for the remaining change and deletion transaction records as they go through the `updateMaster()` process.

Whichever file reaches the end first, the other continues to be read and processed. When that file reaches `eof`, the `bothAtEof` flag will finally be set to "Y". Then, you can perform the `finishUp()` module, as shown with the complete program in Figure 11-27.

Merging files, matching files, and updating a master file from a transaction file require a significant number of steps, because as you read each new input record you must account for many possible scenarios. Planning the logic for programs like these takes a fair amount of time, but by planning the logic carefully, you can create programs that perform valuable work for years to come. Separating the various outcomes into manageable modules keeps the program organized and allows you to develop the logic one step at a time.

FIGURE 11-27: COMPLETE PROGRAM THAT UPDATES MASTER FILE USING TRANSACTION RECORDS THAT CONTAIN ADD, CHANGE, OR DELETE CODES




```
start
      perform housekeeping()
      while bothAtEof = "N"
          perform updateMaster()
      endwhile
      perform finishUp()
stop
```

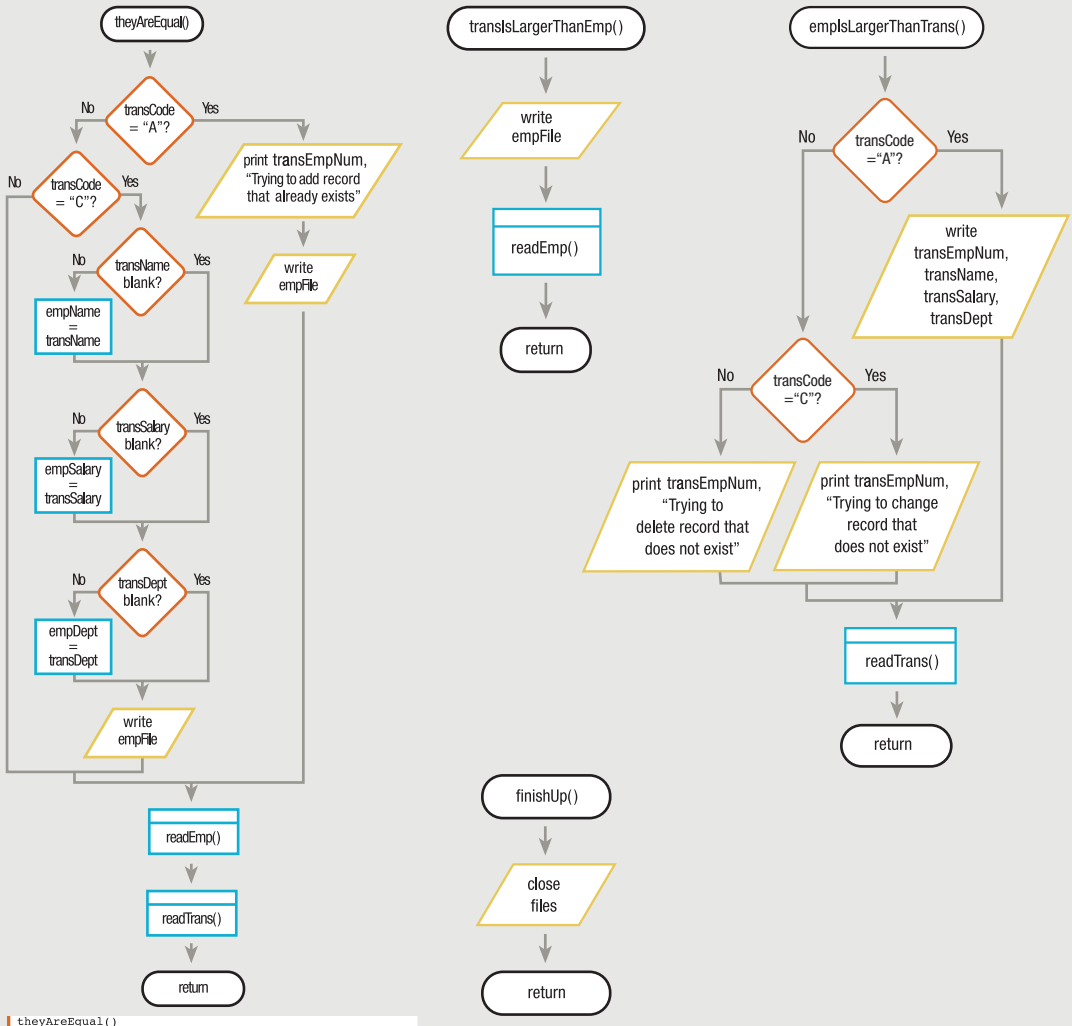
```
housekeeping()
      declare variables
      open files
      perform readEmp()
      perform readTrans()
      if empNum = 999 then
            if transEmpNum = 999 then
                  bothAtEof = "Y"
            endif
      endif
return
```

```
updateMaster()
      if empNum = transEmpNum then
            perform theyAreEqual()
      else
            if empNum > transEmpNum then
                  perform empIsLargerThanTrans()
            else
                  perform transIsLargerThanEmp()
            endif
      endif
      if empNum = 999 then
            if transEmpNum = 999 then
                  bothAtEof = "Y"
            endif
      endif
return
```

```
readTrans()
      read transFile
      if eof then
            transEmpNum = 999
      endif
return
```

```
readEmp()
      read empFile
      if eof then
            empNum = 999
      endif
return
```

FIGURE 11-27: COMPLETE PROGRAM THAT UPDATES MASTER FILE USING TRANSACTION RECORDS THAT CONTAIN ADD, CHANGE, OR DELETE CODES (CONTINUED)




```
theyAreEqual()
     if transCode = "A" then
          print transEmpNum, "Trying to add
            record that already exists"
          write empfile
     else
          if transCode = "C" then
               if transName not blank then
                    empName = transName
               endif
               if transSalary not blank then
                    empSalary = transSalary
               endif
               if transDept not blank then
                    empDept = transDept
               endif
               write empFile
          endif
     endif
     perform readEmp()
     perform readTrans()
return
```

```
transIsLargerThanEmp()
     write empFile
     perform readEmp()
return
```

```
finishUp()
     close files
return
```

```
empIsLargerThanTrans()
   if transCode = "A" then
      write transEmpNum, transName,
        transSalary, transDept
   else
      if transCode = "C" then
        print transEmpNum, "Trying to change
          record that does not exist"
      else
        print transEmpNum, "Trying to delete
          record that does not exist"
      endif
   endif
   perform readTrans()
return
```

CHAPTER SUMMARY

- A sequential file is a file whose records are stored one after another in some order. The field on which you sort records is the key field. Merging files involves combining two or more files while maintaining the sequential order. Each file used in a merge must be sorted in the same order in the same field as the others.
- The mainline logic for a program that merges two files contains a housekeeping module, a module that matches files and repeats until the end of the program, and a final module that performs finishing tasks. The mainline logic checks a flag variable that is turned on when both input files are finished.
- When beginning the repeating module that merges files in a merge program, you compare records from each input file. You write the appropriate record from one of the files to output, and then read a record from the same file. When you encounter `eof` on one of the two input files, set the field on which the merge is based to a high value.
- You use a master file to hold relatively permanent data, and a transaction file to hold more temporary data that corresponds to records in the master file. When you update a master file, you can take two approaches: you can actually change the information in the master file, or you can create a copy of the master file, making the changes in the new version.
- The logic you use to perform a match between master and transaction file records involves comparing the files to determine whether there is a transaction for each master record; when there is, you update the master record. When a master record has no transaction, you write the master record as is; when a transaction record has no corresponding master, you have an error.
- Using the logic that allows multiple transactions per master file record, whenever a transaction matches a master file record, you process the transaction and then you read only from the transaction file. Only when a transaction file key field is greater than a master file key field do you write the master record.
- A sophisticated update program allows you to make changes to data in a record and update a master file by adding new records or eliminating records you no longer want. For this kind of program, it's common to have a transaction file in which each record contains all the same fields as the master file, with an additional code that indicates the type of transaction.

KEY TERMS

A **sequential file** is a file in which records are stored one after another in some order.

Records that are stored in **temporal order** are stored in order based on their creation time.

Merging files involves combining two or more files while maintaining the sequential order.

A **data file** contains only data for another computer program to read, not headings or other formatting.

A **high value** is one that is greater than any possible value in a field.

You use a **master file** to hold relatively permanent data.

A **transaction file** holds more temporary data generated by the entities represented in the master file.

A **matching record** is a transaction file record that contains data about the same entity in a master file record.

To **update a master file** means to make changes to the values in its fields based on transaction records.

The saved version of a master file is the **parent file**; the updated version is the **child file**.

An **addition record** in a transaction file is one that represents a new master record.

A **deletion record** in a transaction file flags a record that should be removed from a master file.

A **change record** in a transaction file indicates an alteration that should be made to a master file record.

REVIEW QUESTIONS

1. **A file in which records are stored one after another in some order is a(n) _____ file.**
   a. temporal
   b. sequential
   c. random
   d. alphabetical

2. **When you combine two or more sorted files while maintaining their sequential order based on a field, you are _____ the files.**
   a. tracking
   b. collating
   c. merging
   d. absorbing

3. **When you write a program that combines two sorted files into one larger, sorted file, you must create an additional work variable whose purpose is to _____.**
   a. count the files
   b. count the records
   c. flag when both files encounter `eof`
   d. flag when two records in the files contain identical data

4. **Unlike when you print a report, when a program's output is a data file, you do not _____.**
   a. include headings or other formatting
   b. open the files
   c. include all the fields represented as input
   d. all of the above

5. **In a program that merges two sorted files, the first task in the main `mergeFiles()` module is to _____.**
   a. read a record from each input file
   b. compare the values of the fields on which the files are sorted
   c. output the record with the lower value in the field on which the files are sorted
   d. output the record with the higher value in the field on which the files are sorted

6. **Assume you are writing a program to merge two files named FallStudents and SpringStudents. Each file contains a list of students enrolled in a programming logic course during the semester indicated, and each file is sorted in student ID number order. After the program compares two records and subsequently writes a Fall student to output, the next step is to _____.**
   a. read a SpringStudents record
   b. read a FallStudents record
   c. write a SpringStudents record
   d. write another FallStudents record

7. **A value that is greater than any possible legal value in a field is called a(n) _____ value.**
   a. great
   b. illegal
   c. merging
   d. high

8. **When you merge records from two or more sequential files, the usual case is that the records in the files _____.**
   a. contain the same data
   b. have the same format
   c. are identical in number
   d. are sorted on different fields

9. **A file that holds more permanent data than a transaction file is a _____ file.**
   a. master
   b. primary
   c. key
   d. mega-

10. **A transaction file is often used to _____ another file.**
    a. augment
    b. remove
    c. verify
    d. update

11. The saved version of a file that does not contain the most recently applied transactions is known as a _____ file.

a. master
b. child
c. parent
d. relative

12. Ambrose Bierce High School maintains a master file containing records for each student in a class. Each record contains fields such as student ID, student name, home phone number, and grade on each exam. A transaction file is created after each exam; it contains records that each hold a test number, a student ID, and the student's grade on the exam. You would write a matching program to match the records in the _____ field.

a. student ID
b. student name
c. test number
d. grade on the exam

13. Larry's Service Station maintains a master file containing records for each vehicle Larry services. Each record contains fields such as vehicle ID, owner name, date of last oil change, date of last tire rotation, and so on. A transaction file is created each day; it contains records that hold a vehicle ID and the name of the service performed. When Larry performs a match between these two files so that the most recent date can be inserted into the master file, which of the following should cause an error condition?

a. A specific vehicle is represented in each file.
b. A specific vehicle is represented in the master file, but not in the transaction file.
c. A specific vehicle is represented in the transaction file, but not in the master file.
d. A specific vehicle is not represented in either file.

14. Sally's Sandwich Shop maintains a master file containing records for each preferred customer. Each record contains a customer ID, name, e-mail address, and number of sandwiches purchased. A transaction file record is created each time a customer makes a purchase; the fields include customer ID and number of sandwiches purchased as part of the current transaction. After a customer surpasses 12 sandwiches, Sally e-mails the customer a coupon for a free sandwich. When Sally runs the match program with these two files so that the master file can be updated with the most recent purchases, which of the following should indicate an error condition?

a. master ID is greater than transaction ID
b. master ID is equal to transaction ID
c. master ID is less than transaction ID
d. none of the above

15. Which of the following is true of master-transaction file-matching processing?

a. A master file record must never match more than one transaction record.
b. A transaction file record must never match any master records.
c. When master and transaction file records match, you must always immediately read another record from each file.
d. A transaction record must match, at most, one master file record.

16. Which of the following is true of master-transaction file-matching processing?

a. A master file's records must be sorted in some sequential order.
b. A transaction file's records must be sorted on a different field than the master file's records.
c. A master file's records must contain more fields than a transaction file's records.
d. A transaction file's records must contain more fields than a master file's records.

17. In a program that updates a master file, a transaction file record might cause a master file record to be _____.

a. modified
b. deleted
c. either of these
d. neither a nor b

18. In a program that updates a master file, if a transaction record indicates a change, then it is an error when the transaction record's matching field is _____ the field in a master file's record.

a. greater than
b. less than
c. both of these
d. neither a nor b

19. In a program that updates a master file, if a master and transaction file match, then it is an error if the transaction record is a(n) _____ record.

a. addition
b. change
c. deletion
d. two of the above

20. In a program that updates a master file, if a master file's comparison field is larger than a transaction file's comparison field, then it is an error if the transaction record is a(n) _____ record.

a. addition
b. change
c. deletion
d. two of the above

FIND THE BUGS

The following pseudocode contains one or more bugs that you must find and correct.

1. **Each time a salesperson sells a car at the Pardeeville New and Used Auto Dealership, a record is created containing the salesperson's name and the amount of the sale. Sales of new and used cars are kept in separate files because several reports are created for one type of sale or the other. However, management has requested a merged file so that all of a salesperson's sales, whether the vehicle was new or used, are displayed together. The following code is intended to merge the files that have already been sorted by salesperson ID number.**

```
start
     perform housekeeping()
     while bothAtEOF = "Y"
          perform mergeModule()
     endwhile
     perform finish()
return

housekeeping()
     declare variables
         newFile
           char newIdNumber
           num newSalePrice
         usedFile
           char usedIdNumber
           num usedSalePrice
         char bothAtEof
     open files
     read newFile
     if eof then
          newIdNumber = 9999999
     endif
     read usedFile
     if eof then
          usedIdNumber = 9999
     endif
     if newIdNumber = 9999999 then
          if usedIdNumber = 9999999 then
               bothAtEof = "Y"
          endif
     endif
return
```

```
mergeModule()
     if newIdNumber = usedIdNumber then
          write newIdNumber, newSalePrice
          read newFile
          if eof then
               newIdNumber = 9999999
          endif
     else
          write usedIdNumber, usedSalePrice
          read usedFile
          if eof then
               usedIdNumber = 999
          endif
     endif
     if newIdNumber = 9999999 then
          if usedIdNumber = 9999999 then
               bothAtEof = "X"
          endif
     endif
return

finish()
     close files
return
```

EXERCISES

1. **The Springwater Township School District has two high schools—Jefferson and Audubon. Each school maintains a student file with fields containing student ID, last name, first name, and address. Each file is in student ID number order. Write the flowchart or pseudocode for a program that merges the two files into one file containing a list of all students in the district, maintaining student ID number order.**

2. **The Redgranite Library keeps a file of all books borrowed every month. Each file is in Library of Congress number order and contains additional fields for author and title.**
   a. Write the flowchart or pseudocode for a program that merges the files for January and February to create a list of all books borrowed in the two-month period.
   b. Modify the program from Exercise 2a so that if there is more than one record for a book number, you print the book information only once.
   c. Modify the program from Exercise 2b so that if there is more than one record for a book number, you not only print the book information only once, you print a count of the total number of times the book was borrowed.

3. **Hearthside Realtors keeps a transaction file for each salesperson in the office. Each transaction record contains the salesperson's first name, date of the sale, and sale price. The records for the year are sorted in descending sale price order. Two salespeople, Diane and Mark, have formed a partnership. Write the flowchart or pseudocode that produces a merged list of their transactions (including name of salesperson, date, and price) in descending order by price.**

4. **Dartmoor Medical Associates maintains two patient files—one for the Lakewood office and one for the Hanover office. Each record contains the name, address, city, state, and zip code of a patient, with the file maintained in zip code order. Write the flowchart or pseudocode that merges the two files to produce one master name and address file that the Dartmoor office staff can use for addressing the practice's monthly Healthy Lifestyles newsletter mailing in zip code order.**

5. **The Willmington Walking Club maintains a master file that contains a record for each of its members. Fields in the master file include the walker's ID number, first name, last name, and total miles walked to the nearest one-tenth of a mile. Every week, a transaction file is produced; the transaction file contains a walker's ID number and the number of miles the walker has logged that week. Each file is sorted in walker ID number order.**

   a. Create the flowchart or pseudocode for a program that matches the master and transaction file records and updates the total miles walked for each club member by adding the current week's miles to the cumulative total for each walker. Not all walkers submit walking reports each week. The output is the updated master file and an error report listing any transaction records for which no master record exists.
   b. Modify the program in Exercise 5a to print a certificate of achievement each time a walker exceeds the 500-mile mark. That is, the certificate—containing the walker's name and an appropriate congratulatory message—is printed during the run of the update program when a walker's mile total changes from a value below 500 to one that is 500 or greater.

6. **The Timely Talent Temporary Help Agency maintains an employee master file that contains an employee ID number, last name, first name, address, and hourly rate for each of the temporary employees it sends out on assignments. The file has been sorted in employee ID number order.**

   Each week, a transaction file is created with a job number, address, customer name, employee ID, and hours worked for every job filled by Timely Talent workers. The transaction file is also sorted in employee ID order.

   a. Create the flowchart or pseudocode for a program that matches the master and transaction file records, and print one line for each transaction, indicating job number, employee ID number, hours worked, hourly rate, and gross pay. Assume each temporary worker works at most one job per week; print one line for each worker who has worked that week.
   b. Modify Exercise 6a so that any individual temporary worker can work any number of separate jobs in a week. Print one line for each job that week.
   c. Modify Exercise 6b so that, although any worker can work any number of jobs in a week, you accumulate the worker's total pay for all jobs and print one line per worker.

7. Claypool College maintains a student master file that contains a student ID number, last name, first name, address, total credit hours completed, and cumulative grade point average for each of the students who attend the college. The file has been sorted in student ID number order.

Each semester, a transaction file is created with the student's ID, the number of credits completed during the new semester, and the grade point average for the new semester. The transaction file is also sorted in student ID order.

Create the flowchart or pseudocode for a program that matches the master and transaction file records and updates the total credit hours completed and the cumulative grade point average on a new master record. Calculate the new grade point average as follows:

- ☐ Multiply the credits in the master file by the grade point average in the master file, giving master honor points—that is, honor points earned prior to any transaction. The honor points value is useful because it is weighted—the value of the honor points is more for a student who has accumulated 100 credits with a 3.0 grade point average than it is for a student who has accumulated only 20 credits with a 3.0 grade point average.
- ☐ Multiply the credits in the transaction file by the grade point average in the transaction file, giving transaction honor points.
- ☐ Add the two honor point values, giving total honor points.
- ☐ Add master and transaction credit hours, giving total credit hours.
- ☐ Divide total honor points by total credit hours, giving the new grade point average.

8. The Amelia Earhart High School basketball team maintains a record for each team player, including player number, first and last name, minutes played during the season, baskets attempted, baskets made, free throws attempted, free throws made, shooting average from the floor, and shooting average from the free throw line. (Shooting average from the floor is calculated by dividing baskets made by baskets attempted; free throw average is calculated by dividing free throws made by free throws attempted.) The master records are maintained in player number order.

After each game, a transaction record is produced for any player who logged playing time. Fields in each transaction record contain player number, minutes played during the game, baskets attempted, baskets made, free throws attempted, and free throws made.

Design the flowchart or pseudocode for a program that updates the master file with the transaction file, including recalculating shooting averages, if necessary.

9. The Tip-Top Talent Agency books bands for social functions. The agency maintains a master file in which the records are stored in order by band code. The records have the following format:

```
TALENT FILE DESCRIPTION
File name: BANDS
FIELD DESCRIPTION   DATA TYPE    COMMENTS           EXAMPLE
Band Code           Numeric      3-digit number     176
Band Name           Character    20 characters      The Polka Pals
Contact Person      Character    20 characters      Jay Sakowicz
Phone               Numeric      10 digits          5554556012
Musical Style       Character    8 characters       Polka
Hourly Rate         Numeric      2 decimal places   75.00
```

The agency has asked you to write an update program, so that once a month the agency can make changes to the file, using transaction records with the same format as the master records, plus one additional field that holds a transaction code. The transaction code is "A" if the agency is adding a new band to the file, "C" if it is changing some of the data in an existing record, and "D" if it is deleting a band from the file.

An addition transaction record contains a band code, an "A" in the transaction code field, and the new band's data. During processing, an error can occur if you attempt to add a band code that already exists in the file. This is not allowed, and an error message is printed.

A change transaction record contains a band code, a "C" in the transaction code field, and data for only those fields that are changing. For example, a band that is raising its hourly rate from $75 to $100 would contain empty fields for the band name, contact person information, and style of music, but the hourly rate field would contain the new rate. During processing, an error can occur if you attempt to change data for a band number that doesn't exist in the master file; print an error message.

A deletion transaction record contains a band code, a "D" in the transaction code field, and no other data. During processing, an error can occur if you attempt to delete a band number that doesn't exist in the master file; print an error message.

Two forms of output are created. One is the updated master file with all changes, additions, and deletions. The other is a printed report of errors that occurred during processing. Rather than just a list of error messages, each line of the printed output should list the appropriate band code along with the corresponding message.

a. Design the print chart or create sample output for the error report.
b. Design the hierarchy chart for the program.
c. Create either a flowchart or pseudocode for the program.

10. Cozy Cottage Realty maintains a master file in which records are stored in order by listing number, in the following format:

```
REALTY FILE DESCRIPTION
File name: HOUSES
FIELD DESCRIPTION   DATA TYPE    COMMENTS          EXAMPLE
Listing Number      Numeric      6-digit number    200719
Address             Character    20 characters     348 Alpine Road
List Price          Numeric      0 decimals        139900
Bedrooms            Numeric      0 decimals        3
Baths               Numeric      1 decimal         1.5
```

The realty company has asked you to write an update program so that, every day, the company can make changes to the file, using transaction records with the same format as the master records, plus one additional field that holds a transaction code. The transaction code is "A" to add a new listing, "C" to change some of the data in an existing record, and "D" to delete a listing that is sold or no longer on the market.

An addition transaction record contains a listing number, an "A" in the transaction code field, and the new house listing's data. During processing, an error can occur if you attempt to add a listing number that already exists in the file. This is not allowed, and an error message is printed.

A change transaction record contains a listing number, a "C" in the transaction code field, and data for only those fields that are changing. For example, a listing that is dropping in price from $139,900 to $133,000 would contain empty fields for the address, bedrooms, and baths, but the price field would contain the new list price. During processing, an error can occur if you attempt to change data for a listing number that doesn't exist in the master file; print an error message.

A deletion transaction record contains a listing code number, a "D" in the transaction code field, and no other data. During processing, an error can occur if you attempt to delete a listing number that doesn't exist in the master file; print an error message.

Two forms of output are created. One is the updated master file with all changes, additions, and deletions. The other is a printed report of errors that occurred during processing. Rather than just a list of error messages, each line of the printed output should list the appropriate house listing number along with the corresponding message.

a. Design the print chart or create sample output for the error report.
b. Design the hierarchy chart for the program.
c. Create either a flowchart or pseudocode for the program.

11. Crown Greeting Cards maintains a master file of its customers stored in order by customer number, in the following format:

```
CROWN CUSTOMER FILE DESCRIPTION
File name: CUSTS
FIELD DESCRIPTION       DATA TYPE   COMMENTS          EXAMPLE
Customer Number         Numeric     5 digits          34492
Name                    Character   20 characters     Roberta Branch
Address                 Character   20 characters     32 Pinetree Lane
Phone Number            Numeric     10 digits         5554448935
Value of Merchandise
  Purchased This Year   Numeric     2 decimal places  525.99
```

The card store has asked you to write an update program so that, every week, the store can make changes to the file, using transaction records with the same format as the master records, plus one additional field that holds a transaction code. The transaction code is "A" to add a new customer, "C" to change some of the data in an existing record, and "D" to delete a customer. In a transaction record, the amount field represents a new transaction instead of the total value of merchandise purchased.

An addition transaction record contains a customer number, an "A" in the transaction code field, and the new customer's name, address, phone number, and first purchase amount. During processing, an error can occur if you attempt to add a customer number that already exists in the file. This is not allowed, and an error message is printed.

A change transaction record contains a customer number, a "C" in the transaction code field, and data for only those fields that are changing. For example, a customer might have a new address or phone number. In a change record, if a value appears in the merchandise value field, it represents an amount that should be added to the total merchandise value in the master record. During processing, an error can occur if you attempt to change data for a customer number that doesn't exist in the master file; print an error message.

A deletion transaction record contains a customer number, a "D" in the transaction code field, and no other data. During processing, an error can occur if you attempt to delete a customer number that doesn't exist in the master file; print an error message.

Three forms of output are created. One is the updated master file with all changes, additions, and deletions. The second output is a printed report of errors that occurred during processing. Rather than just list error messages, each line of the printed output should list the appropriate customer number along with the corresponding message. The third output is a report listing all customers who have currently met or exceeded the $1,000 purchase threshold for the year.

a. Design the print chart or create sample output for the error report, along with the hierarchy chart and either a flowchart or pseudocode for the program.
b. Modify the program in Exercise 11a so that the third output is not a report of all customers who have met or exceeded the $1,000 purchase threshold this year, but a report listing all customers who have just passed the $100 purchase threshold this week.

DETECTIVE WORK

1. What is a random file and how does it differ from a sequential file? In what types of applications are sequential files most useful? In what types of applications are they least useful?

2. What is FIFO and how does it relate to file processing?

UP FOR DISCUSSION

1. In Chapter 5, you considered criteria to use for a program that selects possible candidates for organ transplants. Suppose you are hired by a large hospital that has decided to avoid public criticism of how potential recipients are chosen; they will display recipients sequentially in alphabetical order. The hospital's doctors will consult this list if they have an organ that can be transplanted. If more than 10 patients are waiting for a particular organ, the first 10 are displayed; the user can either select one of these or move on to view the next set of 10 patients. You worry that this system gives an unfair advantage to patients with last names that start with A, B, C, and D. Should you write and install the program? If you do not, many transplant opportunities will be missed while the hospital searches for another programmer who will write the program.

2. Suppose you are hired by a police department to write a program that matches arrest records with court records detailing the ultimate outcome or verdict for each case. Your friend works in the personnel department of a large company and must perform background checks on potential employees. (The job applicants sign a form authorizing the check.) Your friend could look up police records at the courthouse, but it takes many hours per week. As a convenience, should you provide your friend with outcomes of any arrest records of job applicants?

12 ADVANCED MODULARIZATION TECHNIQUES

After studying Chapter 12, you should be able to:

- Understand local and global variables and encapsulation
- Pass a single value to a module
- Pass multiple values to a module
- Return a value from a module
- Use prewritten, built-in modules
- Create an IPO chart
- Understand the advantages of encapsulation
- Reduce coupling and increase cohesion in your modules

UNDERSTANDING LOCAL AND GLOBAL VARIABLES AND ENCAPSULATION

Throughout most of computer programming history, which now totals about 60 years, the majority of programs were written procedurally. A **procedural program** consists of a series of steps or procedures that take place one after another. The programmer determines the exact conditions under which a procedure takes place, how often it takes place, and when the program stops. The logic for every program you have developed so far using this book has been procedural.

TIP You first learned the term *procedural program* in Chapter 4.

It is possible to write procedural programs as one long series of steps. However, by now you should appreciate the benefits of **modularization**, or breaking down programs into reasonable units called modules, subroutines, functions, or methods. The following are benefits of modularization:

- It provides **abstraction**; in other words, it makes it easier to see the "big picture."
- It allows multiple programmers to work on a problem, each contributing one or more modules that later can be combined into a whole program.
- It allows you to reuse your work; you can call the same module from multiple locations within a program.
- It allows you to identify structures more easily.

TIP You first learned the term *modular* in Chapter 2; you learned about *abstraction* in Chapter 3.

TIP Languages that use only global variables are most likely to call their modules "subroutines." Languages that allow local variables and the passing of values are more likely to call their modules "procedures," "methods," or "functions."

Modularization provides many benefits, but using modules and methods in the way you have used them throughout this book also has two major drawbacks:

- Although the modules you have used allow multiple programmers to work on a problem, each programmer must know the names of all the variables used in other modules within the program.
- Although the modules you have used enable you to reuse your work by allowing you to call them from multiple locations within a program, you can't use the modules in other programs unless these programs use the same variable names.

These two limitations have not caused significant problems for you in the programs you have designed so far, for several reasons:

- You most likely have designed every program alone, without using others' modules, so your variable names did not need to agree with anyone else's.
- You most likely have designed each program from beginning to end yourself, either at a single sitting or at least within a relatively short time period, and so you knew and easily remembered all the variable names you declared.

- Your programs have been relatively small, seldom with more than a few variable names to remember.

However, when you become a professional programmer in the business world, many of your programming assignments will involve large applications that will require dozens or even hundreds of modules written by many people. Some modules that you need to use might have been written by others years ago; some modules you write might not be used by other programmers until years from now. Some modules might even be purchased from programmers who work outside your organization, perhaps in another country. It would be virtually impossible to create such programs without some conflicting variable names in the various modules.

In addition, suppose that you have a well-written module that you want to reuse. Consider a module that formats a name and address to fit on a mailing label. You would want to use this module in programs that mail letters to stockholders, invoices to current customers, orders to suppliers, and so on. It would be inconvenient and inefficient to write separate modules containing statements such as `print stockholderName`, `print customerName`, and `print supplierName`. Instead, you would want to create a single module containing a statement such as `print name`, and allow that module to handle data stored in any variable that represents a name.

So that you could more easily understand how to write computer programs, the programs you have written so far have been relatively small, and all the variables you have used throughout this book have been global variables. A **global variable** is one that is available to every module in a program. That is, every module has access to the variable, can use its value, and can change its value. When you declare a variable named `grandTotal` in a program's `housekeeping()` module, add a value to it in a `mainLoop()` module, and print it in a `finish()` module, then `grandTotal` is a global variable within that program. If you tried to reuse the `mainLoop()` or `finish()` module in another program in which the grand total value was named `finalTotal`—or any name other than `grandTotal`—then the new program would fail.

With many older computer programming languages, all variables are global variables. Newer, more modularized languages allow you to use local variables as well. A **local variable** is one whose name and value are known only to its own module. A local variable is declared within a module and ceases to exist when the module ends. Within a module, a variable is said to be **in scope**—that is, existing and usable—from the moment it is declared until it ceases to exist; then it is **out of scope**.

TIP A locally declared variable always goes out of scope when its module ends. In some programming languages, you can purposely destroy variables earlier.

When you declare local variables within modules, you usually do so as the first step within a module, but some languages allow you to declare variables at any point within a module. Sometimes, you declare a local variable because the value is needed only within one module. At other times, the variable is needed in other modules within a program, but you still choose to declare local variables to gain some of the advantages they provide. When you use local variables:

- Programmers of other modules do not need to know the names of your variables.
- Each module becomes an enclosed unit, declaring all the variables it needs. Using this approach, you can more easily reuse your modules in other programs, regardless of the names of the other variables declared in those programs.

As an example of a program that uses local variables because they are needed within only one module, consider a very simple program that asks a student just one arithmetic question. For simplicity, this example won't loop; it provides a single user with a single question. A program such as this one could be contained in a single main module, but you can divide it into three separate modules, as shown in Figure 12-1. The program contains three steps: `housekeeping()`, `askQuestion()`, and `finish()`.

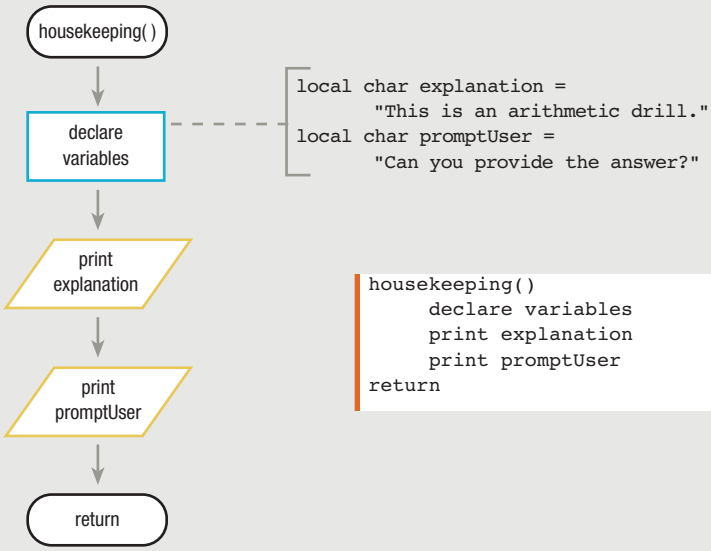
FIGURE 12-1: MAINLINE LOGIC FOR A PROGRAM THAT USES ONLY LOCAL VARIABLES


```
start
     perform housekeeping()
     perform askQuestion()
     perform finish()
stop
```

Figure 12-2 shows the `housekeeping()` module, in which directions are displayed on the screen. Within `housekeeping()`, you can declare variables named `explanation` and `promptUser`; these hold the characters that the user will see as directions. The `explanation` and `promptUser` variables can be local to the `housekeeping()` module because the `askQuestion()` and `finish()` modules never need access to these variables; `housekeeping()` uses the variables, but the other modules do not need to use the two variables or alter them in any way.

TIP Programming languages that use local variables do not require you to modify the variable declaration with the term *local*, as shown in Figure 12-2. The term *local* is used in Figure 12-2 just for emphasis.

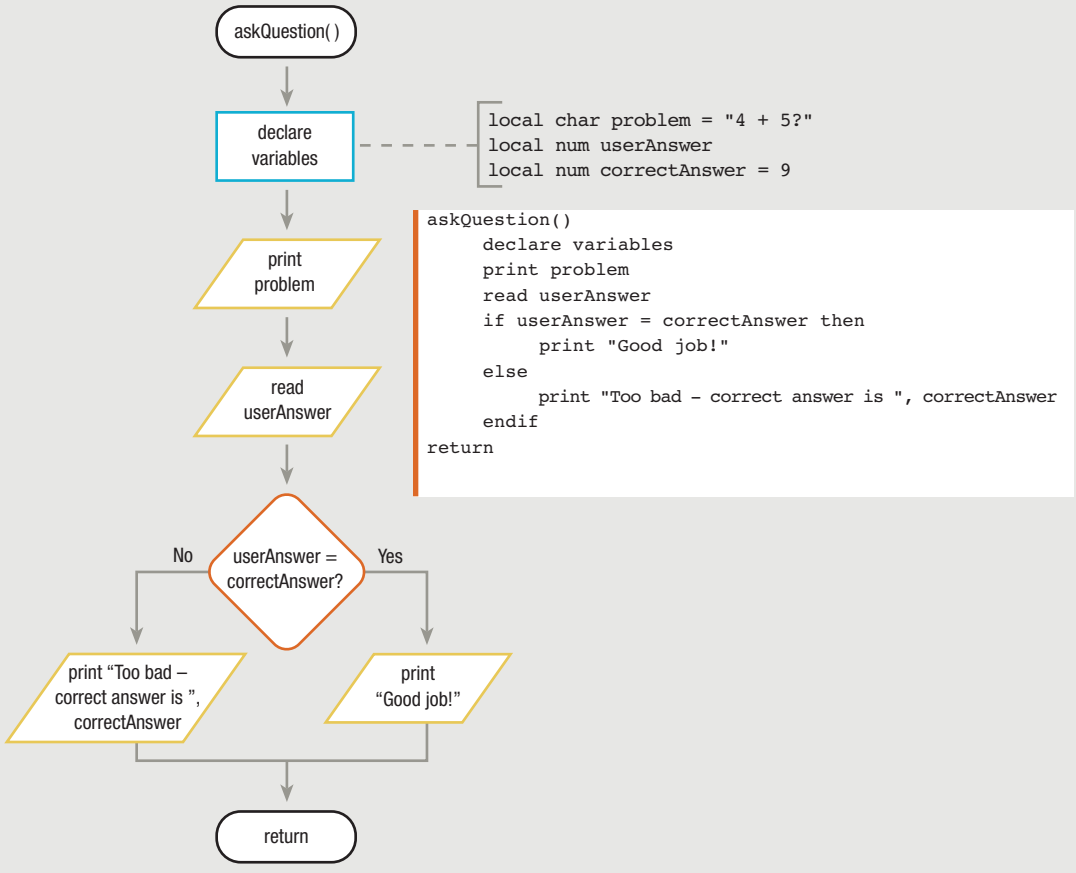
FIGURE 12-2: THE `housekeeping()` MODULE FOR A PROGRAM THAT USES ONLY LOCAL VARIABLES



Within the `askQuestion()` module of this arithmetic program, shown in Figure 12-3, you display an arithmetic problem, accept an answer, determine whether the answer is correct, and write a message. The `askQuestion()` module does not need to know about the `explanation` and `promptUser` variables, but the `askQuestion()` module does need a `problem` variable to hold the arithmetic problem to present to the user, a `userAnswer` variable in which to store the user's answer to the arithmetic problem, and a `correctAnswer` variable to hold the value to which the user's answer will be compared. Within the `askQuestion()` module, you declare these variables and use them. By the time you reach the end of the `askQuestion()` module, the three variables have served their purposes; there is no reason for any other module to have access to their values.

Figure 12-4 shows the `finish()` module for the arithmetic drill program. This module does not need to know the values of any of the variables in the first two modules called by the program; instead, it needs only its own locally declared `endingMessage`.

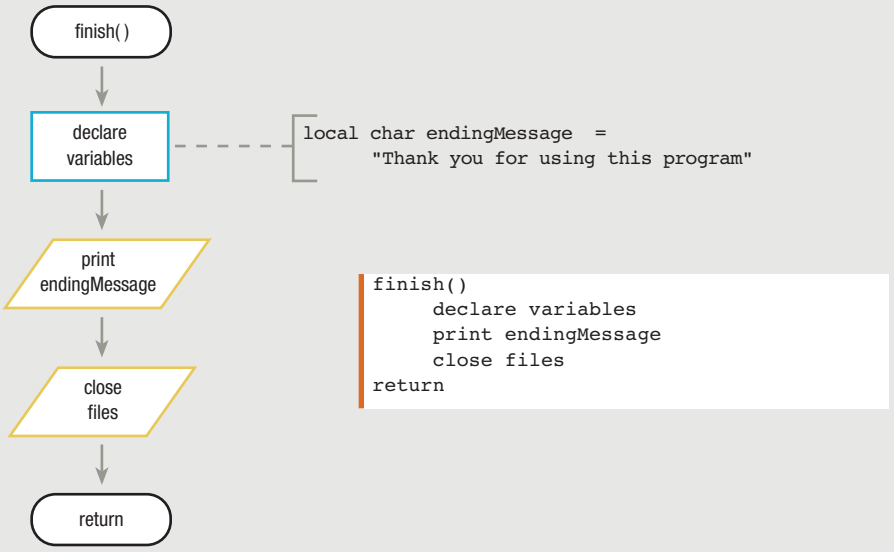
FIGURE 12-3: THE `askQuestion()` MODULE FOR A PROGRAM THAT USES ONLY LOCAL VARIABLES



This arithmetic drill program employs a principle known as **encapsulation**, which means that program components are bundled together. Encapsulation provides a means for **information hiding**, or **data hiding**, which means that the data or variables you use are completely contained within—and accessible only to—the module in which they are declared. In other words, the data and variables are "hidden from" the other program modules. Using encapsulation provides you with several advantages:

- Because each module contains all its own variable names, each module can be inserted easily into another program as a self-contained unit, requiring no changes within any modules in the new program.
- Because each module needs to use only the variable names declared within it, multiple programmers can create the individual modules without knowing the data names used by the other modules.
- Because the variable names in each module are hidden from all other modules, programmers can even use the same variable names as those used in other modules, and no conflict will arise.

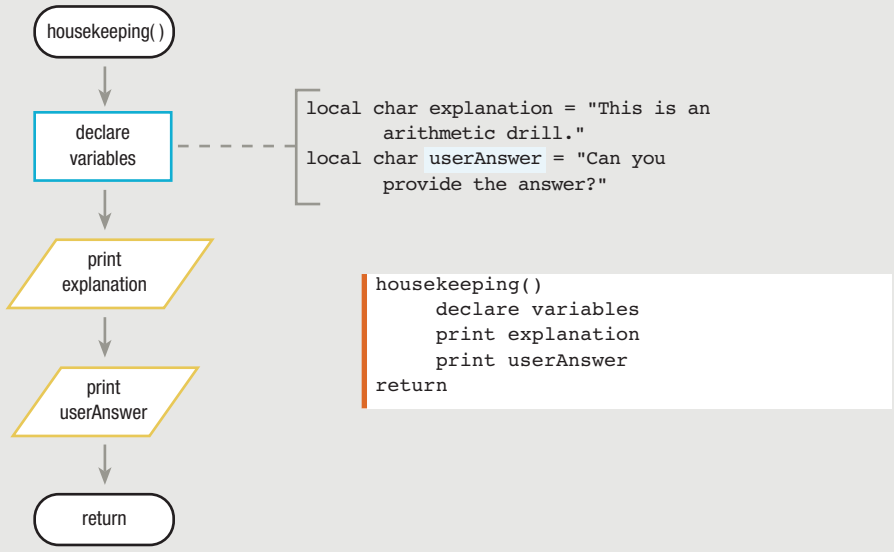
FIGURE 12-4: THE `finish()` MODULE FOR A PROGRAM THAT USES ONLY LOCAL VARIABLES



TIP The terms "encapsulation" and "information hiding" are often used synonymously, but encapsulation only facilitates (not guarantees) the hiding of information.

To illustrate this last point, consider the `housekeeping()` module for the arithmetic drill program shown in Figure 12-2. Programmers who work on this module can give the local variables any name they want. For example, a programmer could decide to call the `promptUser` variable `userAnswer`, as highlighted in Figure 12-5. In a program that employs local variables, giving the `housekeeping()` module's variable this name would have no effect on the usefulness of the identically named variable defined in the `askQuestion()` module. The two `userAnswer` variables are completely separate variables with unique memory addresses. One holds the character prompt "Can you provide the answer?" and the other holds a numeric user answer. Changing the value of `userAnswer` in one module (which is what happens when the user enters an arithmetic problem answer in the `askQuestion()` module) has no effect whatsoever on the separate `userAnswer` variable in the other module. A large program might contain dozens of modules, and each module might contain dozens of variable names. As programs grow in size and complexity, it is a great convenience for a programmer who is working on one module not to have to worry about conflicting with all the other variable names used in the program.

FIGURE 12-5: THE MODIFIED `housekeeping()` MODULE CONTAINING `userAnswer` VARIABLE



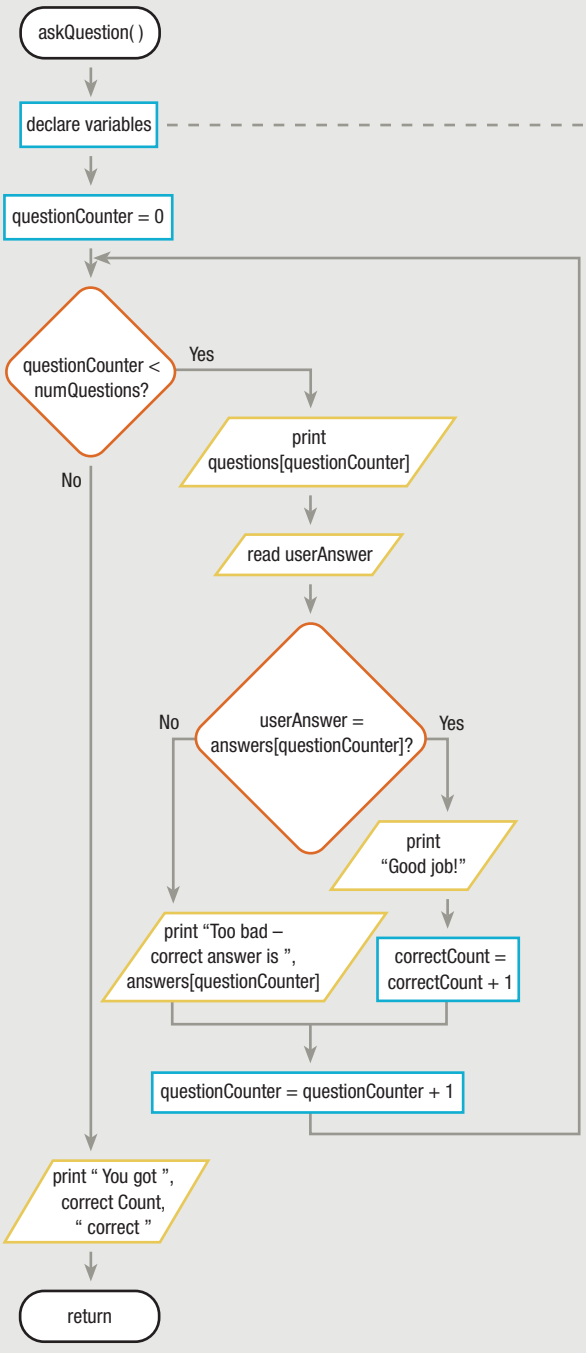
TIP

As an analogy, think of modules as households. Referring to a person named "Edward" in the Johnson household causes no confusion with a person named "Edward" in another household. The same name can be used locally within different households without conflict, in the same way that identical variable names can be used in multiple modules. Conversely, although two men can legally be named "Edward" within the same household, families almost always apply a nickname or qualification to at least one of the like-named people to avoid confusion, perhaps referring to "Ed" and "Eddie," or "Big Edward" and "Little Edward." Similarly, within any module, variable names must differ, if only by a single character.

PASSING A SINGLE VALUE TO A MODULE

It may be convenient for a programmer to use local variables without worrying about naming conflicts, but using local variables produces a problem in many programs. By definition, a local variable is accessible to one module only; however, sometimes more than one module needs access to the same variable value. Consider a new arithmetic drill program. Instead of a single arithmetic problem, it is more reasonable to expect such a program to ask the user a series of problems and keep score. Figure 12-6 shows a revised `askQuestion()` module that accesses an array to provide a series of five questions for the arithmetic drill. The module compares the user's answer to the correct answer that is stored in the corresponding position in a parallel array, and adds 1 to a `correctCount` variable when the answer is correct. After the user completes all five problems, but before the module ends, the value of `correctCount` is displayed.

FIGURE 12-6: THE MODIFIED `askQuestion()` MODULE THAT PROVIDES FIVE PROBLEMS AND KEEPS SCORE




```
local num userAnswer
local num questionCounter
local num numQuestions = 5
local array questions[5]
      questions[0] = "4 + 5?"
      questions[1] = "3 + 3?"
      questions[2] = "2 + 7?"
      questions[3] = "1 + 2?"
      questions[4] = "4 + 1?"
local array answers[5]
      answers[0] = 9
      answers[1] = 6
      answers[2] = 9
      answers[3] = 3
      answers[4] = 5
local num correctCount = 0
```

FIGURE 12-6: THE MODIFIED `askQuestion()` MODULE THAT PROVIDES FIVE PROBLEMS AND KEEPS SCORE (CONTINUED)

```
askQuestion()
     declare variables
     questionCounter = 0
     while questionCounter < numQuestions
          print questions[questionCounter]
          read userAnswer
          if userAnswer = answers[questionCounter] then
               print "Good job!"
               correctCount = correctCount + 1
          else
               print "Too bad - correct answer is ", answers[questionCounter]
          endif
          questionCounter = questionCounter + 1
     endwhile
     print " You got " , correctCount,  " correct"
return
```

The module shown in Figure 12-6 correctly counts and displays the number of correct answers for the user. However, suppose when the user completes the arithmetic drill, you want to print not only the count of correct answers, but also the percentage of correct answers along with one of two messages based on the user's performance. With these additions to the post-problem-solving process, there are enough steps involved that you decide to place these steps in their own module, named `finalStatistics()`. In other words, you want to be able to add to the user's `correctCount` value in the `askQuestion()` module, but you want to be able to determine the `correctCount` percentage and display it from within the `finalStatistics()` module. You must declare a `correctCount` variable, but where?

- If `correctCount` is declared locally within the `askQuestion()` module so you can add to it when the user answers correctly, then the `finalStatistics()` module does not have access to it.
- If `correctCount` is declared locally in the `finalStatistics()` module so you can compute the correct percentage and display it, then the `askQuestion()` module cannot add to it.
- If you attempt to solve the dilemma by declaring a local `correctCount` variable in each module, they are not the same variable; that is, they do not have the same memory address. Therefore, adding to the `correctCount` variable in one module does not alter the value of the unique `correctCount` variable in the other module.
- If you decide not to use local variables but declare `correctCount` as a global variable, the program will work, but you will have avoided using the principle of encapsulation and will have lost the advantages it provides.

The solution to using a locally declared variable within another module lies in a program's ability to pass the value of a local variable from one module to the other. **Passing a value** means sending a copy of data in one module of a program to another module for use. Exactly how you accomplish this differs slightly among languages, but it usually involves including the name of the variable that holds the value you want to pass within parentheses in the call to the module that needs to receive a copy of the value. Figure 12-7 provides an overview of the process. A value is sent from the method call in the `askQuestion()` module into the `finalStatistics()` module. When the `finalStatistics()` module is complete, program control returns to the `askQuestion()` module, where it would proceed with any additional statements in the module; in this case, the next task is to return from the `askQuestion()` module to the mainline program logic. Figure 12-8 shows the flowchart and pseudocode that modify the `askQuestion()` module to pass a copy of the `correctCount` value to the `finalStatistics()` module.

FIGURE 12-7: PASSING `correctCount` TO THE `finalStatistics()` MODULE

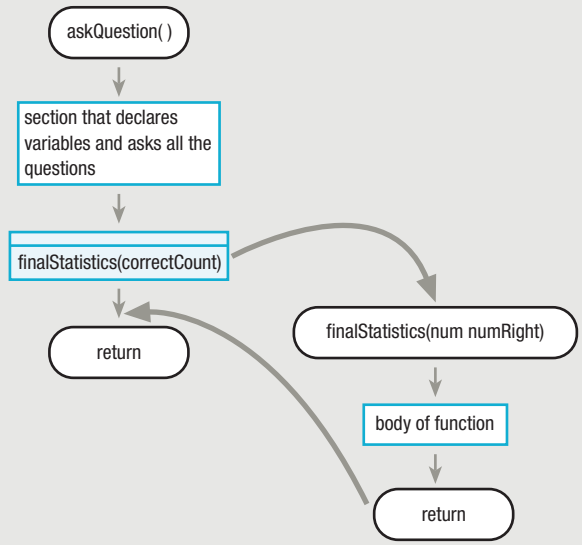


FIGURE 12-8: THE MODIFIED `askQuestion()` MODULE THAT PASSES `correctCount` TO A `finalStatistics()` MODULE

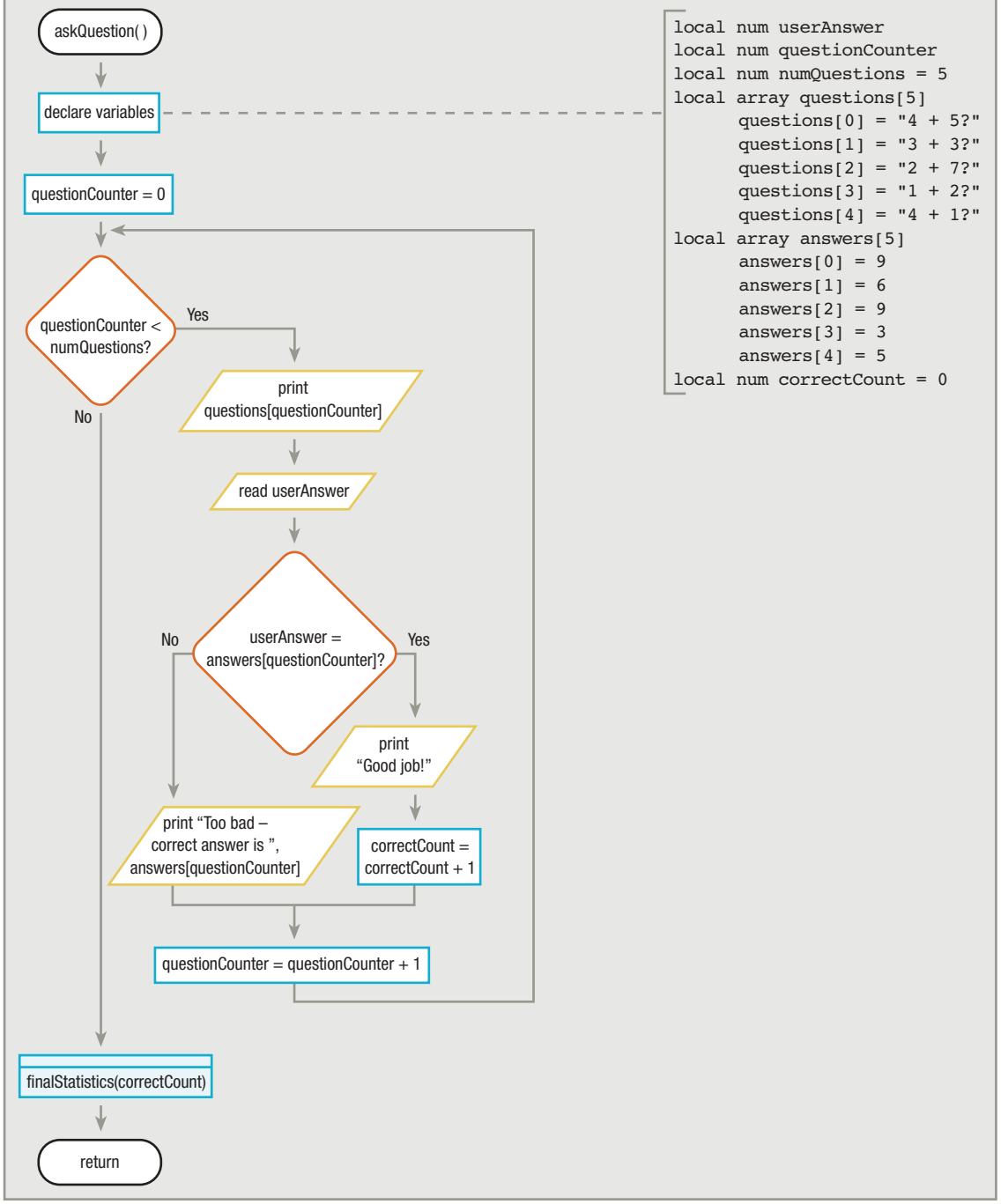


FIGURE 12-8: THE MODIFIED `askQuestion()` MODULE THAT PASSES `correctCount` TO A `finalStatistics()` MODULE (CONTINUED)

```
askQuestion()
     declare variables
     questionCounter = 0
     while questionCounter < numQuestions
          print questions[questionCounter]
          read userAnswer
          if userAnswer = answers[questionCounter] then
               print "Good job!"
               correctCount = correctCount + 1
          else
               print "Too bad - correct answer is ", answers[questionCounter]
          endif
          questionCounter = questionCounter + 1
     endwhile
     perform finalStatistics(correctCount)
return
```

Figure 12-9 shows the `finalStatistics()` module for the program. To prepare this module to receive a copy of the `correctCount` value, you declare a name for the passed value within parentheses in the **module header**, or introductory title statement of the module. The passed variable named within the module header is a parameter to the function.

TIP

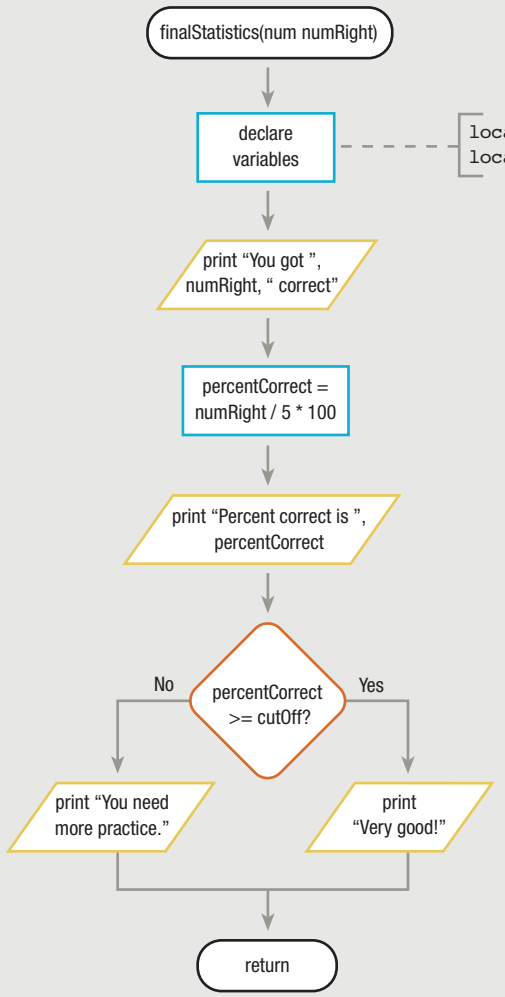
The words "argument" and "parameter" are often used interchangeably, although many programmers make a clear distinction between the two. An **argument** is the expression in the comma-separated list in a function call, while a **parameter** is an object or reference that is declared in a function prototype (declaration) or definition (header).

In Figure 12-9, the `finalStatistics()` module declares a numeric variable named `numRight` in its header statement. Declaring a variable within the parentheses of the module header indicates that this variable is not a regular variable declared locally within the module; it is a special variable that is local to the module but receives its value from the outside. In Figure 12-9, `numRight` receives its value when the `askQuestion()` module in Figure 12-8 calls the `finalStatistics()` module. The `askQuestion()` module passes the value of `correctCount` to `finalStatistics()`; then, within the `finalStatistics()` module, `numRight` takes on the value of `correctCount`, and the percentage of correct answers is calculated using `numRight`.

TIP

Passing a copy of a value to a module sometimes is called *passing by value*. Some languages allow you to pass the actual memory address of a variable to a module; this is called *passing by reference*. When you pass by reference, you lose some of the advantages of information hiding because the module has access to the address of the passed variable, not just to a copy of the value of the passed variable. However, program performance improves because the computer doesn't have to make a copy of the value, thereby saving time (and in the case of very large passed objects, saving significant memory). Both the ability to pass by reference and the syntax to do so vary by programming language.

FIGURE 12-9: THE `finalStatistics()` MODULE THAT RECEIVES `correctCount` VALUE AND CALLS IT `numRight`




```
finalStatistics(num numRight)
     declare variables
     print "You got ", numRight, " correct"
     percentCorrect = numRight / 5 * 100
     print "Percent correct is ",
          percentCorrect
     if percentCorrect >= cutOff then
          print "Very good!"
     else
          print "You need more practice."
     endif
return
```

The `finalStatistics()` module contains its own local variables, `percentCorrect` and `cutOff`. The `percentCorrect` variable is used to hold a calculated percentage of correct answers based on five arithmetic questions, and `cutOff` is used to compare the user's final percentage score with a minimum acceptable percentage. Any module can contain some values that are passed in, like `numRight`, and some that are stored in locally declared variables, such as `percentCorrect` and `cutOff`. The only restriction is that within any module, each variable must have a unique name; however, those names might or might not match any other variable names in other modules. For example, within the `finalStatistics()` module of the arithmetic drill program, you could choose to name the passed local value `correctCount` instead of `numRight`, giving it the same name as its counterpart in the `askQuestion()` module. Whether the name of the variable that holds the count in `finalStatistics()` is the same as that of the corresponding value in the `askQuestion()` module is irrelevant. The `correctCount`

variable used as an argument to `finalStatistics()` within the `askQuestion()` module and the numeric parameter in the `finalStatistics()` module represent two unique memory locations, no matter what name you decide to give the variable that holds the count of right answers within the `finalStatistics()` module.

PASSING MULTIPLE VALUES TO A MODULE

In the `finalStatistics()` module of the arithmetic drill program in Figure 12-9, `numRight`, `percentCorrect`, and `cutOff` all remain in scope from the point at which they are declared until the end of the module. After the `finalStatistics()` module receives its parameter, it contains everything it needs to calculate the percentage of addition problems that the user answered correctly and to determine which message to display. You could easily insert this self-contained module into different programs that calculate correct percentages—for example, programs that display subtraction or multiplication problems, or even those that ask history or grammar questions. As long as those programs pass a value indicating the number of correct answers, no matter what the name of the counter variable is in those programs, the `finalStatistics()` module works correctly—with one major flaw. The `finalStatistics()` module calculates the correct percentage only when the calling program contains exactly five problems—it divides the `numRight` variable by a constant, 5. A more useful `finalStatistics()` module accepts two parameters—one containing the number of correct user answers, and another containing the total number of possible correct answers. Then, whether you call `finalStatistics()` from a program containing a three-question quiz or a 200-item exam, the percentage will be correct.

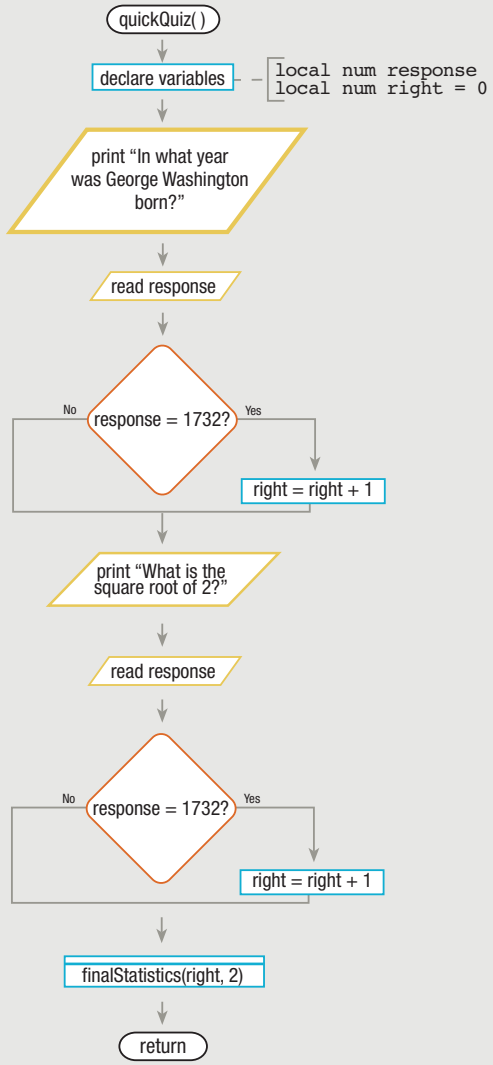
Figure 12-10 shows a module named `quickQuiz()` that includes a call to a `finalStatistics()` module that accepts two parameters, `numRight` and `numPossible`. This version of the `finalStatistics()` module differs from the version of the module in Figure 12-9 in only the highlighted areas. The addition of the `numPossible` parameter makes the module more flexible. The series of parameters that appears in the module header is called a **parameter list**. You could call this module from the `askQuestion()` module shown in Figure 12-8, replacing the current highlighted call to `finalStatistics()` with the statement `perform finalStatistics(correctCount, numQuestions)`. With this call, the `finalStatistics()` module would accept the value of `correctCount` and place it in `numRight`, and then accept the value of `numQuestions` and place it in `numPossible`. Alternatively, as shown in Figure 12-10, you could use the same module with a two-question quiz, passing a variable (`right`) and a constant (2), and the percentage correct would still be accurate.

Notice several important facts about the `finalStatistics()` method header in Figure 12-10:

- The two parameters in the header are separated by a comma. This is the convention in most modern languages such as Java, C++, and C#—any number of parameters is acceptable, but each must be separated from the others using a comma.
- Each parameter consists of both a data type and an identifier. This also is the convention in most modern programming languages. The parameter list might contain any combination of numeric and character items, but the data type of each must be explicitly mentioned with the identifier.
- Each identifier adheres to the rules for naming variables you have used throughout this book—specifically, no spaces are allowed in the identifier names, but each identifier might contain letters and digits.

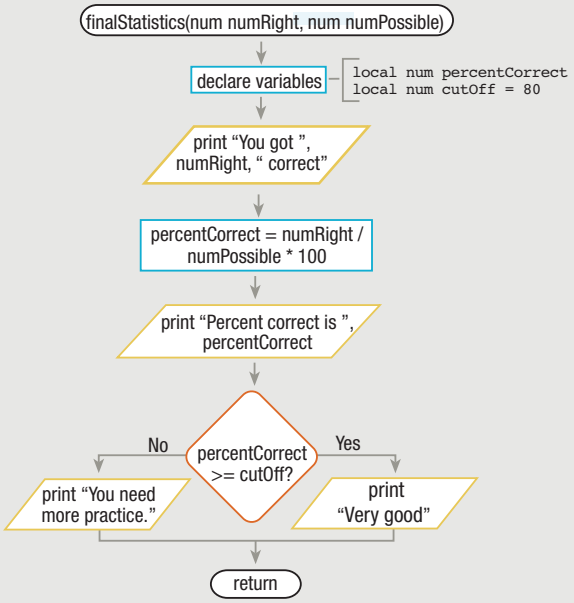
- The order of the parameters is very important. The only way that a module assigns values to the variables named in its parameter list is based on the order in which the arguments are passed from the calling module; the values passed into a module are assigned sequentially as they are received. If, for example, you pass variables containing the values 5 and 100 to the `finalStatistics()` module in that order, the module will display a 5 percent correct result. However, if you reverse the order of the passed values, sending 100 and 5, the module produces a very different result—2,000 percent correct.

FIGURE 12-10: THE `quickQuiz()` MODULE THAT PASSES TWO ARGUMENTS TO THE `finalStatistics()` MODULE




```
quickQuiz()
     declare variables
     print "In what year was George
        Washington born?"
     read response
     if response = 1732 then
          right = right + 1
     endif
     print "What is the square root of 2?"
     read response
     if response = 1.732 then
          right = right + 1
     endif
     perform finalStatistics(right, 2)
return
```

FIGURE 12-10: THE `quickQuiz()` MODULE THAT PASSES TWO ARGUMENTS TO THE `finalStatistics()` MODULE (CONTINUED)




```
finalStatistics(num numRight, num numPossible)
      declare variables
      print "You got ", numRight, " correct"
      percentCorrect = numRight / numPossible
         * 100
      print "Percent correct is ",
            percentCorrect
      if percentCorrect >= cutOff then
            print "Very good!"
      else
            print "You need more practice."
      endif
return
```

TIP

If you send arguments that are the wrong data types to a module, or you send too many or too few, you receive a syntax error message and the program will not compile or execute. However, if you send arguments that are the correct data types but that represent the wrong values, then you create a logical error that produces incorrect output. For example, if a module expects two numeric parameters representing a retail price and a discount in that order, and you pass 100.00 and 20.00, the module might correctly bill a customer a discounted price of $80.00. If you pass 20.00 and 100.00 by mistake, the module will perform a subtraction and produce a bill that indicates the customer has an $80.00 credit.

You can call a module from other modules in a variety of ways—you can use any combination of variables and constants as arguments in a module call. For example, consider the module shown in Table 12-1. The `printCustOrder()` module header shows that it accepts four parameters; the module uses the argument information to calculate a price and print a customer order. To use that module, you could call it in any of the ways shown in the middle section of the table, using any combination of variables and constants as arguments. The bottom part of the table shows some illegal calls and explains why each is unacceptable.

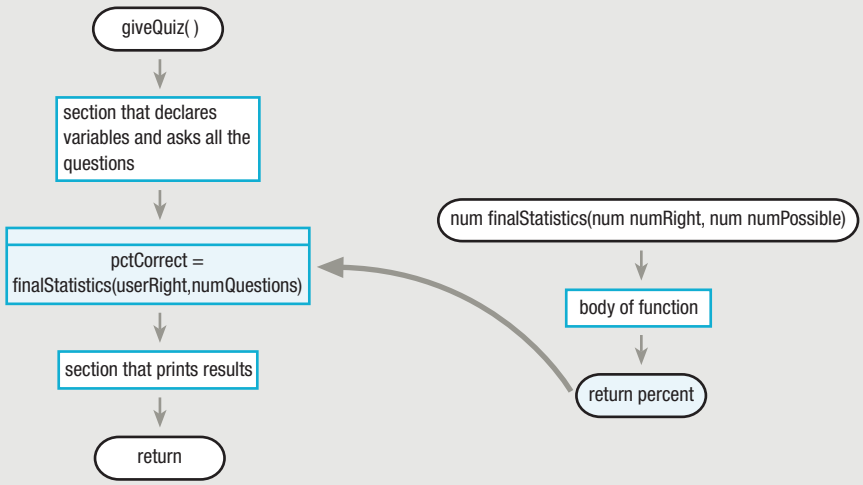
TABLE 12-1: THE `printCustOrder()` MODULE

Module header	
`printCustOrder(num itemNum, num quantity, char custName, char custAddress)`	
Legal calls from a module that contains declared variables named `stockNumber`, `amount`, `lastName`, `firstName`, and `streetAddress`	
Call using four variables	`printCustOrder(stockNumber, amount, lastName, streetAddress)`
Call using three variables and a constant	`printCustOrder(stockNumber, amount, lastName, "Will pick up")`
Call using two variables and two constants	`printCustOrder(stockNumber, 1, "Resident", streetAddress)`
Call using four constants	`printCustOrder(1342, 12, "Lewis", "900 Evergreen Avenue")`
Illegal calls from a module that contains declared variables named `stockNumber`, `amount`, `lastName`, and `streetAddress`	
Not enough arguments	`printCustOrder(stockNumber, amount, lastName)`
Too many arguments	`printCustOrder(stockNumber, amount, lastName, firstName, streetAddress)`
Arguments do not exist as variables in the calling function	`printCustOrder(itemNum, quantity, custName, custAddress)`
Arguments do not match order in module header	`printCustOrder(stockNumber, lastName, amount, streetAddress)`

RETURNING A VALUE FROM A MODULE

Suppose you decide to organize the arithmetic drill program from Figure 12-10 so that the `finalStatistics()` module still computes the user's correct percentage, but the calling module handles the printing of the final statistics. In this case, you pass the values of the count of correct questions and the total number of questions available to the `finalStatistics()` module as before, but the `finalStatistics()` module must **return the value** of the calculated correct percentage back to the calling module. Just as you can pass a value into a module, you can pass back, or return a value to a calling module. Usually, this is accomplished within the `return` statement of the called module. For example, Figure 12-11 shows an overview of how a value is passed back from the `finalStatistics()` module and stored in the `giveQuiz()` module. Figure 12-12 shows the flowchart and pseudocode for a `giveQuiz()` module that calls a rewritten `finalStatistics()` module.

FIGURE 12-11: RETURNING `percent` FROM THE `finalStatistics()` MODULE TO `pctCorrect` IN THE `giveQuiz()` MODULE



The `giveQuiz()` module in Figure 12-12 declares an array of questions and a parallel array holding correct answers. The module displays each question in sequence, compares the user's answer to the correct answer, and determines whether to add 1 to a variable used to keep track of the number of correct responses. Notice that near the end of the `giveQuiz()` module, you call the `finalStatistics()` module and pass in the `userRight` and `numQuestions` values. In the same statement, you assign the return value of the `finalStatistics()` module to the variable named `pctCorrect`. The `pctCorrect` variable is declared locally within the `giveQuiz()` module; its purpose is to receive the value returned by the `finalStatistics()` module. Then, you can use the value of the `pctCorrect` variable within the remainder of the `giveQuiz()` module.

TIP

Within the `giveQuiz()` module in Figure 12-12, the `finalStatistics()` module is called without using the word `perform`. The module actually is performed in the same way as all other modules you have performed using this book. In a flowchart or pseudocode, it would be perfectly acceptable to write `pctCorrect = perform finalStatistics(userRight,numQuestions)`. However, in this book, the word `perform` is eliminated in module examples that return a value, for two reasons: for simplicity in an already-complicated statement, and because the resulting syntax (eliminating `perform`) closely resembles that of popular modern languages such as C++, C#, and Java.

Notice that the variable type name `num` is used as the first word in the header of the `finalStatistics()` module in Figure 12-12. The use of a data type preceding the method header indicates the type of data that will be returned by the module; this use follows the format for methods that return values in many programming languages, such as C++, Java, and C#. The return type of a method is also called the **method's type** or **method's return type**.

FIGURE 12-12: A `giveQuiz()` MODULE THAT SENDS VALUES TO AND RECEIVES A VALUE RETURNED FROM A `finalStatistics()` MODULE

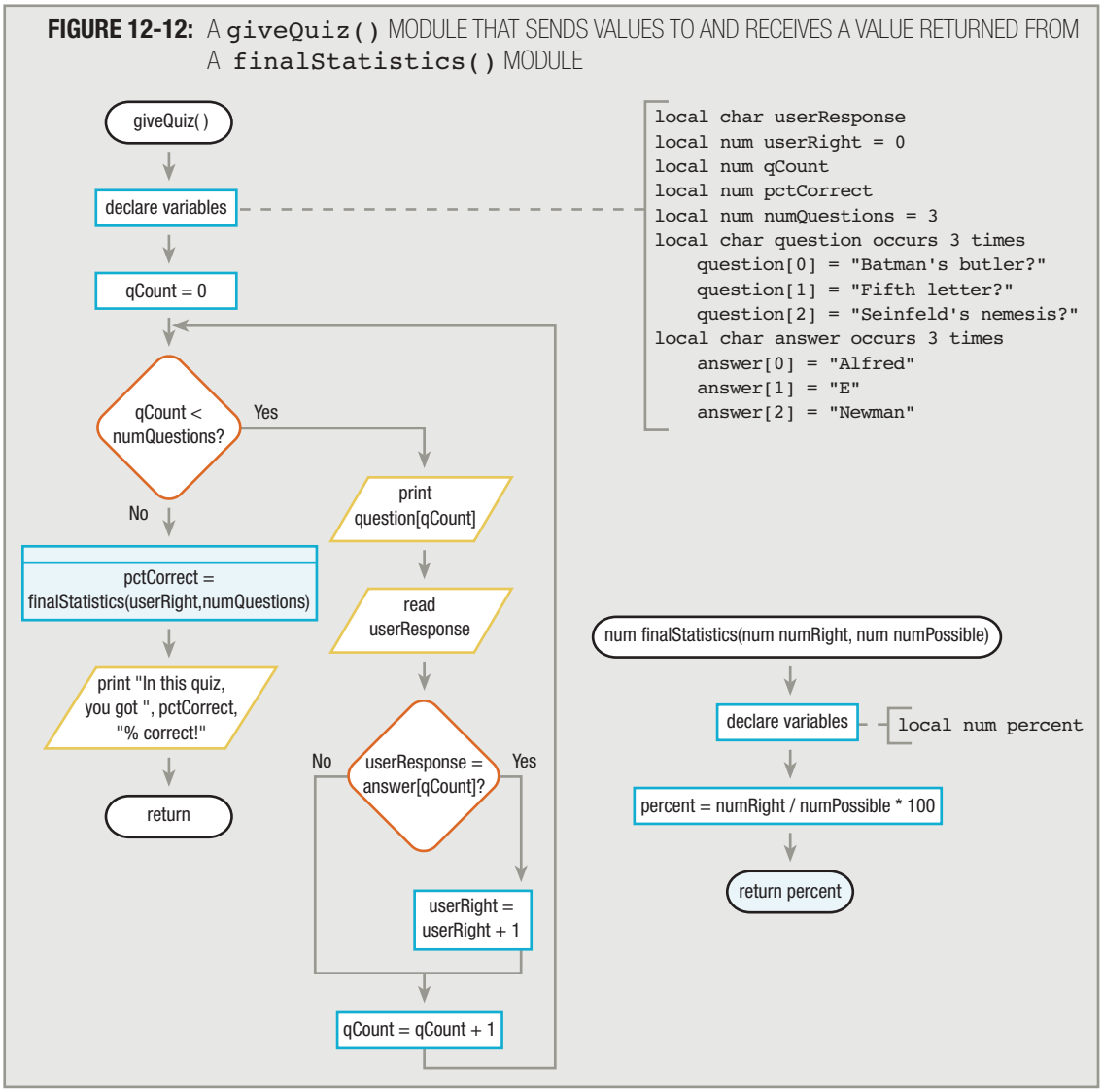


FIGURE 12-12: A `giveQuiz()` MODULE THAT SENDS VALUES TO AND RECEIVES A VALUE RETURNED FROM A `finalStatistics()` MODULE (CONTINUED)

```
giveQuiz()
     declare variables
     qCount = 0
     while qCount < numQuestions
          print question[qCount]
          read userResponse
          if userResponse = answer[qCount] then
               userRight = userRight + 1
          endif
          qCount = qCount + 1
     endwhile
     pctCorrect = finalStatistics(userRight,numQuestions)
     print "In this quiz, you got ", pctCorrect, "% correct!"
return
num finalStatistics(num numRight, num numPossible)
     declare variables
     percent = numRight / numPossible * 100
return percent
```

TIP A function or module should have, at most, one return value, and the `return` statement should always be the last statement in the module. Following these rules complies with the principles of structured programming you have used throughout this book. Recall from Chapter 2 that a structure can have only one entry point and one exit point; because a `return` statement provides a module's exit point, if the module is structured, it will have only one `return` statement, and hence, one return value.

TIP In several programming languages, such as Java, C++, and C#, if a module does not return a value, then the return type you list in the header is void, and the method is referred to as a void method. The word **void** means "empty" or "nothing." You have seen many modules that do not return values throughout this book; their `return` statement simply contains `return`.

TIP If you place statements within a module after the `return` statement, those statements will never execute. They are examples of **unreachable code**, or **dead code**.

USING PREWRITTEN, BUILT-IN MODULES

Many programming languages contain **built-in methods**, or **built-in functions**—prewritten modules that perform frequently needed tasks. For example, many languages contain a module that calculates the square root of a number. Within a program, you could perform the necessary calculations yourself, but it's a tedious process, and one that should not have to be rewritten by every programmer who needs it. The creators of many language compilers include a square root module so that programmers can use their valuable time to solve problems that are more unique to their business.

The only way you can discover whether the language you are using contains a built-in module such as a square root method is to examine the program language documentation; for example, you can read the manual that accompanies a language compiler, search through online help, or examine language-specific textbooks. When you find an available module that suits your needs, you need to discover three facts:

1. The name of the method
2. The arguments you need to pass to the method, if any
3. The type of value returned from the method, if any

As a matter of fact, these are the same three facts that another programmer needs to know to be able to use any method you write. For example, you might discover that in a particular language, the documentation indicates that the format of its square root function is `num sqrt(num)`, indicating that the function name is `sqrt`, that it requires a single numeric variable or constant as an argument, and that it returns a numeric value. A statement such as `num sqrt(num)` fully describes how you can use the method. To use the method, you might create statements similar to the following:

```
num myValue = 16
num squareRootAnswer
squareRootAnswer = sqrt(myValue)
```

You use the method name `sqrt`, pass the value stored in `myValue` to it, and receive an answer back; the answer can then be used in the same way you would use any other value of the same type—you can print it, assign it to a variable, use it as part of a more complex arithmetic calculation, and so on. After the three preceding statements execute, for example, the variable `squareRootAnswer` would hold 4, the square root of 16.

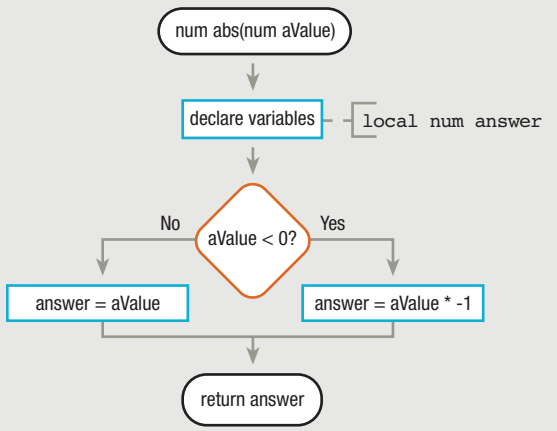
TIP In some languages, such as C++ and Java, a function's name and list of parameters are called its **signature**. When the signature is combined with the method's return type (and other punctuation), it is called the method's **prototype**.

As a programmer who uses a built-in method or function, you do not need to understand how the square root is calculated within the function; the method acts as a **black box**, or a device you can use without understanding its internal processes. In real life, you use many black box items—for example, most of us can use a telephone very well without having any idea how our voice is transported to friends and relatives around the world. Similarly, you can operate a television set without any knowledge of how the images appear there. What you understand about black box devices is their interface—the means of interaction, such as the buttons and speakers. Well-written program methods have the same features—the user understands how to use them through the interface (the signature) but does not need to understand their internal workings.

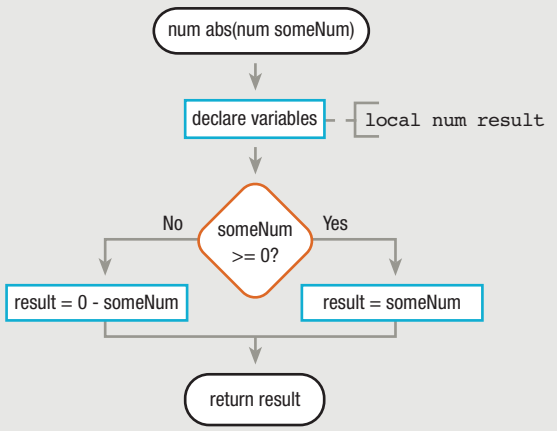
Consider the three `abs()` functions shown in Figure 12-13. Each version of the `abs()` method returns the absolute value of a number. A number's **absolute value** is the positive value of the number; as examples, the absolute value of –5 is 5, and the absolute value of 17 is 17. In other words, taking the absolute value of a number removes the negative sign, if the number has one. The set of statements within each of the three modules is different, yet a programmer would use each of the modules in an identical fashion. To store the absolute value of `myNumber` in a variable named `answer`, you write `answer = abs(myNumber)`. Just as you do not really care whether your television

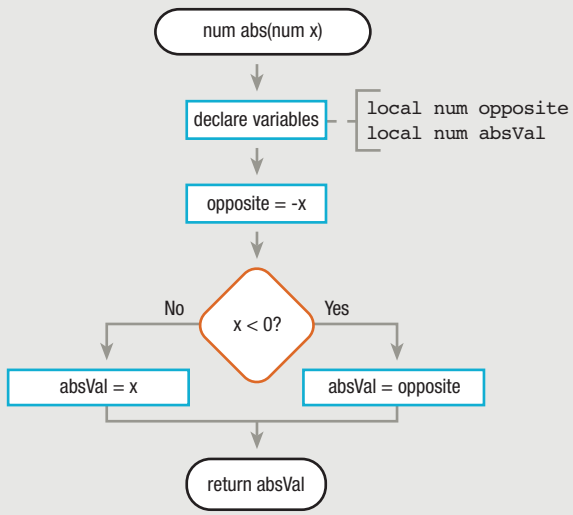
operates using household AC current or a battery, or is powered by a hamster on a wheel, as a programmer using a black box method, you don't really care which of the three versions of the `abs()` function shown in Figure 12-13 exists in the programming language you are using. Like the built-in methods, the internal operations of the methods you write should be invisible to the user.

FIGURE 12-13: THREE VERSIONS OF AN `abs()` FUNCTION




```
num abs(num aValue)
     declare variables
     if aValue < 0 then
          answer = aValue * -1
     else
          answer = aValue
return answer

num abs(num someNum)
     declare variables
     if someNum >= 0 then
          result = someNum
     else
          result = 0 - someNum
return result

num abs(num x)
     declare variables
     opposite = -x
     if x < 0
          absVal = opposite
     else
          absVal = x
return absVal
```





TIP In Figure 12-13, notice how the name of the numeric parameter in the function header can be different in each version of the `abs()` method. The variable's local name in no way affects how the method is called from another module; any numeric value passed into a method takes on the local name provided in the method header.

USING AN IPO CHART

When designing modules to use within larger programs, some programmers find it helpful to use an **IPO chart**, a tool that identifies and categorizes each item needed within the module as pertaining to input, processing, or output. For example, when you design the `finalStatistics()` module in the arithmetic drill program, you can start by placing each of the module's components in one of the three processing categories, as shown in Figure 12-14.

FIGURE 12-14: IPO CHART FOR THE `finalStatistics()` MODULE

Input	Processing	Output
Correct count	Divide correct count by total number of problems and multiply by 100, producing percentage correct	Percentage correct

The IPO chart in Figure 12-14 provides you with an overview of the processing steps involved in the `finalStatistics()` module. Like a flowchart or pseudocode, an IPO chart is just another tool to help you plan the logic of your programs. Many programmers create an IPO chart only for specific modules in their programs and as an alternative to flowcharting or writing pseudocode. IPO charts provide an overview of input to the module, the processing steps that must occur, and the result.

TIP This book emphasizes creating flowcharts and pseudocode. You can find many more examples of IPO charts on the Web.

UNDERSTANDING THE ADVANTAGES OF ENCAPSULATION

When writing a module that receives a variable, you can give the variable any name you like. This feature is especially beneficial if you consider that a well-written module may be used in dozens of programs, each supporting its own unique variable names. To beginning programmers, using only global variables seems like a far simpler option than declaring local variables and being required to pass them from one module to another. If a variable holds a count of correct responses, why not create a single variable, call it `correctCount`, and let every module in the program have access to the data stored there?

As an example of why this is a limiting idea, consider this: The `finalStatistics()` module of the arithmetic drill program might be useful in other programs within the organization—maybe the company creates drills in subjects other than arithmetic, but all drills require final statistics. If it is well-written, the `finalStatistics()` module can be used by other programs in the company for years to come. If the variables that `finalStatistics()` uses are

not declared to be local, then every programmer working on every application within the organization will have to know the names of those variables, to avoid conflict. If `correctCount` is global, then all programmers who use the module must be aware of the name and purpose of the variable and avoid using it in any other context.

If the `finalStatistics()` module is so useful that you sell it to other companies, and if `correctCount` is global, all programmers in those organizations will need to know its name and will have to avoid using it for any other purpose in their programs. The name `correctCount` represents just one variable. Multiply the limitations on global variable name usage by all the variable names used in the programs all over the world, and you can see that using global variable names correctly will soon become impossible. The logistics would be similar to providing a unique first name to every person at birth; you could do it, but you would end up using awkward, cryptic names.

Even if you could provide unique variable names for every program, there are other benefits to using local variables that are passed to modules. Passing values to a module helps facilitate encapsulation. A programmer can write a program (or module) and use procedures developed by others without knowing the details of those procedures; the programmer can use the modules as black boxes. You don't need to know—maybe you don't even care—how a procedure uses the data you send, as long as the results are what you want.

When procedures use local variables, the procedures become miniprograms that are relatively autonomous. Modules that contain their own sets of instructions and their own variables are not dependent on the program that calls them. The details within a module are hidden and contained, or encapsulated, which helps to make the module reusable.

Many real-world examples of encapsulation exist. When you build a house, you don't invent plumbing and heating systems. You incorporate systems that have already been designed. You don't need to know all the fine details of how the systems work; they are self-contained units you attach to your house. This certainly reduces the time and effort it takes to build a house. Assuming the plumbing and electrical systems you choose are already in use in other houses, choosing existing systems also improves your house's reliability. **Reliability** is a feature of programs or modules that have been tested and proven to work correctly. Not only is a prefabricated furnace reliable, but it is unnecessary to know how your furnace works, and if you replace one model with another, you don't care if the internal operations of the new model are different. Whether heat is created from electricity, natural gas, or solar power, only the result—a warm house—is important to you.

Similarly, software that is reusable saves time and money and is more reliable. If the `finalStatistics()` module has been tested previously, you can be confident that it will work correctly when you use it within a different program. If another programmer creates a new and improved `finalStatistics()` module, you don't care how it works, as long as it correctly calculates and prints using the data you send to it.

The concept of passing variables to modules allows programmers to create variable names locally in a module without changing the value of similarly named variables in other modules. The ability to pass values to modules makes programming much more flexible, because independently created modules can exchange information efficiently. However, there are limitations to the ways procedural programs use modules. Any procedural program that uses a module must not reuse its name for any other module within the same program. With procedural programs, you also must know exactly what type of data to pass to a module, and if you have use for a similar module that works on a different type of data or a different number of data items, you must create a new module with a different name. These limitations are eliminated in programs that are object-oriented. In Chapter 13, you will learn the principles of object-oriented programming.

REDUCING COUPLING AND INCREASING COHESION

When you begin to design computer programs, it is difficult to decide how much to put into a module or subroutine. For example, a process that requires 40 instructions can be contained in a single module, two 20-instruction modules, 20 two-instruction modules, or any other combination. In most programming languages, any of these combinations is allowed. That is, you can write a program that will execute and produce correct results no matter how you divide the individual steps into modules. However, placing either too many or too few instructions in a single module makes a program harder to follow and reduces flexibility. When deciding how to organize your program steps into modules, you should adhere to two general rules:

- Reduce coupling.
- Increase cohesion.

REDUCING COUPLING

Coupling is a measure of the strength of the connection between two program modules; it is used to express the extent to which information is exchanged by subroutines. Coupling is either tight or loose, depending on how much one module depends on information from another. **Tight coupling**, which occurs when modules excessively depend on each other, makes programs more prone to errors; there are many data paths to keep track of, many chances for bad data to pass from one module to another, and many chances for one module to alter information needed by another module. **Loose coupling** occurs when modules do not depend on others. In general, you want to reduce coupling as much as possible because connections between modules make them more difficult to write, maintain, and reuse.

Imagine four cooks wandering in and out of the kitchen while preparing a stew. If each is allowed to add seasonings at will without the knowledge of the other cooks, you could end up with a culinary disaster. Similarly, if four payroll program modules are allowed to alter your gross pay figure "at will" without the "knowledge" of the other modules, you could end up with a financial disaster. A program in which several modules have access to your gross pay figure has modules that are tightly coupled. A superior program would control access to the payroll figure by limiting its passage to modules that need it.

You can evaluate whether coupling between modules is loose or tight by looking at the intimacy between modules and the number of parameters that are passed between them.

- Tight coupling—The least intimate situation is one in which modules have access to the same globally defined variables; these modules have tight coupling. When one module changes the value stored in a variable, other modules are affected.
- Loose coupling—The most intimate way to share data is to pass a copy of needed variables from one module to another. That way, the sharing of data is always purposeful—variables must be explicitly passed to and from modules that use them. The loosest (best) subroutines and methods pass single arguments rather than many variables or entire records, if possible.

Usually, you can determine that coupling is occurring at one of several levels. **Data coupling** is the loosest type of coupling; therefore, it is the most desirable. Data coupling is also known as **simple data coupling** or **normal coupling**. Data coupling occurs when modules share a data item by passing arguments. For example, a module that determines a student's eligibility for the dean's list might receive a copy of the student's grade point average to use in making the determination.

Data-structured coupling is similar to data coupling, but an entire record is passed from one module to another. For example, consider a module that determines whether a customer applying for a loan is creditworthy. You might write a module that receives the entire customer record and uses many of its fields to determine whether the customer should be granted the loan. If you need many of the customer fields—such as salary, length of time on the job, savings account balance, and so on—then it makes sense to pass a customer's record to a module. Figure 12-15 shows an example of such a module.

FIGURE 12-15: MODULE THAT DETERMINES CUSTOMER CREDITWORTHINESS

```
char checkCredit(Record custRec)
   declare variables ----------------------------
   creditIsOk = YES_CODE                          |
   if custSalary < MIN_SALARY then                |
      creditIsOk = NO_CODE                        |
   endif                                          |
   if custTimeOnJob < MIN_TIME then               |
      creditIsOk = NO_CODE                        |
   endif                                          |
   if custSavingsBal < MIN_SAVINGS then           |
      creditIsOk = NO_CODE                        |
   endif                                          |
return creditIsOk                                 |
                                                  |
local char creditIsOk                             |
local const char YES_CODE = "Y"                   |
local const char NO_CODE  = "N"                   |
local const num MIN_SALARY = 20000.00             |
local const num MIN_TIME = 2                      |
local const num MIN_SAVINGS = 3000.00             |
```

In the `checkCredit()` module in Figure 12-15, an entire record (`custRec`), rather than any single data field, is passed to the module. The coupling could have been made looser by writing three separate modules: one to check salary, one to check time on the job, and one to check savings balance. However, because so many fields in the customer's record are needed, in this case it is very appropriate to pass the entire record to the module.

Control coupling occurs when a main program (or other module) passes an argument to a module, controlling the module's actions or telling it what to do. For example, Figure 12-16 shows a module that receives a user's choice and calls one of several other modules.

FIGURE 12-16: THE `selectMethod()` MODULE

```
selectMethod(num userChoice)
     if userChoice = 1 then
          perform addRecordToFile()
     else
          if userChoice = 2 then
               perform deleteRecordFromFile()
          else
               if userChoice = 3 then
                    perform printRecords()
               else
                    perform invalidChoice()
               endif
          endif
     endif
return
```

Although control coupling is appropriate at times, the implication in the `selectMethod()` module is that any module that calls it is aware of how `selectMethod()` works—after all, an appropriate choice had to be made and passed to `selectMethod()`. The program that uses `selectMethod()` probably prompts the user for a choice and passes that choice to `selectMethod()`. Therefore, the calling program must know how to phrase the prompt correctly to elicit an appropriate `userChoice`. This coupling is relatively tight. This is a problem, because if you make a change to the `selectMethod()` module—for example, by adding a new option or changing the order of the existing options—then all the programs and other modules that use `selectMethod()` will have to know about the change. If they don't, their prompts will offer incorrect choices, and they won't be sending the appropriate `userChoice` value to the module. Once you have to start keeping track of all the modules and programs that might call a module, the opportunity for errors in a system increases dramatically.

External coupling and **common coupling** occur, respectively, when two or more modules access the same global variable or record. When data can be modified by more than one module, programs become harder to write, read, and modify. That's because if you make a change in a single module, many other modules can be affected. For example, if one module increases a field that holds the year from two digits to four, then all other modules that use the year will have to be altered before they can operate correctly. For another example, if one module can increase your gross pay figure by 10 percent based on years of service, and another module can increase your pay by 20 percent based on annual sales, it makes a difference which module operates first. It's possible that a third module won't work when the salary increases over a specified limit. If you avoid external or common coupling and pass variables instead, you can control how and when the modules receive the data.

Pathological coupling occurs when two or more modules change one another's data. An especially confusing case occurs when `moduleOne()` changes data in `moduleTwo()`, `moduleTwo()` changes data in `moduleThree()`, and `moduleThree()` changes data in `moduleOne()`. This makes programs extremely difficult to follow, and you should avoid pathological coupling at all costs.

INCREASING COHESION

Analyzing coupling lets you see how modules connect externally with other modules and programs. You also want to analyze a module's **cohesion**, which refers to how the internal statements of a module or subroutine serve to accomplish the module's purposes. In highly cohesive modules, all the operations are related, or "go together." Such modules are usually more reliable than those that have low cohesion; they are considered stronger, and they make programs easier to write, read, and maintain.

Functional cohesion occurs when all operations in a module contribute to the performance of only one task. Functional cohesion is the highest level of cohesion; you should strive for it in all methods you write. For example, a module that calculates gross pay appears in Figure 12-17. The module receives two parameters, `hours` and `rate`, and computes gross pay, including time-and-a-half for overtime. The functional cohesion of this module is high because each of its instructions contributes to one task—computing gross pay. If you can write a sentence describing what a module does, using only two words—for example, "Compute gross," "Cube value," or "Print record"—the module is probably functionally cohesive.

FIGURE 12-17: THE `computeGrossPay()` MODULE

```
num computeGrossPay(num hours, num rate)
      declare variables - - - - - - - - - - - - - - -  local num gross
                                                        local const num WORK_WEEK = 40
      if hours <= WORK_WEEK then
         gross = hours * rate
      else
         gross = (WORK_WEEK * rate) + (hours - WORK_WEEK) * (rate * 1.5)
      endif
return gross
```

You might work in a programming environment that has a rule such as "No module will be longer than can be printed on one page" or "No module will have more than 30 lines of code." The rule maker is trying to achieve more cohesion, but this is an arbitrary way of going about it. It's possible for a two-line module to have low cohesion and—although less likely—for a 40-line module to have high cohesion. Because good, functionally cohesive modules perform only one task, they tend to be short. However, the issue is not size. If it takes 20 statements to perform one task within a module, then the module is still cohesive.

Two types of cohesion are considered inferior to functional cohesion, but still acceptable. **Sequential cohesion** takes place when a module performs operations that must be carried out in a specific order on the same data. Sequential cohesion is a slightly weaker type of cohesion than functional cohesion—even though the module might perform a variety of tasks, the tasks are linked because they use the same data, often transforming the data in a series of steps. **Communicational cohesion** occurs in modules that perform tasks that share data. The tasks are not related; only the data items are. If the tasks must be performed in order, the module is sequentially cohesive. If the tasks are not performed in any sequential order but only share the same data, the module is communicationally cohesive; this is considered a weaker form of cohesion than functional or sequential cohesion.

Modules with several other types of cohesion are considered generally inferior to modules that are functionally, sequentially, or communicationally cohesive, but there still are occasions when they can be used appropriately. **Temporal cohesion** takes place when the tasks in a module are related by time. That is, the tasks are placed together because of when they must take place—for example, at the beginning of a program. The prime examples of temporally cohesive modules you have seen are `housekeeping()` and `finishUp()` modules. **Procedural cohesion** takes place when, as with sequential cohesion, the tasks of a module are performed in sequence. However, unlike operations in sequentially cohesive methods, the tasks in procedurally cohesive methods do not share data. Main program modules are often procedurally cohesive; they consist of a series of steps that must be performed in sequence, but perform very different tasks, such as `housekeeping()`, `mainLoop()`, and `finishUp()`. A mainline logic module can also be called a **dispatcher module**, because it dispatches messages to a sequence of more cohesive modules. Unless you are examining your main module, if you sense that a module you have written has only procedural cohesion (that is, it consists of a series of steps that use unrelated data), you probably want to turn it into a dispatcher module. You accomplish this by changing the module so that, instead of performing many different types of tasks, it calls other modules in which the diverse tasks take place. Each of the new modules can be functionally, sequentially, or communicationally cohesive. **Logical cohesion** takes place when a member module performs one or more tasks depending on

a decision, whether the decision is in the form of a `case` structure or a series of `if` statements. The actions performed might go together logically (that is, perform the same type of action), but they don't work on the same data. Like a module that has procedural cohesion, a module that has only logical cohesion should probably be turned into a dispatcher.

One type of cohesion is generally considered to be inferior. **Coincidental cohesion**, as the name implies, is based on coincidence—that is, the operations in a module just happen to have been placed together. Obviously, this is the weakest form of cohesion and is not desirable. However, if you modify programs written by others, you might see examples of coincidental cohesion. Perhaps the program designer did not plan well, or perhaps an originally well-designed program was modified to reduce the number of modules, and now a number of unrelated statements are grouped in a single module.

TIP Coincidental cohesion is almost an oxymoron—cohesion that is simply coincidental is really not cohesion at all.

Most programmers do not think about the names of these cohesion types on a day-to-day basis. In other words, they do not tend to say, "My, this program is temporally cohesive." Rather, they develop a "feel" for what types of tasks rightfully belong together, and for which subsets of tasks should be diverted to their own modules.

Additionally, there is a time and a place for shortcuts. If you need a result from spreadsheet data in a hurry, you can type two values and take a sum rather than creating a formula with proper cell references. If a memo must go out in five minutes, you don't have to change fonts or add clip art with your word processor. Similarly, if you need a quick programming result, you might very well use cryptic variable names, tight coupling, and coincidental cohesion. When you create a professional application, however, you should keep professional guidelines in mind.

CHAPTER SUMMARY

- A procedural program consists of a series of steps or procedures that take place one after the other. Breaking programs into reasonable units called modules, subroutines, functions, or methods provides abstraction, allows multiple programmers to work on a problem, allows you to reuse your work, and allows you to identify structures more easily. By using local rather than global variables, you can take advantage of encapsulation, creating modules without knowing the data names used by other programmers.
- When multiple modules need access to the same variable value, you can pass a variable to the module. The passed variable is called a parameter and usually is named within the module header.
- You can pass multiple values to a module. When you do so, you must observe the order and data types of the arguments.
- Just as you can pass a value into a module, you can pass back a value from a called module to a calling module.
- Many programming languages provide built-in methods, which are preprogrammed modules you can use to perform common tasks.
- When designing modules to use within larger programs, some programmers find it helpful to use an IPO chart, which identifies and categorizes each item needed within the module as pertaining to input, processing, or output.
- The concept of passing variables to modules allows programmers to create variable names locally in a module without changing the value of similarly named variables in other modules. Passing values to a module helps facilitate encapsulation; you need to understand only the interface to the procedure. In addition, passing variables helps to make modules reusable and improves their reliability.
- When writing modules, you should strive to achieve loose coupling and high cohesion.

KEY TERMS

A **procedural program** consists of a series of steps or procedures that take place one after another.

Modularization is the process of breaking down programs into reasonable units called modules, subroutines, functions, or methods.

Abstraction is the process of ignoring minor details, making it easier to see the "big picture."

A **global variable** is one that is available to every module in a program.

A **local variable** is one whose name and value are known only to its own module.

A local variable is **in scope**—that is, existing and usable—from the moment it is declared until it ceases to exist.

A variable that is **out of scope** has ceased to exist.

Encapsulation means that program components are bundled together.

Information hiding, or **data hiding**, means that the data or variables you use are completely contained within—and accessible only to—the module in which they are declared.

Passing a value means that you are sending a copy of data in one module of a program to another module for use.

A **module header** is the introductory title statement of a module.

An **argument** is the expression in the comma-separated list in a function call.

A **parameter** is an object or reference that is declared in a function prototype (declaration) or definition (header).

A **parameter list** is the series of parameters, or passed values, that appears in a module header.

A module might **return a value** to a module that calls it, passing back a copy of the value.

A **method's type** or **method's return type** is the data type of the value it returns.

A method that returns no value is a **void** method. The word "void" means "empty" or "nothing."

Unreachable or **dead code** is any set of program statements that will never execute—for example, those statements within a module that follow the `return` statement.

Built-in methods, or **built-in functions**, are prewritten modules that perform frequently needed tasks.

A method's **signature** includes its name and parameter list. In some languages, a signature, along with the return type (and other punctuation), is also called a **prototype**.

A **black box** is a device you can use without understanding its internal processes.

A number's **absolute value** is the positive value of the number.

An **IPO chart** is a tool that identifies and categorizes each item needed within a module as pertaining to input, processing, or output.

Reliability is a feature of modules or programs that have been tested and proven to work correctly.

Coupling is a measure of the strength of the connection between two program modules.

Tight coupling occurs when modules excessively depend on each other; it makes programs more prone to errors.

Loose coupling occurs when modules do not depend on others.

Data coupling is the loosest type of coupling; therefore, it is the most desirable. Data coupling is also known as **simple data coupling** or **normal coupling**. Data coupling occurs when modules share a data item by passing parameters.

Data-structured coupling is similar to data coupling, but an entire record is passed from one module to another.

Control coupling occurs when a main program (or other module) passes an argument to a module, controlling the module's actions or telling it what to do.

External coupling and **common coupling** occur, respectively, when two or more modules access the same global variable or record.

Pathological coupling occurs when two or more modules change one another's data.

Cohesion is a measure of how the internal statements of a module or subroutine serve to accomplish the module's purposes.

Functional cohesion occurs when all operations in a module contribute to the performance of only one task. Functional cohesion is the highest level of cohesion; you should strive for it in all methods you write.

Sequential cohesion takes place when a module performs operations that must be carried out in a specific order on the same data.

Communicational cohesion occurs in modules that perform tasks that share data. The tasks are not related, just the data items.

Temporal cohesion takes place when the tasks in a module are related by time.

Procedural cohesion takes place when, as with sequential cohesion, the tasks of a module are performed in sequence. However, unlike operations in sequential cohesion, the tasks in procedural cohesion do not share data.

A **dispatcher module** dispatches messages to a sequence of more cohesive modules.

Logical cohesion takes place when a member module performs one or more tasks depending on a decision. The actions performed might go together logically (that is, perform the same type of action), but they don't work on the same data.

Coincidental cohesion is based on coincidence—that is, the operations in a module just happen to have been placed together.

REVIEW QUESTIONS

1. **Which of the following is not a synonym for "module"?**
   a. procedure
   b. function
   c. method
   d. program

2. **Which of the following is not a benefit of modularization?**
   a. Modularization provides abstraction.
   b. Modularization allows multiple programmers to work on a problem.
   c. Modularization ensures the elimination of logical errors.
   d. Modularization allows programmers to reuse their work more easily.

3. **A variable that is available to every module in a program is a(n) _____ variable.**
   a. global
   b. international
   c. local
   d. neighborhood

4. **A local variable is usable when it is _____.**
   a. in view
   b. in scope
   c. in range
   d. limitless

5. **When variables located in a module are hidden from other modules, the program is using _____.**
   a. encapsulation
   b. secret coding
   c. condensation
   d. functional composition

6. **When you pass a value to a module, within the module, the passed variable _____ as the original.**
   a. has the same memory address
   b. has the same name
   c. has the same value
   d. all of the above

7. **The introductory title statement of a module is its _____.**
   a. banner
   b. label
   c. header
   d. caption

8. **A variable passed to a module is a(n) _____.**
   a. argument
   b. quarrel
   c. claim
   d. return type

9. **The series of parameters received by a module is the module's _____.**
   a. return type
   b. directory
   c. sequence
   d. parameter list

10. **Assume you have written a module with the following header: `myModule(char name, num age)`. Which of the following module calls is correct?**
    a. `myModule("Joan", 32)`
    b. `myModule(19, "Sean")`
    c. Both of these are correct.
    d. Neither a nor b is correct.

11. Assume you have written a module with the following header: `anotherModule(char name, num age, num salary)`. Which of the following module calls is correct?

a. `anotherModule("Jerry", 32)`
b. `anotherModule("Elaine", 39, 20000)`
c. both of the above
d. neither a nor b

12. A module that sends a value back to a module that calls it _____ the value.

a. exports
b. imports
c. returns
d. delivers

13. The return type of a method is also called the _____.

a. exact value
b. method's type
c. secondary type
d. parameter list

14. Built-in functions are _____.

a. methods without a return type
b. methods without parameter lists
c. prewritten, automatically available methods
d. customized methods used by a particular type of business or industry

15. To use a method written by another programmer, you must know all of the following except _____.

a. the name of the method
b. the types of arguments passed to the method
c. the number of statements within the method
d. the return type of the method

16. To programmers, a black box is a module that _____.

a. you use without knowing the arguments or return type
b. is built into a programming language
c. you use without knowing how it works internally
d. records instructions as they are executed

17. A tool that identifies input, processing, and output steps for a program or module is a(n) _____.

a. IPO chart
b. hierarchy chart
c. flowchart
d. debugger

18. Programmers should strive to _____.

a. increase coupling
b. increase cohesion
c. both of the above
d. neither a nor b

19. When several modules have access to the same variables and the ability to alter them, the modules are _____ coupled.

a. loosely
b. tightly
c. pathologically
d. morbidly

20. The most desirable level of cohesion is _____ cohesion.

a. coincidental
b. temporal
c. procedural
d. functional

FIND THE BUGS

The following pseudocode contains one or more bugs that you must find and correct.

1. The main program calls a method that prompts the user for an initial and returns it to the main module.

```
start
     declare variables
       char usersInitial
       askUserForInitial()
     print "Your initial is ", usersInitial
stop

char askUserForInitial()
    declare variables
       char letter
    print "Please type your initial"
    read letter
return usersInitial
```

2. **The main program passes a user's entry to a function that displays a multiplication table using the entry multiplied by every value from 2 through 10.**

```
start
   declare variables
      num usersChoice
   print "Enter a number"
   read choice
   multiplicationTable(usersChoice)
stop

multiplicationTable(num value)
   declare variables
      const num LOW = 2
      const num HIGH = 10
      num x;
   while num <= HIGH
     answer = choice * x
     print value, " times ", x, " is ", answer
     num = num + 1
   endwhile
return
```

3. **The main program prompts a user for a Social Security number, name, and income, and then computes tax. The tax calculation and the printing of the taxpayer's report are in separate modules. Tax rates are based on the following table:**

Income	Percent tax rate
0–14,999	0
15,000–21,999	15
22,000–29,999	18
30,000–44,999	22
45,000–59,999	28
60,000 and up	30

```
start
   declare variables
         num socSecNum
         char name
         num income
         num taxDue
   print "Enter socSecNum"
```

```
   read socSecNum
   while socSecNum not = 0
      print "Enter name"
      read name
      print "Enter annual income"
      read name
      taxCalculations()
      print taxReport(socSecNum, taxDue)
      print "Enter socSecNum"
      read socSecNum
   endwhile
stop

num taxCalculations(num income)
   num tax
   const num NUMBRKTS = 6
   num brackets[2] = 0, 15000, 22000, 30000,
       45000, 60000
   num rates[NUMBRKTS - 1] = 0.0, 0.15, 0.18, 0.22, 0.28, 0.30
   num count = NUMBRKTS
   while count >= 0
     if income = brackets[count]
        count = count - 1
     endif
   endwhile
   tax = income * rates[count]
return tax

taxReport(num socSecNum, num name, num taxDue)
   print socSecNum, name, taxDue
return
```

EXERCISES

1. **Create an IPO chart for each of the following modules:**
   a. The module that produces your paycheck
   b. The module that calculates your semester tuition bill
   c. The module that calculates your monthly car payment

2. **Plan the logic for a program that contains two modules. The first module prompts the user for a grade on an exam. Pass the grade to a second module that prints "Pass" if the grade is 60 percent or higher and "Fail" if it is not.**

3. **Complete the following tasks:**
   a. Plan the logic for a program that contains two modules. The first module asks for your employee ID number. Pass the ID number to a second module that prints a message indicating whether the ID number is valid or invalid. A valid employee ID number falls between 100 and 799, inclusive.
   b. Plan the logic for a program that contains two modules. The first module asks for your employee ID number. Pass the ID number to a second module that returns a code to the first module indicating whether the ID number is valid or invalid. A valid employee ID number falls between 100 and 799, inclusive. The first module prints an appropriate message.

4. **Complete the following tasks:**
   a. Plan the logic for an insurance company's premium-determining program that contains three modules. The first module prompts the user for the type of policy needed—health or auto. Pass the user's response to the second module, where the premium is set—$250 for a health policy or $175 for an auto policy. Pass the premium amount to the last module for printing.
   b. Modify Exercise 4a so that the second module calls one of two additional modules—one that determines the health premium or one that determines the auto premium. The health insurance module asks users whether they smoke; the premium is $250 for smokers and $190 for nonsmokers. The auto insurance module asks users to enter the number of traffic tickets they have received in the last three years. The premium is $175 for those with three or more tickets, $140 for those with one or two tickets, and $95 for those with no tickets. Each of these two modules returns the premium amount to the second module, which sends the premium amount to the printing module.

5. **Plan the logic for a program that reads inventory records from a file that contains the following fields: item number, item name, quantity in stock, and price each. In turn, pass each item number, quantity, and price to a module named `printDiscountInfo()`.**

   This is a prewritten module that calculates a new price for each item, taking one of 10 discount percentages, depending on the quantity of the item remaining in stock. The module's signature is `printDiscountInfo(num itemNo, num quantityInStock, num priceEach)`. You do not need to write this module—just call it to display each item's discount amount.

6. **Plan the logic for a program that prompts a user for a customer number, stock number of item being ordered, and quantity ordered.**

   If the customer number is not between 1000 and 7999, inclusive, continue to prompt until a valid customer number is entered. If the stock number of the item is not between 201 and 850, inclusive, continue to prompt for the stock number. Pass the stock number to a method that a colleague at your organization has written; the module's signature is `num getPrice(num stockNumber)`. The `getPrice()` module accepts a stock number and returns the price of the item. Multiply the price by the quantity ordered, giving the total due. Pass the customer number and the calculated price to an already written method whose signature is `printBill(num custNum, num price)`. This method determines the customer's name and address by using the customer ID number, and calculates the final bill, including tax, using the price. Organize your program using as many modules as you feel are appropriate. You do not need to write the `getPrice()` and `printBill()` modules—assume they have already been written.

7. **Plan the logic for a program that prompts a user for numeric values and continues to read them until the user enters 999.**

   Display the numeric average of the values; then, display each number and a statement of how far away it is from the average. For example, if the user enters 5, 6, and 7, the output is:

```
The average is 6
5 is 1 away from the average
6 is 0 away from the average
7 is 1 away from the average
```

   Assume that you can use a built-in absolute value function whose signature is `num abs(num value)`. The function accepts a numeric value and returns its absolute value.

8. **The Information Services Department at the Springfield Library has created modules with the following signatures:**

Signature	Description
`num getNumber(num high, num low)`	Prompts the user for a number. Continues to prompt until the number falls between designated high and low limits. Returns a valid number.
`char getCharacter()`	Prompts the user for a character string and returns the entered string.
`num lookUpISBN(char title)`	Accepts the title of a book and returns the ISBN. Returns a 0 if the book cannot be found.
`char lookUpTitle(num isbn)`	Accepts the ISBN of a book and returns a title. Returns a space character if the book cannot be found.
`char isBookAvailable(num isbn)`	Accepts an ISBN, searches the library database, and returns a "Y" or "N" indicating whether the book is currently available.

   a. Design an interactive program that does the following, using the prewritten modules wherever they are appropriate.

   - ☐ Prompt the user for and read a library card number, which must be between 1000 and 9999.
   - ☐ Prompt the user for and read a search option—1 to search for a book by ISBN, 2 to search for a book by title, and 3 to quit. Allow no other values to be entered.
   - ☐ While the user does not enter 3, prompt for an ISBN or title, based on the user's previous selection. If the user enters an ISBN, get and display the book's title and ask for confirmation—a "Y" or "N" as to whether the title is correct.

- If the user has entered a valid ISBN, or a title that matches a valid ISBN, check whether the book is available, and display an appropriate message for the user.
- The user can continue to search for books until he or she enters 3 as the search option.

b. Develop the logic for each of the modules in Exercise 8a.

DETECTIVE WORK

1. **In some programming languages, beginning programmers traditionally write their first module to perform what specific task?**
2. **What is beta testing?**

UP FOR DISCUSSION

1. **Modularized furniture comes with sections that can be assembled in a variety of configurations. What other everyday items are modularized?**
2. **As a professional programmer, you might never write an entire program. Instead, you might be asked to write specific modules that are destined to become part of a larger system. Is this appealing to you?**

13 OBJECT-ORIENTED PROGRAMMING

After studying Chapter 13, you should be able to:

- Understand the basic principles of object-oriented programming
- Define classes and create class diagrams
- Understand public and private access
- Instantiate and use objects
- Understand inheritance
- Understand polymorphism
- Understand protected access
- Understand the role of the `this` reference
- Use constructors and destructors
- Describe GUI classes as an example of built-in classes
- Understand the advantages of object-oriented programming

AN OVERVIEW OF OBJECT-ORIENTED PROGRAMMING

Object-oriented programming (OOP) is a style of programming that focuses on an application's data and the methods you need to manipulate that data. Object-oriented programming uses all of the concepts you are familiar with from modular procedural programming, such as variables, modules, and passing values to modules. Modules in object-oriented programs continue to use sequence, selection, and looping structures and make use of arrays. However, object-oriented programming adds several new concepts to programming and involves a different way of thinking. A considerable amount of new vocabulary is involved as well. First, you will read about object-oriented programming concepts in general; then you will learn the specific terminology.

Objects both in the real world and in object-oriented programming are made up of attributes and methods. **Attributes** are the characteristics that define an object as part of a class. For example, some of your automobile's attributes are its make, model, year, and purchase price. Other attributes include whether the automobile is currently running, its gear, its speed, and whether it is dirty. All automobiles possess the same attributes, but not, of course, the same values for those attributes. Similarly, your dog has the attributes of its breed, name, age, and whether his or her shots are current.

TIP

In grammar, a noun is similar to an object in object-oriented programs, and the values of an object's attributes are like adjectives—they describe the characteristics of the objects. Programmers also call the values of an object's attributes the **properties** of the object. The **state of an object** is the collective value of all its attributes at any point in time. Later in this chapter, you will learn about the methods in a class, which are equivalent to verbs.

In object-oriented terminology, a **class** is a term that describes a group or collection of objects with common properties. An **instance** of a class is an existing object of a class. Therefore, your `red Chevrolet Automobile` with the dent can be considered an instance of the class that is made up of all automobiles, and your `Golden Retriever Dog` named Ginger is an instance of the class that is made up of all dogs. Thinking of items as instances of a class allows you to apply your general knowledge of the class to individual members of the class. A particular instance of an object takes its attributes from the general category. If your friend purchases an `Automobile`, you know it has a model name, and if your friend gets a `Dog`, you know the dog has a breed. You might not know the current state of your friend's `Automobile`, such as its current speed, or the status of her `Dog`'s shots, but you do know what attributes exist for the `Automobile` and `Dog` classes, and this allows you to imagine these objects reasonably well before you see them. When you visit your friend and see the `Automobile` or `Dog` for the first time, you probably will recognize it as the new acquisition. As another example, when you use a new application on your computer, you expect each component to have specific, consistent attributes, such as a button being clickable or a window being closeable, because each component gains these attributes as a member of the general class of GUI (graphical user interface) components.

When you approach a new programming assignment using object-oriented programming techniques:

- You analyze the objects you are working with and the tasks that need to be performed with, and on, those objects. Then you design classes that encapsulate the attributes and functionality of those objects.

- You pass messages to objects, requesting the objects to take action. The same message works differently (and appropriately) when applied to different objects. This means that, if well-designed, you can use a single module or procedure name to work appropriately with different types of data it receives.
- Objects can share or inherit traits of objects that have already been created, reducing the time it takes to create new objects.
- Encapsulation and information hiding are emphasized.

OBJECTS AND CLASSES

The real world is full of objects. Consider a door. A door needs to be opened and closed. You open a door with an easy-to-use interface known as a doorknob. Object-oriented programmers would say you are "passing a message" to the door when you "tell" it to open by turning its knob. The same message (turning a knob) has a different result when applied to your radio than when applied to a door. The procedure you use to open something—call it the "open" procedure—works differently on a door to a room than it does on a desk drawer, a bank account, a computer file, or your eyes, but, even though these procedures operate differently using the different objects, you can call all of these procedures "open." In object-oriented programming, procedures are called **methods**.

With object-oriented programming, you focus on the objects that will be manipulated by the program—for example, a customer invoice, a loan application, or a menu from which the user will select an option. You define the characteristics of those objects and the methods each of the objects will use; you also define the information that must be passed to those methods.

METHODS

You can create multiple methods with the same name, which will act differently and appropriately when used with different types of objects. This concept is **polymorphism**, which literally means "many forms"—a method can have many configurations that each work appropriately based on the context in which they are used. In most object-oriented programming languages, method names are followed by a set of parentheses; this helps you distinguish method names from variable names. You have been using this style throughout this book. For example, a method named `display()` might be usable to display the characteristics of an `Automobile`, `Dog`, or `CustomerInvoice`. Because you can use the same method name, `display()`, to describe the different actions needed to display these diverse objects, you can write statements in object-oriented programming languages that are more like English; you can use the same method name to describe the same type of action, no matter what type of object is being acted upon. Using the method name `display()` is easier than remembering `displayAutomobile()`, `displayDog()`, and so on. In English, you understand the difference between "running a race," "running a business," and "running a computer program." Object-oriented languages understand verbs in context, just as people do. In object-oriented programs, when you create multiple methods with the same name but different argument lists, you **overload the method**.

TIP

Purists find a subtle difference between overloading and polymorphism. Some reserve the term "polymorphism" (or **pure polymorphism**) for situations in which one function body is used with a variety of arguments. For example, a single function that can be used with any type of object is polymorphic. The term "overloading" is applied to situations in which you define multiple functions with a single name (for example, three functions, all named `display()`, that display a number, an employee, and a student, respectively. Certainly, the two terms are related; both refer to the ability to use a single name to communicate multiple meanings. For now, think of overloading as a primitive type of polymorphism.

As another example of the advantages to using one name for a variety of objects, consider a screen you might design for a user to enter data into an application you are writing. Suppose the screen contains a variety of objects—some forms, buttons, scroll bars, dialog boxes, and so on. Suppose also that you decide to make all the objects blue. Instead of having to memorize the names that these objects use to change color—perhaps `changeFormColor()`, `changeButtonColor()`, and so on—your job would be easier if the creators of all those objects had developed a `setColor()` method that works appropriately and in the same way with each type of object.

INHERITANCE

Another important concept in object-oriented programming is **inheritance**, which is the process of acquiring the traits of one's predecessors. In the real world, a new door with a stained glass window inherits most of its traits from a standard door. It has the same purpose, it opens and closes in the same way, and it has the same knob and hinges. The door with the stained glass window simply has one additional trait—its window. Even if you have never seen a door with a stained glass window, when you encounter one you know what it is and how to use it because you understand the characteristics of all doors. Similarly, you understand the traits of a `Convertible` because it inherits almost all of its features from an `Automobile` and you understand most of the characteristics of a `Poodle` if you know it is a `Dog`. With object-oriented programming, once you create an object, you can develop new objects that possess all the traits of the original object plus any new traits you desire. If you develop a `customerBill` object, there is no need to develop an `overdueCustomerBill` object from scratch. You can create the new type of object to contain all the characteristics of the already developed object, and simply add necessary new characteristics. This not only reduces the work involved in creating new objects, it makes them easier to understand because they possess most of the characteristics of already developed objects.

ENCAPSULATION

Real-world objects often employ encapsulation and information hiding. **Encapsulation** is the process of combining all of an object's attributes and methods into a single package. **Information hiding** is the concept that other classes should not alter an object's attributes—only the methods of an object's own class should have that privilege. Outside classes should only be allowed to make a request that an attribute be altered; then it is up to the class methods to determine whether the request is appropriate. When using a door, you usually are unconcerned with the latch or hinge construction features, and you don't have access to the interior workings of the knob or know what color of paint might have been used on the inside of the door panel. You care only about the functionality and the **interface**, the user-friendly boundary between the user and the internal mechanisms of the device. Similarly, the detailed workings of objects you create within object-oriented programs can be hidden from outside programs and modules if you want

them to be. When the details are hidden, programmers can focus on the functionality and the interface, as people do with real-life objects.

TIP Information hiding is also called **data hiding**.

In summary, to understand object-oriented programming, you must consider five concepts that are integral components of all object-oriented programming languages:

- Classes
- Objects
- Inheritance
- Polymorphism
- Encapsulation

DEFINING CLASSES AND CREATING CLASS DIAGRAMS

A class is a category of things; an object is a specific instance of a class. A **class definition** is a set of program statements that tell you the characteristics of the class's objects and the methods that can be applied to its objects.

For example, `Dish` is a class. When you know an object is a `Dish`, you know it can be held in your hand and you can eat from it. The specific object `myBlueDinnerPlateWithTheChipOnTheEdge` is an instance of the `Dish` class; so is `auntJanesAntiquePunchBowl` and `myCatsFoodBowl`. You can use the phrase **is-a** to test whether an object is an instance of a class. Because you can say, "My plate *is a* `Dish`," you can discern the object-class relationship. On the other hand, you cannot say, "A Dish is my plate," because many dishes are *not* my plate. Each button on the toolbar of a word-processing program is an instance of a `Button` class. In a program used to manage a hotel, `thePentHouse`, `theBridalSuite`, `room201`, and `room202` all are instances of `HotelRoom`. Although each room is a different object, as members of the same class they share characteristics—each has a maximum number of occupants, a square footage, and a price.

TIP In object-oriented languages such as C++ and Java, by convention, most class names are written with the initial letter of each new word in uppercase, as in *Dish* or *HotelRoom*. Specific objects' names usually are written in lowercase or using camel casing.

TIP Object-oriented programmers also use the term "is-a" to describe class-to-class inheritance relationships.

A class can contain three parts:

- Every class has a name.
- Most classes contain data, although this is not required.
- Most classes contain methods, although this is not required.

For example, you can create a class named `Employee`. Each `Employee` object will represent one employee who works for an organization. Data members, or attributes of the `Employee` class, include **fields** such as `idNum`, `lastName`, `hourlyWage`, and `weeklyPay`.

The methods of a class include all actions you want to perform with the class. Appropriate methods for an `Employee` class might include `setFieldValues()`, `calculateWeeklyPay()`, and `printFieldValues()`. The job of `setFieldValues()` is to provide values for an `Employee`'s data fields, the purpose of `calculateWeeklyPay()` is to multiply the `Employee`'s `hourlyWage` by 40 to calculate a weekly salary, and the purpose of `printFieldValues()` is to print the values in the `Employee`'s data fields. With object-oriented languages, you think of the class name, data, and methods as a single encapsulated unit.

Programmers often use a class diagram to illustrate class features. A **class diagram** consists of a rectangle divided into three sections, as shown in Figure 13-1. The top section contains the name of the class, the middle section contains the names and data types of the attributes, and the bottom section contains the methods. This generic class diagram shows two attributes and three methods, but for a given class there might be any number of either, including none. Figure 13-2 shows the class diagram for the `Employee` class.

FIGURE 13-1: GENERIC CLASS DIAGRAM

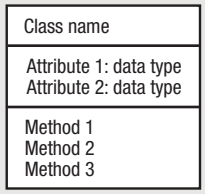
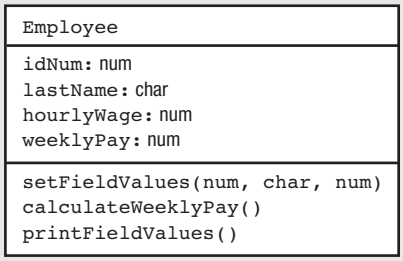


FIGURE 13-2: `Employee` CLASS DIAGRAM



TIP Later in this chapter, you will learn to add access specifiers to your class diagrams.

TIP Some class designers prefer to define any field that never will be used in a computation as a non-numeric data type. For example, in the `Employee` class diagram in Figure 13-2, you might prefer to define `Employee idNum` as a field that can contain characters.

Figures 13-1 and 13-2 both show that a class diagram is intended to be only an overview of class attributes and methods. A class diagram shows *what* data items and methods the class will use, not the details of the methods nor *when* they will be used. It is a design tool that helps you see the big picture in terms of class requirements. Later, when you plan the code that actually creates the class, you include method implementation details; at that point, you might draw a flowchart or write pseudocode for each method, as you have been doing throughout this book.

In Figure 13-2 in the `setFieldValues()` method, the class diagram indicates that three items will be sent into the method—a numeric data item, a character data item, and another numeric data item. When you view the class diagram, you don't know how these will be used, but when you write the class definition, their use is defined. For example, Figure 13-3 shows some pseudocode you can use to show the details for the methods contained within the `Employee` class.

FIGURE 13-3: `Employee` CLASS PSEUDOCODE WITHOUT ACCESS SPECIFIERS

```
class Employee
      num idNum
      char lastName
      num hourlyWage
      num weeklyPay

      setFieldValues(num id, char last, num rate)
         const num MAX_RATE = 25.00
         idNum = id
         lastName = last
         if rate <= MAX_RATE then
            hourlyWage = rate
         else
            hourlyWage = MAX_RATE
         endif
      return

      calculateWeeklyPay()
         const num WORK_WEEK = 40
         weeklyPay = hourlyWage * WORK_WEEK
      return

      printFieldValues()
         print idNum, lastName, hourlyWage, weeklyPay
      return
endClass
```

In Figure 13-3, the `Employee` class attributes or fields are identified with a data type and a field name. In addition to listing the data fields required, Figure 13-3 shows the complete methods for the `Employee` class. The purpose of two of the methods is to communicate with the outside world—the `setFieldValues()` method takes values that come in from the outside and assigns them to the `Employee`'s attributes, and the `printFieldValues()` method displays the `Employee`'s attributes on an output device. The purpose of the `calculateWeeklyPay()` module is to multiply `hourlyWage` by 40. Each method can contain elements with which you are familiar from non-object-oriented programs. For example, the `setFieldValues()` method declares a constant and makes a decision on how to set the `Employee`'s pay rate based on the value of the constant.

UNDERSTANDING PUBLIC AND PRIVATE ACCESS

When you buy a product with a warranty, one of the conditions of the warranty is usually that the manufacturer must perform all repair work. For example, if your computer has a warranty and something goes wrong with its operation, you cannot open the CPU yourself, remove and replace parts, and then expect to get your money back for a device that does not work properly. Instead, when something goes wrong with your computer, you must take the device to the manufacturer. The manufacturer guarantees that your machine will work properly only if the manufacturer can control how the internal mechanisms of the machine are modified.

Similarly, in object-oriented design, usually you do not want any outside programs or methods to alter your class's data fields unless you have control over the process. For example, you might design a class that performs a complicated statistical analysis on some data and stores the result. You would not want others to be able to alter your carefully crafted product. As another example, you might design a class from which others can create an innovative and useful GUI screen object. In this case, you would not want others altering the dimensions of your artistic design. In the `Employee` class in Figure 13-3, you do not want `hourlyWage` to be initialized to more than $25.00.

To prevent outsiders from changing your data fields in ways you do not endorse, you force other programs and methods to use a method that is part of the class, such as `setFieldValues()`, to alter data. (You have already learned that the principle of keeping data private and inaccessible to outside classes is called information or data hiding.) Object-oriented programmers usually specify that their data fields will have **private access**—that is, the data cannot be accessed by any method that is not part of the class. The methods themselves, like `setFieldValues()`, allow **public access**, which means that other programs and methods may use the methods. An **access specifier** (or **access modifier**) is an adjective that defines the type of access outside classes will have to the attribute or method (`public` or `private`). Figure 13-4 shows a complete `Employee` class to which shaded access specifiers have been added to describe each attribute and method.

TIP Classes can contain public data and private methods, but it is common for most data to be private and most methods to be public.

TIP In some object-oriented programming languages, such as C++, you can label a set of data fields or methods as public or private using the access specifier name just once. In other languages, such as Java, you use the specifier `public` or `private` with each field or method. For clarity, this book will label each field and method as public or private.

TIP Many object-oriented languages provide more specific access specifiers than just `public` and `private`. Later in this chapter, you learn about the `protected` access specifier.

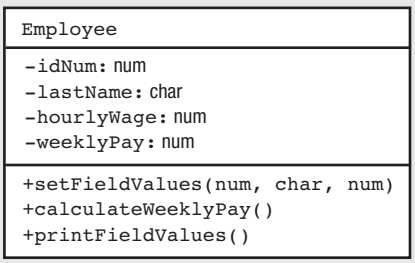
TIP Notice that the last line in the `Employee` class in both Figures 13-3 and 13-4 is an `endClass` statement. Similar to the way this book has used `endif` and `endwhile` to mark the end of `if` and `while` blocks of code, this book will use `endClass` to indicate the end of a class definition.

FIGURE 13-4: `Employee` CLASS USING `private` AND `public` ACCESS SPECIFIERS

```
class Employee
      private num idNum
      private char lastName
      private num hourlyWage
      private num weeklyPay

      public setFieldValues(num id, char last, num rate)
         const num MAX_RATE = 25.00
         idNum = id
         lastName = last
         if rate <= MAX_RATE then
            hourlyWage = rate
         else
            hourlyWage = MAX_RATE
         endif
      return

      public calculateWeeklyPay()
         const num WORK_WEEK = 40
         weeklyPay = hourlyWage * WORK_WEEK
      return

      public printFieldValues()
         print idNum, lastName, hourlyWage, weeklyPay
      return
endClass
```

When creating a class diagram, many programmers like to specify whether each data item and method in a class is public or private. Figure 13-5 shows the conventions that are typically used. A minus sign (–) precedes items that are private; a plus sign (+) precedes those that are public.

FIGURE 13-5: `Employee` CLASS DIAGRAM WITH `public` AND `private` ACCESS SPECIFIERS



TIP When you learn more about inheritance later in this chapter, you will learn about the `protected` access specifier. You use an octothorpe, also called a pound sign or number sign (#), to indicate protected access.

INSTANTIATING AND USING OBJECTS

When you write an object-oriented program, you create objects that are members of a class. You **instantiate** (or create) a class object (or instance) with a statement that includes the type of object and an identifying name. For example, the following statement creates an `Employee` object named `myAssistant`:

```
Employee myAssistant
```

TIP

In some object-oriented programming languages, you need to add more to the declaration statement to actually create an `Employee` object. For example, in Java, you would write:

```
Employee myAssistant = new Employee();
```

This syntax, using the class name followed by parentheses, will be explained later in this chapter when you learn about constructor methods.

When you declare `myAssistant` as an `Employee` object, the `myAssistant` object contains all of the data fields or attributes defined in the class, and has access to all the class's methods. You can use any of an `Employee`'s methods—`setFieldValues()`, `calculateWeeklyPay()`, and `printFieldValues()`—with the `myAssistant` object. The usual syntax is to provide an object name, a dot (period), and a method name. For example, you can write a program that contains statements such as the ones shown in the pseudocode in Figure 13-6.

FIGURE 13-6: PROGRAM THAT USES AN `Employee` OBJECT

```
start
   declare variables
      Employee myAssistant
   myAssistant.setFieldValues(123, "Tyler", 12.50)
   myAssistant.calculateWeeklyPay()
   myAssistant.printFieldValues()
stop
```

TIP

Besides referring to `Employee` as a class, many programmers would refer to it as a **user-defined type**; a more accurate term is **programmer-defined type**. Programming languages in which you can create your own data types are **extensible**, meaning extendable. A class is also an **abstract data type** (ADT)—a type whose internal form is hidden behind a set of methods you use to access the data.

The following statements contain method calls:

```
myAssistant.setFieldValues(123, "Tyler", 12.50)
myAssistant.calculateWeeklyPay()
myAssistant.printFieldValues()
```

These calls are similar to module or method calls you have seen throughout this book, but in this case the methods themselves are part of the `Employee` class, which is why an `Employee` object can use them. You can think of the

Employee object myAssistant as "owning" or "driving" those methods; when those methods refer to data fields, they refer to the myAssistant object's data fields and not the data fields of any other Employee.

When you write the program in Figure 13-6, you do not need to know what statements are written within the methods of the Employee class, although you could make an educated guess based on the methods' names. Before you could execute the application in Figure 13-6, you would have to write appropriate statements within the Employee class's methods, but if another programmer has already written the methods, then you can use the application in Figure 13-6 without knowing the details contained in the methods. The ability to use methods without knowing the details of their contents is a feature of encapsulation.

TIP Programmers like to say the method details are contained in a black box—a device you can use without knowing how its contents operate. You first learned the term "black box" in Chapter 10.

A program or method that uses a class object is a **client of the class**. Many programmers write only client programs, never creating classes themselves, but using only classes that others have created. In the client program in Figure 13-6, the focus is on the object—the Employee named myAssistant—and the methods you can use with that object. This is the essence of object-oriented programming.

TIP Of course, the program in Figure 13-6 is very short. In a more useful real-life program, you might read employee data from a data file before assigning it to the object's fields, and you might create hundreds of objects in turn.

TIP In older object-oriented programming languages, simple numbers and characters are said to be **primitive data types**; this distinguishes them from objects that are class types. In the newest programming languages, such as C#, every item you name, even one that is a num or char type, really is an object that is an instance of a class that contains both data and methods.

TIP When you instantiate objects, the data fields of each are stored at separate memory locations. However, all members of the same class share one copy of the class methods.

UNDERSTANDING INHERITANCE

The concept of class is useful because of its reusability; you can create new classes that are descendents of existing classes. The **descendent classes** (or **child classes**) can inherit all of the attributes of the **original class** (or **parent class**), or the descendent class can override those attributes that are inappropriate. For example, if you have created a class named BankLoan, it probably contains fields such as the account number, the name, address, and phone number of the loan recipient, the amount of the loan, and the interest rate. The class probably also contains methods that set, display, and manipulate these values. When you need a more specific class for a CarLoan that contains data about the car, or HomeImprovementLoan that contains data about the home improvement, you do not want to have to start from scratch. It makes sense to inherit existing features from the BankLoan class, adding only the new features that the more specific loans require.

TIP You can call a parent class a **base class** or **superclass**. You can refer to a child class as a **derived class** or **subclass**.

As another example, to accommodate part-time workers in your personnel programs, you might want to create a child class from the `Employee` class. Part-time workers need an ID, name, and hourly wage, just as regular employees do, but the regular `Employee` pay calculation assumes a 40-hour workweek. You might want to create a `PartTimeEmployee` class that inherits all the data fields contained in `Employee`, but adds a new one—`hoursWorked`. In addition, you want to create a modified `setFieldValues()` method that includes assigning a value to `hoursWorked`, and a new `calculateWeeklyPay()` method that operates correctly for `PartTimeEmployee` objects. This new method multiplies `hourlyWage` by `hoursWorked` instead of by 40. The `printFieldValues()` module that already exists within the `Employee` class works appropriately for both the `Employee` and the `PartTimeEmployee` classes, so there is no need to include a new version of this module within the `PartTimeEmployee` class; `PartTimeEmployee` objects can simply use their parent's existing method.

TIP You can think of a child class as being more specific than a parent class. For example, `PartTimeEmployee` is a specific type of `Employee`.

TIP A child class contains all the data fields and methods of its parent, plus any new ones you define. A parent class does not gain any child class members.

When you create a child class, you can show its relationship to the parent with a class diagram like the one for `PartTimeEmployee` in Figure 13-7. The complete `PartTimeEmployee` class appears in Figure 13-8.

FIGURE 13-7: `PartTimeEmployee` CLASS DIAGRAM

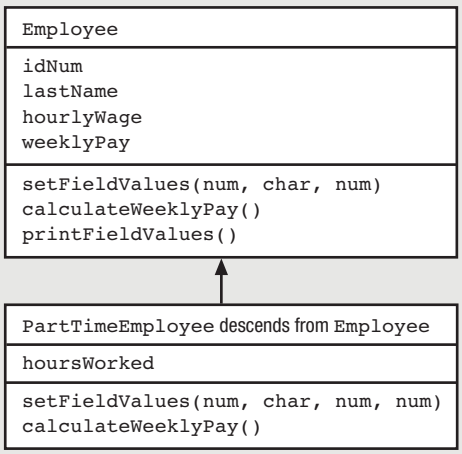


FIGURE 13-8: THE `PartTimeEmployee` CLASS

```
class PartTimeEmployee descends from Employee
   private num hoursWorked
   public void setFieldValues(num id, char last, num rate, num hours)
      Employee class version: setFieldValues(id, last, rate)
      hoursWorked = hours
   return
   public void calculateWeeklyPay()
      weeklyPay = hourlyWage * hoursWorked
   return
endClass
```

TIP The class in Figure 13-8 uses the phrase "descends from" to indicate inheritance. Each programming language uses its own syntax. For example, using Java, you would write "extends", in Visual Basic .NET you would write "inherits", and in C++ and C# you would use a colon between the class name and its parent.

The `PartTimeEmployee` class shown in Figure 13-8 contains five data fields—all the fields that `Employee` contains plus one new one, `hoursWorked`. The `PartTimeEmployee` class also contains three methods. Two of the methods, `setFieldValues()` and `calculateWeeklyPay()`, have been rewritten for the `PartTimeEmployee` child class, because they will operate differently when used with `PartTimeEmployee` than when used with `Employee`. The other method, `printFieldValues()`, is not rewritten because the parent class version is a usable version for the child class.

In Figure 13-8, the `PartTimeEmployee` class `setFieldValues()` method takes four arguments. Three are passed to the parent class `setFieldValues()` method, where they can be assigned to the class fields. Because the parent class method already provides statements that set the values of three of the class fields, the `PartTimeEmployee` class can take advantage of the fact that part of the work has been done. Being able to reuse code is an advantage of inheritance. In Figure 13-8, calling the parent class method is indicated by the phrase "Employee class version:". The actual syntax you use when writing code varies among programming languages.

The fourth argument to the `PartTimeEmployee` class `setFieldValues()` method, `hours`, is assigned to `hoursWorked` in the child class method because the parent class does not contain that field.

The `calculateWeeklyPay()` method in the `PartTimeEmployee` class uses the variable `hoursWorked` instead of the constant 40 to calculate weekly pay. The methods in the child class that have the same name and argument list as those in the parent class are said to **override**, or take precedence over, the parent class methods.

TIP A child class method overrides a parent's method when it has the same name and argument list. It overloads a parent's method just as any method is overloaded—when it has the same name as another, but a different argument list.

TIP Before the `PartTimeEmployee` child class can use the `hourlyWage` and `weeklyPay` fields, object-oriented programming languages require one additional modification to the `Employee` parent class. You will learn about this modification, making the parent class fields protected, later in this chapter.

The `PartTimeEmployee` class also contains the `printFieldValues()` method, which it inherits unchanged from its parent. You do not see a copy of the `printFieldValues()` method in the `PartTimeEmployee` class in Figure 13-8, because the phrase `descends from Employee` in the first line of the class means that all `Employee` class members automatically are included in the child class unless they have been overridden. When you write an application such as the one shown in Figure 13-9, declaring `Employee` as well as `PartTimeEmployee` objects, different `setFieldValues()` and `calculateWeeklyPay()` methods containing different statements are called for each object, but the same `printFieldValues()` method is called in each case.

FIGURE 13-9: APPLICATION THAT USES `Employee` AND `PartTimeEmployee` OBJECTS

```
start
   declare variables
      Employee myAssistant
      PartTimeEmployee myDriver
   myAssistant.setFieldValues(123, "Tyler", 12.50)
   myDriver.setFieldValues(234, "Mitchell", 15.00, 20)
   myAssistant.calculateWeeklyPay()
   myDriver.calculateWeeklyPay()
   myAssistant.printFieldValues()
   myDriver.printFieldValues()
stop
```

In the program in Figure 13-9, two objects are declared. The `myAssistant` object is a "plain" `Employee`; the `myDriver` object is a more specific `PartTimeEmployee`. The statement `myDriver.setFieldValues()` calls a different method than `myAssistant.setFieldValues()`; the two methods have the same name, but belong to different classes. The compiler knows which method to call based on the type of object, but the programmer can use one easy-to-remember method name in both cases. The method name `setFieldValues()` can be used with either type of object, and it works appropriately with either type.

In Figure 13-9, the two calls to `calculateWeeklyPay()` cause two different method executions; the compiler knows which version to use because the objects associated with the calls belong to different classes.

The final two statements before the `stop` statement in Figure 13-9 call the `printFieldValues()` method with each of the two objects. In these statements, the same method is called each time. Naturally, the `myAssistant` object uses the `printFieldValues()` method contained in the `Employee` class. The `myDriver` object also uses the `printFieldValues()` method from the `Employee` class because of the following reasoning:

- `myDriver` is a `PartTimeEmployee`.
- The `PartTimeEmployee` class does not contain its own version of the `printFieldValues()` method.

- The `PartTimeEmployee` class is a child class of `Employee`.
- The `Employee` class contains a `printFieldValues()` method that the `myDriver` object can use.

A child class will use its parent class methods unless the child class has its own version that either overrides or overloads the parent's version.

TIP A good way to determine whether a class is a parent or a child is to use the "is-a" test. A child "is an" example of its parent. For example, it is always true that a `PartTimeEmployee` "is an" `Employee`. However, it is not necessarily true that an `Employee` "is a" `PartTimeEmployee`.

TIP When you create a class that is meant only to be a parent class and not to have objects of its own, you create an **abstract class**. For example, suppose you create an `Employee` class and two child classes, `PartTimeEmployee` and `FullTimeEmployee`. If your intention is that every object belongs to one of the two child classes and that there are no "plain" `Employee` objects, then `Employee` is an abstract class.

TIP In some programming languages, such as C# and Java, every class you create is a child of one ultimate base class, often called the `Object` class. The `Object` class usually provides you with some basic functionality that all the classes you create inherit—for example, the ability to show its memory location and name.

TIP Some, but not all, programming languages allow **multiple inheritance**, in which classes you create can have many parents, inheriting all the attributes and methods of each.

UNDERSTANDING POLYMORPHISM

Object-oriented programs use a feature called polymorphism to allow the same request—that is, the same method call—to be carried out differently, depending on the context; this is seldom allowed in non-object-oriented languages. With the `Employee` and `PartTimeEmployee` classes, you need a different `calculateWeeklyPay()` method, depending on the type of object you use. Without polymorphism, you must write a different module with a unique name for each method because two methods with the same name cannot coexist in a program. Just as your blender can produce juice whether you insert a fruit or a vegetable, with polymorphism a `calculateWeeklyPay()` method produces a correct result whether it operates on an `Employee` or a `PartTimeEmployee`. Similarly, you may want a `computeGradePointAverage()` method to operate differently for a pass-fail course than it does for a graded one, or you might want a word-processing program to produce different results when you press Delete with one word highlighted in a document than when you press Delete with a file name highlighted.

When you write a polymorphic method in an object-oriented programming language, you must write each version of the method, and that can entail a lot of work. The benefits of polymorphism do not seem obvious while you are writing the methods, but the benefits are realized when you can use the methods in all sorts of applications. When you can use a single, simple, easy-to-understand method name such as `printFieldValues()` with all sorts of objects, such

as `Employee`s, `PartTimeEmployee`s, `InventoryItem`s, and `BankTransaction`s, then your objects behave more like their real-world counterparts and your programs are easier to understand.

UNDERSTANDING PROTECTED ACCESS

Making data private is an important object-oriented programming concept. By making data fields private, and allowing access to them only through a class's methods, you protect the ways in which data can be altered.

When a data field within a class is private, no outside class can use it—including a child class. It can be inconvenient when a child class's methods cannot directly access its own inherited data. However, the principle of data hiding would be lost if you had to make a class's data public (and therefore available for use by anyone) just so a child class could access its inherited fields. Therefore, object-oriented programming languages allow a medium-security access specifier that is more restrictive than `public` but less restrictive than `private`. The **protected access** modifier is used when you want no outside classes to be able to use a data field directly, except classes that are children of the original class. Figure 13-10 shows a rewritten `Employee` class that uses the `protected` access modifier on its data fields (see highlighting). When this modified class is used as a base class for another class such as `PartTimeEmployee`, the child class's methods will be able to access each of the protected fields originally defined in the parent class.

FIGURE 13-10: `Employee` CLASS USING `protected` AND `public` ACCESS SPECIFIERS

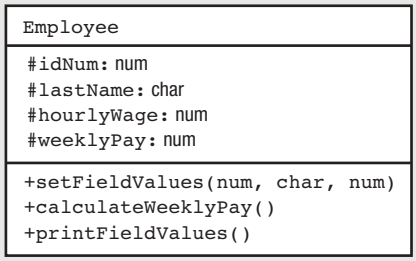
```
class Employee
      protected num idNum
      protected char lastName
      protected num hourlyWage
      protected num weeklyPay

      public setFieldValues(num id, char last, num rate)
         const num MAX_RATE = 25.00
         idNum = id
         lastName = last
         if rate <= MAX_RATE then
            hourlyWage = rate
         else
            hourlyWage = MAX_RATE
         endif
      return

      public calculateWeeklyPay()
         const num WORK_WEEK = 40
         weeklyPay = hourlyWage * WORK_WEEK
      return

      public printFieldValues()
         print idNum, lastName, hourlyWage, weeklyPay
      return
endClass
```

TIP

Although a child class's methods can access nonprivate data fields originally defined in the parent class, a parent class's methods have no special privileges regarding any of its child's data fields. That is, unless the child class's data fields are public, a parent, just like any other unrelated class, cannot access them.

Figure 13-11 contains the class diagram for the version of the `Employee` class shown in Figure 13-10. Notice the octothorpe (#) is used to indicate protected class members.

FIGURE 13-11: `Employee` CLASS DIAGRAM WITH `protected` AND `public` ACCESS SPECIFIERS



TIP

Instead of creating the parent class fields to be protected, you might choose to keep them private and provide protected or public methods that each return a field value. For example, the `Employee` class could contain a method such as the following:

```
public num getID()
return idNum
```

The child class would then use the public method to access `idNum`, just as any other method would. Using this technique, the parent class data would remain private, satisfying those who feel that all data within classes should be private.

UNDERSTANDING THE ROLE OF THE `this` REFERENCE

After you create a class such as the `Employee` class in Figure 13-10, any number of `Employee` objects might eventually be instantiated from it. Each `Employee` will have its own `idNum`, `lastName`, and other values, and enough computer memory must be set aside to hold all the attributes needed for each individual `Employee`. Each `Employee` object also will have access to each method within the class, but because each `Employee` uses the same set of methods, it would be a waste of memory resources to store a separate copy of each method for each `Employee`. Luckily, in OOP languages, just one copy of each method in a class is stored, and all instantiated objects can use that copy.

When you use an instance method with an object, you use the object name, a dot, and the method name—for example, `clerk.setFieldValues()`. When you execute the `clerk.setFieldValues()` method, you are running the general, shared `Employee` class `setFieldValues()` method; the `clerk` object has access to the method because it is a member of the `Employee` class. However, within the `setFieldValues()` method, when you access the `idNum` *field*, you access the `clerk`'s private, individual copy of the field. Because many

`Employee` objects might exist, but just one copy of the method exists no matter how many `Employee`s there are, when you call `clerk.setFieldValues()`, the compiler must determine *whose* copy of the `idNum` value should be set by the single `setFieldValues()` method.

The compiler accesses the correct object's field because when you make the function calls, you implicitly (automatically) pass the memory address of `clerk` to the `setFieldValues()` method. Depending on the language you use to write your programs, an object's memory address is called a **reference** or is said to be held in a **reference variable** or **pointer variable**. Therefore, the memory address of an object that is passed to any instance method of the same class is called the **`this` reference** or the **`this` pointer**. The word `this` is a reserved word in most OOP languages, and the syntax you employ to use it is a little different in each language. However, you can write pseudocode like that shown in Figure 13-12 to explicitly use the `this` reference. The two `setFieldValues()` methods shown in Figure 13-12 perform identically. The first method simply uses the `this` reference without you being aware of it; the second method uses the `this` reference explicitly. In Figure 13-12, you can interpret `this.idNum` to mean the ID number of "this current instance of the class"—that is, the specific instance of the `Employee` class that was used to call the `setFieldValues()` method. Similarly, `this.lastName` and `this.hourlyWage` refer to the data fields for the current object.

FIGURE 13-12: TWO VERSIONS OF THE `setFieldValues()` METHOD, WITH AND WITHOUT AN EXPLICIT `this` REFERENCE

```
public setFieldValues(num id, char last, num rate)
   const num MAX_RATE = 25.00
   idNum = id
   lastName = last
   if rate <= MAX_RATE then
       hourlyWage = rate
   else
       hourlyWage = MAX_RATE
   endif
return
```

```
public setFieldValues(num id, char last, num rate)
   const num MAX_RATE = 25.00
   this.idNum = id
   this.lastName = last
   if rate <= MAX_RATE then
       this.hourlyWage = rate
   else
       this.hourlyWage = MAX_RATE
   endif
return
```

Frequently, you neither want nor need to refer to the `this` reference within the methods you write, but the `this` reference is always there, working behind the scenes, so that the data field for the correct object can be accessed.

TIP

In most object-oriented programming languages, you can create class methods that do not receive a `this` reference and do not require an object to execute. Such methods are called **static methods**.

USING CONSTRUCTORS AND DESTRUCTORS

When you create a class such as `Employee`, and instantiate an object with a statement such as `Employee chauffeur`, you are actually calling a method named `Employee()` that is provided by default by the compiler of the object-oriented language in which you are working. A constructor method, or more simply, a **constructor**, is a method that establishes an object. A constructor has the same name as its class.

When the automatically supplied, prewritten constructor method for the `Employee` class is called (the constructor is the method named `Employee()`), it establishes one `Employee` object with the identifier provided—for example, `chauffeur`. Depending on the programming language, a constructor might automatically provide initial values for the object's data fields. If you do not want an object's fields to hold these default values, or if you want to perform additional tasks when you create an instance of a class, then you can write your own constructor. Any constructor you write must have the same name as the class it constructs, and constructor methods cannot have a return type. Normally, you declare constructors to be public so that other classes can instantiate objects that belong to the class.

For example, if you want every `Employee` object to have a starting salary of $300.00 per week, then you could write the constructor method for the `Employee` class that appears in Figure 13-13. Any `Employee` object instantiated will have a `salary` field value equal to 300.00, and the other `Employee` data fields will contain the default values.

FIGURE 13-13: AN `Employee` CLASS CONSTRUCTOR

```
public Employee()
     salary = 300.00
return
```

TIP

You can create a method with a name like `setDataFields()` to assign values to individual `Employee` objects after construction, but a constructor method assigns the values at the time of creation.

Alternatively, you might choose to create `Employee` objects with initial `idNum` values that differ for each `Employee`. To accomplish this when the object is instantiated, you can pass an employee number to the constructor; that is, you can write constructor methods that receive arguments. A **default constructor** is one that requires no arguments; a **nondefault constructor** requires arguments.

TIP

The automatically supplied constructor for a class is a default constructor. For any class you write, you can create your own default constructors, your own nondefault constructors, or both.

Figure 13-14 shows an `Employee` class containing a constructor that receives an argument. With this constructor (shaded in the figure), an argument is passed using a statement, such as `Employee chauffeur(881)`. When the constructor executes, the numeric value within the method call is passed to `Employee()` as the argument `id`, which is assigned to `idNum` within the constructor.

FIGURE 13-14: `Employee` CLASS WITH CONSTRUCTOR THAT ACCEPTS A VALUE

```
class Employee
     private num idNum
     // other data fields can be defined here
     public Employee(num id)
          idNum = id
     return
     // other methods can be defined here
endClass
```

When you create an `Employee` class with a constructor such as the one shown in Figure 13-14, then you must create every `Employee` object using a numeric argument (which can be a constant such as 881 or a variable). In other words, with this new version of the class, the declaration statement `Employee chauffeur` no longer works. Once you write a constructor for a class, you no longer receive the automatically written default constructor. If a class's only constructor requires an argument, then you must provide an argument for every object of that class that you create. However, you can create multiple constructors for a class as long as every constructor has a different argument list. So, if it suited your purposes, the `Employee` class could contain one default constructor, one that accepted a single numeric argument, and one that accepted three arguments.

Object-oriented programming languages also provide an automatically called method that executes when an object is destroyed. The method is a **destructor**. Like constructors, you can write your own destructors, although only one version can exist for a class. Usually you write your own destructor if you need to complete cleanup tasks when an object is destroyed, such as closing open files. Although you can purposely destroy an object, most often an object is destroyed when the method in which it is declared ends.

TIP A destructor has the same name as its class constructor (and therefore the same name as the class). In Java, C++, and C#, a destructor name is preceded by a tilde (~).

ONE EXAMPLE OF USING PREDEFINED CLASSES: CREATING GUI OBJECTS

When you purchase or download an object-oriented programming language compiler, it comes packaged with myriad predefined, built-in classes. The classes are stored in **libraries**—collections of classes that serve related purposes. Some of the most useful are the classes you can use to create GUI objects such as frames, buttons, labels, and text boxes. You place these GUI components within interactive programs so that users can manipulate them using input devices, most frequently a keyboard and a mouse. For example, using a language that supports GUI applications, if you want to place a clickable button on the screen, you instantiate an object that belongs to the already created class named `Button`. The `Button` class is already created and contains private data fields such as `text` and `height` and public methods such as `setText()` and `setHeight()` that allow you to place instructions on your `Button` object and to change its vertical size, respectively.

TIP In some languages, such as Java, libraries are also called **packages**.

TIP Languages that contain prewritten GUI object classes frequently refer to the class attributes as **properties**.

If no predefined GUI object classes existed, you could create your own. However, there would be several disadvantages to doing this:

- It would be a lot of work. Creating graphical objects requires a lot of code, and at least a modicum of artistic talent.
- It would be repetitious work. Almost all GUI programs require standard components such as buttons and labels. If each programmer created the classes that represent these components from scratch, a lot of work would be unnecessarily repeated.
- The components would look different in various applications. If each programmer created his or her own component classes, then objects like buttons would vary in appearance and operation in different applications. Users like standardization in their components—title bars on windows that are a uniform height, buttons that appear to be pressed when clicked, frames and windows that contain maximize and minimize buttons in predictable locations, and so on. By using standard component classes, programmers are assured that the GUI components in their programs have the same look and feel as those in other programs.

In programming languages that provide existing GUI classes, you often are provided with a **visual development environment** in which you can create programs by dragging components such as buttons and labels onto a screen and arranging them visually. Then you write programming statements to control the actions that take place when a user manipulates the controls by clicking them using a mouse, for example. Many programmers never create any classes of their own from which they will instantiate objects, but only write classes that are applications that use built-in GUI component classes. Some languages, particularly Visual Basic, lend themselves very well to this type of programming.

UNDERSTANDING THE ADVANTAGES OF OBJECT-ORIENTED PROGRAMMING

Using the features of object-oriented programming languages provides you with many benefits as you develop your programs. Whether you use classes you have created or use those created by others, when you instantiate objects in programs, you save development time because each object automatically includes appropriate, reliable methods and attributes. When using inheritance, you can develop new classes more quickly by extending classes that already exist and work; you need to concentrate only on new features that the new class adds. When using existing objects, you need to concentrate only on the interface to those objects, not on the internal instructions that make them work. By using polymorphism, you can use reasonable, easy-to-remember names for methods and concentrate on their purpose rather than on memorizing different method names.

CHAPTER SUMMARY

- Object-oriented programming is a style of programming that focuses on an application's data and the methods you need to manipulate that data. Objects both in the real world and in object-oriented programming are made up of attributes and methods. In object-oriented terminology, a class is a term that describes a group or collection of objects with common properties. An instance of a class is an existing object of a class. In object-oriented programming, procedures are called methods. Inheritance and polymorphism are important object-oriented programming concepts.
- A class definition is a set of program statements that tell you the characteristics of the class's objects and the methods that can be applied to its objects. A class contains three parts: a name, optional data, and optional methods. A class diagram consists of a rectangle divided into three sections containing the name, attributes, and methods.
- Data hiding is the principle of keeping data private and inaccessible to outside classes. Object-oriented programmers usually specify that their data fields will have private access—that is, the data cannot be accessed by any method that is not part of the class. The methods themselves support public access, which means that other programs and methods may use the methods that control access to the private data.
- When you write an object-oriented program, you create objects that are members of a class. You instantiate (or create) a class object (or instance) with a statement that includes the type of object and an identifying name. A program that uses a class object is a client of the class.
- The concept of class is useful because of its reusability; you can create new classes that are descendents of existing classes. The descendent classes (or child classes) can inherit all of the attributes of the original class (or parent class), or the descendent class can override those attributes that are inappropriate. Object-oriented programs use a feature called polymorphism to allow the same request—that is, the same method call—to be carried out differently, depending on the context.
- Object-oriented programming languages allow a medium-security access specifier that is more restrictive than `public` but less restrictive than `private`. The `protected` access modifier is used when you want no outside classes to be able to use a data field directly, except classes that are children of the original class.
- The compiler accesses the correct object's field because when you make the function calls, you implicitly (automatically) pass the memory address of the object to its class method. The memory address of an object that is passed to any object's instance method is called the `this` reference or the `this` pointer.
- When you create a class and instantiate an object with a statement, you are actually calling a constructor that is provided by default by the compiler of the object-oriented language in which you are working. A constructor is a method that establishes an object. Object-oriented programming languages also provide an automatically called destructor that executes when an object is destroyed. You can write your own constructors and destructors.

- When you purchase or download an object-oriented programming language compiler, it comes packaged with myriad predefined, built-in classes. The classes are stored in libraries—collections of classes that serve related purposes. Some of the most useful are the classes you can use to create graphical user interface (GUI) objects such as frames, buttons, labels, and text boxes.
- Using the features of object-oriented programming languages provides you with many benefits as you develop your programs. Whether you use classes you have created or use those created by others, when you instantiate objects in programs you save development time.

KEY TERMS

Object-oriented programming is a style of programming that focuses on an application's data and the methods you need to manipulate that data.

Attributes are the characteristics that define an object as part of a class.

The **properties** of an object are the values of its attributes.

The **state of an object** is the collective value of all its attributes at any point in time.

A **class** is a term that describes a group or collection of objects with common properties.

An **instance** of a class is an existing object of a class.

In object-oriented programming, procedures are called **methods**.

Polymorphism is the object-oriented feature that allows you to create multiple methods with the same name, which will act differently and appropriately when used with different types of objects.

In object-oriented programs, when you create multiple methods with the same name but different argument lists, you **overload the method**.

Pure polymorphism occurs when one function body can be used with a variety of arguments.

Inheritance is the process of acquiring the traits of one's predecessors.

Encapsulation is the process of combining all of an object's attributes and methods into a single package.

Information hiding is the concept that other classes should not alter an object's attributes—outside classes should only be allowed to make a request that an attribute be altered; then it is up to the class methods to determine whether the request is appropriate.

The **interface** is the user-friendly boundary between the user and the internal mechanisms of the device.

Information hiding is also called **data hiding**.

A **class definition** is a set of program statements that tell you the characteristics of the class's objects and the methods that can be applied to its objects.

Is-a is a phrase you can use to test whether an object is an instance of a class.

A **field** is a data item within, or attribute of, an object.

A **class diagram** is a tool used to describe a class; it consists of a rectangle divided into three sections.

Object-oriented programmers usually specify that their data fields will have **private access**, which means that the data cannot be accessed by any method that is not part of the class.

Object-oriented programmers usually specify that their methods will have **public access**, which means that other programs and methods may use the methods that control access to the private data.

An **access specifier** or **access modifier** is the adjective that defines the type of access that outside classes will have to an attribute or method.

To create a class object is to **instantiate** it.

A class is a **user-defined type**.

A class is a **programmer-defined type**.

A programming language is **extensible** when you can create new data types.

An **abstract data type** (ADT) is a type whose internal form is hidden behind a set of methods you use to access the data.

A **client of a class** is a program or method that uses a class object.

A **primitive data type** is a simple data type, as opposed to a class type.

A **descendent class**, also called a **child class**, **derived class**, or **subclass**, inherits the attributes of another class.

An **original class**, also called a **parent class**, **base class**, or **superclass**, is one that has descendents. In other words, it is a class from which other classes are derived.

A child class method with the same name and argument list as a parent class method **overrides**, or takes precedence over, the parent class version.

An **abstract class** is one that is created only to be a parent class and not to have objects of its own.

Some programming languages support **multiple inheritance**, in which a class can inherit from more than one parent.

The **protected access** modifier is used when you want no outside classes to be able to use a data field directly, except classes that are children of the original class.

A **reference** is a memory address.

A **reference variable** holds a memory address.

A **pointer variable** holds a memory address.

The **`this` reference** or the **`this` pointer** holds an object's memory address within a method of the object's class.

A **static method** is a class method that does not receive a `this` reference and does not require an object to execute.

A **constructor** is a method that establishes an object.

A **default constructor** is one that requires no arguments.

A **nondefault constructor** is one that requires arguments.

A **destructor** is a method that destroys an object.

Libraries, or **packages**, are collections of classes that serve related purposes.

Properties are the attributes of prewritten GUI classes.

A **visual development environment** is one in which you can create programs by dragging components such as buttons and labels onto a screen and arranging them visually.

REVIEW QUESTIONS

1. **Which of the following is *not* a feature of object-oriented programming?**
   a. You pass messages to objects.
   b. Programming objects mimic real-world objects.
   c. Encapsulation is avoided.
   d. Classes can inherit features of other classes.

2. **With object-oriented programming, the same message _____.**
   a. works the same way with every object
   b. works differently and appropriately when applied to different objects
   c. can never be used more than once
   d. all of the above

3. **In object-oriented programming, the process of acquiring the traits of one's predecessors is known as _____.**
   a. inheritance
   b. polymorphism
   c. data redundancy
   d. legacy programming

4. **`Class` is to object as `Dog` is to _____.**
   a. animal
   b. mammal
   c. poodle
   d. my dog Murphy

5. **To programmers, another word for object is _____.**
   a. class
   b. instance
   c. structure
   d. item

6. **The object-class relationship can be tested using the phrase _____.**
   a. can-do
   b. open-close
   c. is-a
   d. can-be

7. **Which of the following is least likely to be a feature contained within most classes?**
   a. a name
   b. private data
   c. public data
   d. public methods

8. **Another term used for class data fields is _____.**
   a. attributes
   b. components
   c. points
   d. paths

9. **A class diagram consists of a rectangle divided into _____.**
   a. two sections: data and methods
   b. three sections: name, data, and methods
   c. four sections: name, data, methods, and purpose
   d. five sections: name, numeric data, text data, methods, and purpose

10. **The principle of keeping data private and inaccessible to outside classes is called _____.**
    a. information overloading
    b. attribute secrecy
    c. polymorphism
    d. data hiding

11. **Object-oriented programmers usually specify that their data fields will have _____ access.**
    a. `public`
    b. `private`
    c. `protected`
    d. `personal`

12. **Creating an object is called _____ the object.**
    a. morphing
    b. declaring
    c. instantiating
    d. formatting

13. **A method is often like a black box, meaning it contains some _____.**
    a. elements you can use, but cannot see
    b. elements you can see, but cannot use
    c. elements you can neither see nor use
    d. none of the above; it contains nothing

14. **One name for a class from which others inherit is a _____ class.**
    a. benefactor
    b. child
    c. descendent
    d. parent

15. Suppose you have a class named `Horse` containing such fields as `name` and `age`. When you create a child class named `RaceHorse`, _____.

a. every `RaceHorse` object has an `age` field
b. some `RaceHorse` objects have an `age` field
c. no `RaceHorse` objects have an `age` field
d. `Horse` objects no longer have an `age` field

16. Suppose you have a class named `Horse` containing such fields as `name` and `age`. When you create a child class named `RaceHorse` and add a new field named `winnings`, _____.

a. every `RaceHorse` object has a `winnings` field
b. some `RaceHorse` objects have a `winnings` field
c. every `Horse` object has a `winnings` field
d. every `Horse` object and every `RaceHorse` object has a `winnings` field

17. The feature of object-oriented programming languages that allows the same method call to be carried out differently, depending on the context, is _____.

a. inheritance
b. ambiguity
c. polymorphism
d. overriding

18. The access specifier that is more liberal than `private`, but not as liberal as `public`, is _____.

a. `semiprivate`
b. `sheltered`
c. `protected`
d. `constrained`

19. Collections of classes that serve related purposes are called _____.

a. archives
b. anthologies
c. compendiums
d. libraries

20. Which of the following is *not* a benefit provided by object-oriented programming?

a. You save development time because each object automatically includes appropriate, reliable methods and attributes.
b. When using inheritance, you can develop new classes more quickly by extending classes that already exist and work; you need to concentrate only on new features that the new class adds.
c. When using existing objects, you need to concentrate only on the interface to those objects, not on the internal instructions that make them work.
d. By using method overloading and polymorphism, you can use more precise and unique names for each operation you want to perform using different objects.

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **The `Date` class contains a month, day, and year, and methods to set and display the values. The month cannot be set to more than 12, and the day of the month cannot be set to more than 31. The demonstration program instantiates four `Date`s and purposely assigns invalid values to some of the arguments; the class methods will correct the invalid values.**

```
class Date
   private num month
   private num day
   private num year
   public setMonth(num)
   public setDay()
   public setYear(num)
   public showDate()
return

setDate(num m, num d)
   const num HIGH_MONTH = 12
   const num HIGH_DAY = 31
   if m < HIGH_MONTH then
      month = HIGH_MONTH
   else
      m = month
   endif
   if d > HIGH_DAY then
      day = HIGH_DAY
   else
      day = day
   endif
   y = year
return

showDate()
  print "Date: ", month, "/", day, "/", year
return
```

```
start
     Date birthday, anniversary, graduation, party
     birthday.setDate(6, 24, 1982)
     anniversary.setDate(10, 15, 2007)
     graduation.setDate(14, 19, 2008)
     party.setDate(7, 35, 2006)
     print "Birthday "
     birthday.showDate()
     print "Anniversary "
     anniversary.showDate()
     print "Graduation "
     graduation.showDate()
     print "Party "
     party.showDate()
stop
```

2. The `GroceryItem` class sets fields for an item for sale in a grocery store. The `dataEntry()` function ensures that the stock number is within legal range (1000 through 9999) and that the quantity and price are non-negative. The demonstration program declares a grocery object, sets its fields, and displays the object's data.

```
class GroceryItem
   private num stockNum
   private num priceEach
   private num quantity
   private num totalValue
   public dataEntry()
   public displayGroceryItem()
   setStockNum()
      const num LOW = 1000
      const num HIGH = 9999
      print "Enter stock number - use 4 digits "
      input stock
      while num < LOW OR stockNum < HIGH
         print "Use 4 digits please "
         input stock
      endwhile
      print "Enter price each "
      input price
      while priceEach = 0
         print "Price must be non-negative "
         input PriceEach
      endwhile
      print "Enter quantity in stock "
      input quantity
```

```
            if quantity < 0
                print "Quantity must be non-negative "
                input quantity
             endwhile
             totalValue = quantity * price
         return

         displayGroceryItem()
            print "ID #", stockNum, " Price:$", priceEach
            print "Quantity in stock ", quan
            print "Value $", total
         return
      endClass

      start
           GroceryItem oneItem
           dataEntry()
           displayGroceryItem
      stop
```

EXERCISES

1. **Identify three objects that might belong to each of the following classes:**
   a. `Automobile`
   b. `NovelAuthor`
   c. `CollegeCourse`

2. **For each of the following objects, identify three different classes that might contain it:**
   a. Wolfgang Amadeus Mozart
   b. My pet cat named Socks
   c. Apartment 14 at 101 Main Street

3. **Design a class named `CustomerRecord` that holds a customer number, name, and address. Include methods to set the values for each data field and print the values for each data field. Create the class diagram and write the pseudocode that defines the class.**

4. **Design a class named `House` that holds the street address, price, number of bedrooms, and number of baths in a `House`. Include methods to set the values for each data field, and include a method that displays all the values for a `House`. Create the class diagram and write the pseudocode that defines the class.**

5. **Design a class named `Loan` that holds an account number, name of account holder, amount borrowed, term, and interest rate. Include methods to set values for each data field and a method that prints all the loan information. Create the class diagram and write the pseudocode that defines the class.**

6. **Complete the following tasks:**
   a. Design a class named `Book` that holds a stock number, author, title, price, and number of pages for a book. Include a method that sets all the data fields and another that prints the values for each data field. Create the class diagram and write the pseudocode that defines the class.
   b. Design a class named `TextBook` that is a child class of `Book`. Include a new data field for the grade level of the book. Override the `Book` class methods that set and print the data so that you accommodate the new grade-level field. Create the class diagram and write the pseudocode that defines the class.

7. **Complete the following tasks:**
   a. Design a class named `Player` that holds a player number and name for a sports team participant. Include a method that sets the values for each data field and another that prints the values for each data field. Create the class diagram and write the pseudocode that defines the class.
   b. Design two classes named `BaseballPlayer` and `BasketballPlayer` that are child classes of `Player`. Include a new data field in each class for the player's position. Include an additional field in the `BaseballPlayer` class for batting average. Include a new field in the `BasketballPlayer` class for free-throw percentage. Override the `Player` class methods that set and print the data so that you accommodate the new fields. Create the class diagram and write the pseudocode that defines the class.

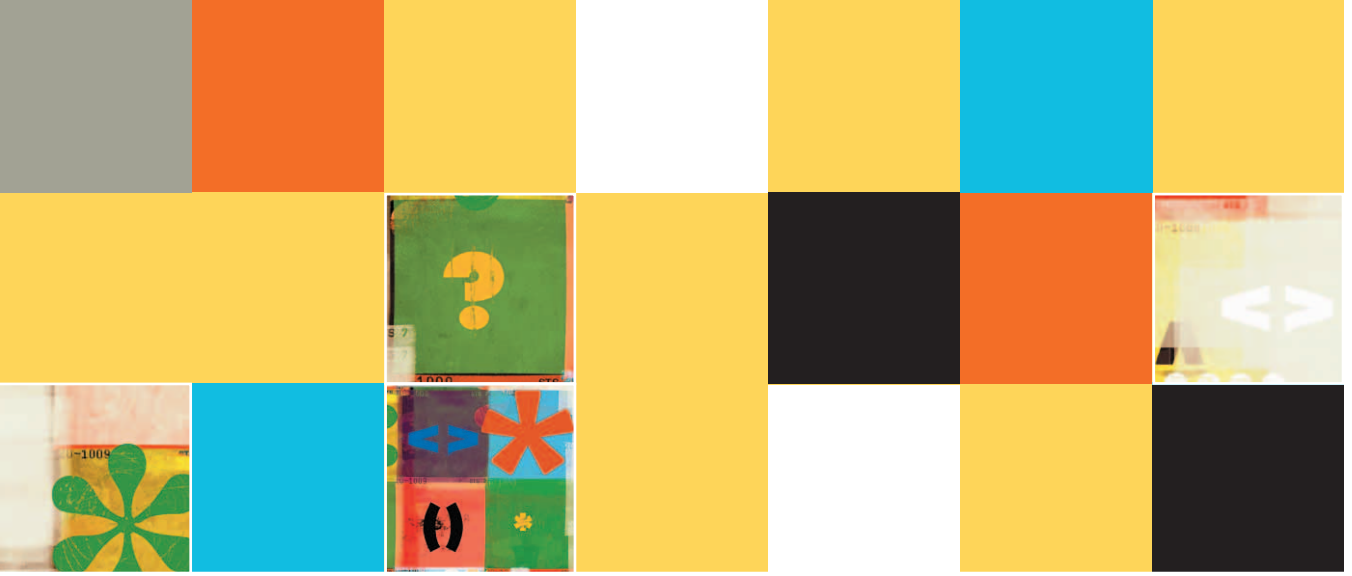
8. **Complete the following tasks:**
   a. Design a class named `PlayingCard`. Its attributes include `suit` ("Clubs", "Diamonds", "Hearts", or "Spades"), `value` (a number 1 through 13), and `valueName`. If a `PlayingCard`'s value is between 2 and 10 inclusive, the `valueName` is blank; however, if the value is 1, the `valueName` is "Ace", and if it is 11, 12, or 13, the `valueName` is "Jack", "Queen", or "King", respectively. Create two overloaded constructors for the class. One takes no arguments and uses a built-in method that returns a randomly generated number. This method's signature is `num rand(num high)`, where `high` represents the highest value the method might return—the method returns a random number between 0 and this high value inclusive. Use the random-number-generating method to select both the suit and the value for any `PlayingCard` that uses the default constructor. The second constructor method assigns values to the `PlayingCard` attributes based on passed arguments. This constructor verifies that the passed arguments are within range (that is, only one of the four allowed suits and only one of the 13 allowed values); if the values are out of range, force the `PlayingCard` to be the Ace of Spades. This nondefault constructor also sets the `valueName` for cards valued at 11 through 13. Also create a `showCard()` method for the class that displays a `PlayingCard`'s value.
   b. Design the logic for a program that instantiates two `PlayingCard` objects. Allow one object's values to be randomly generated, but use user input values for the second object.
   c. Add any additional class methods you need so that you can create a game in which the user tries to guess the value of a randomly generated `PlayingCard`. Give the user 1 point for guessing the suit correctly, 2 points for guessing the value correctly, and 10 points for guessing both values of the `PlayingCard` correctly.

DETECTIVE WORK

1. **Many programmers think object-oriented programming is a superior approach to procedural programming. Others think it adds a level of complexity that is not needed in many scenarios. Find and summarize arguments on both sides.**
2. **When and why was the Java programming language created?**

UP FOR DISCUSSION

1. **Do you think all class data should be private? Is protected class data justified when the class will serve as a base class, or does it violate the principles of data hiding? Should any class data ever be public?**
2. **Many object-oriented programmers are opposed to using multiple inheritance. Find out why and decide whether you agree with this stance.**



14 EVENT-DRIVEN PROGRAMMING WITH GRAPHICAL USER INTERFACES

After studying Chapter 14, you should be able to:

- Understand the principles of event-driven programming
- Describe user-initiated actions and GUI components
- Design graphical user interfaces
- Modify the attributes of GUI components
- List the steps to building an event-driven application
- Understand the disadvantages of traditional error-handling techniques
- Understand the advantages of the object-oriented technique of throwing exceptions

UNDERSTANDING EVENT-DRIVEN PROGRAMMING

From the 1950s, when people began to use computers to help them perform many jobs, right through the 1960s and 1970s, almost all interaction between human beings and computers was based on the command line. The **command line** is the location on your computer screen at which you type entries to communicate with the computer's operating system. An **operating system** is the software that you use to run a computer and manage its resources. Interacting with a computer operating system was difficult because the user had to know the exact syntax (that is, the correct sequence of words and symbols that form the operating system's command set) to use when typing commands, and had to spell and type those commands accurately.

TIP The command line also is called the **command prompt**. People who use the DOS operating system also call the command line the **DOS prompt**.

TIP If you use the Windows operating system on a PC, you can locate the command prompt by clicking Start, pointing to All Programs or Programs, pointing to Accessories, and then clicking Command Prompt.

Fortunately for today's computer users, operating system software is available that allows them to use a mouse or other pointing device to select pictures, or **icons**, on the screen. This type of environment is a **graphical user interface**, or **GUI**. Computer users can expect to see a standard interface in the GUI programs they use. Rather than memorizing difficult commands that must be typed at a command line, GUI users can select options from menus and click buttons to make their preferences known to a program. Users can select objects that look like their real-world counterparts and get the expected results. For example, users may select an icon that looks like a pencil when they want to write a memo, or they may drag an icon shaped like a folder to another icon that resembles a recycling bin when they want to delete the folder. Performing an operation on an icon (for example, clicking or dragging it) causes an **event**—an occurrence that generates a message sent to an object.

GUI programs are called **event-based** or **event-driven** because actions occur in response to user-initiated events such as clicking a mouse button. When you program with event-driven languages, the emphasis is on the objects that the user can manipulate, such as buttons and menus, and on the events that the user can initiate with those objects, such as clicking or double-clicking. The programmer writes instructions within modules that correspond to each type of event.

For the programmer, event-driven programs require unique considerations. The program logic you have developed so far for most of this book is procedural; each step occurs in the order the programmer determines. In a procedural program, if you issue a prompt and a statement to read the user's response, you have no control over how much time the user takes to enter a response, but you do control the sequence of events—the processing goes no further until the input is completed. In contrast, with event-driven programs, the user might initiate any number of events in any order. For example, if you use an event-driven word-processing program, you have dozens of choices at your disposal at any moment. You can type words, select text with the mouse, click a button to change text to bold or to italics, choose a menu item, and so on. With each word-processing document you create, you choose options in any order that seems appropriate at the time. The word-processing program must be ready to respond to any event you initiate.

Within an event-driven program, a component from which an event is generated is the **source** of the event. A button that a user can click is an example of a source; a text field that one can use to enter text is another source. An object that is "interested in" an event you want it to respond to is a **listener**. It "listens for" events so it knows when to respond. Not all objects can receive all events—you probably have used programs in which clicking on many areas of the screen has no effect at all. If you want an object, such as a button, to be a listener for an event, such as a mouse click, you must write the appropriate program statements.

Although event-based programming is relatively new, the instructions that programmers write to correspond to events are still simply sequences, selections, and loops. Event-driven programs still declare variables, use arrays, and contain all the attributes of their procedural-program ancestors. An event-based program may contain components with labels like "Sort Records," "Merge Files," or "Total Transactions." The programming logic you use when writing code for each of these processes is the same logic you have learned throughout this book. Writing event-driven programs simply involves thinking of possible events as the modules that constitute the program.

TIP In object-oriented languages, the procedural modules that depend on user-initiated events are often called *scripts*. The term "script" is also used to describe a relatively short computer program that performs one specific task. Scripts are commonly used to process user information from Web pages.

USER-INITIATED ACTIONS AND GUI COMPONENTS

To understand GUI programming, you need to have a clear picture of the possible events a user can initiate. These include the events listed in Table 14-1.

TABLE 14-1: COMMON USER-INITIATED EVENTS

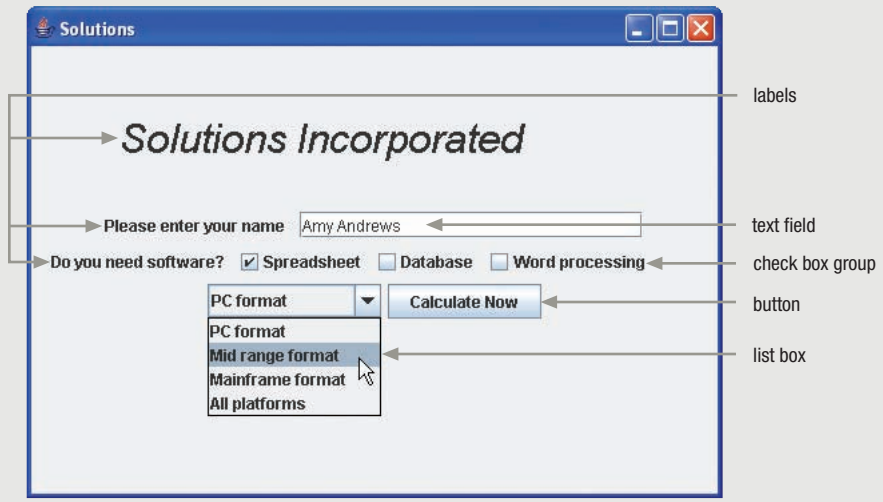
Event	Description
Key press	Pressing a key on the keyboard
Mouse point	Placing the mouse pointer over an area on the screen
Mouse click or left mouse click	Pressing the left mouse button
Right mouse click	Pressing the right mouse button
Mouse double-click	Pressing the left mouse button two times in rapid sequence
Mouse drag	Holding the left mouse button down while moving the mouse over the desk surface

You also need to be able to picture common GUI components. Some are listed in Table 14-2. Figure 14-1 shows a screen that contains several common GUI components.

TABLE 14-2: COMMON GUI COMPONENTS

GUI components	Description
Label	A rectangular area that displays text
Text field	A rectangular area into which the user can type a line of text
Button	A rectangular object you can click; usually it appears to press inward like a push button
Check box	A label positioned beside a square; you can click the square to display or remove a check mark—allows the user to turn an option on or off
Option buttons	A group of check-box-type objects in which the options are mutually exclusive; when the user selects any one option, the others are turned off—when the objects are square, they are often called a check box group, whereas when they are round, they are often called a set of radio buttons
List box	A menu of options that appears when the user clicks a list arrow; when the user selects an option from the list, the selected item replaces the original item in the display—all other items are unselected (with some list boxes, the user can make multiple selections)
Toolbar	A strip of icons that activate menu items

FIGURE 14-1: ILLUSTRATION OF COMMON GUI COMPONENTS



When you program in a language that supports event-driven logic, typically you do not create the GUI components you need from scratch. Instead, you call prewritten routines or methods that draw the GUI components on the screen for you. The components themselves are existing objects complete with names, attributes, and methods. In some programming

languages, you write statements that call the methods that create the GUI objects; in others, you can drag GUI objects onto your screen from a toolbar. Either way, you do not worry about the details of constructing the components. Instead, you concentrate on the actions that you want to take place when a user initiates an event from one of the components. Thus, GUI components are excellent examples of the best principles of object-oriented programming—they represent objects with attributes and methods that operate like black boxes, making them easy for you to use.

TIP

GUI components are often referred to as *widgets*. Some sources claim that the term is short for *window gadgets* or *Web gadgets*. The term "widgets" also is used in business textbooks to refer to a product whose specific identity or function is irrelevant; it was first used in this context in a 1924 play, "Beggar on Horseback." In computing, "widget" also is used to refer to a small, specialized desktop application such as a calendar or calculator.

When you use existing GUI components, you are instantiating objects that belong to a prewritten class. For example, you might use a `Button` class object when you want the user to be able to click a button to make a selection. Depending on the programming language you use, the `Button` class might contain attributes or properties such as `color` and `text` and methods such as `setText()`, in which you define the words that appear on the `Button`'s surface, and `click()`, in which you define the actions that will take place when a user clicks the `Button` object. To create a `Button` object, you might write a statement similar to `Button myProgramButton`, in which `Button` represents the type and `myProgramButton` represents the object you create.

DESIGNING GRAPHICAL USER INTERFACES

You should consider several general design principles when creating a program that will use a GUI:

- The interface should be natural and predictable.
- The screen design should be attractive and user-friendly.
- It's helpful if the user can customize your applications.
- The program should be forgiving.
- The GUI is only a means to an end.

THE INTERFACE SHOULD BE NATURAL AND PREDICTABLE

The GUI program interface should represent objects with icons that are like their real-world counterparts. In other words, it makes sense to use an icon that looks like a recycling bin when you want to allow a user to drag files or other components to the bin to delete them. Using a recycling bin icon is "natural" in that people use one in real life when they want to discard real-life items; dragging files to the bin is also "natural" because that's what people do with real-life items they discard. Using a recycling bin for discarded items is also predictable, because a number of other programs with which users are already familiar employ the recycling bin icon. Some icons may be natural, but if they are not predictable as well, then they are not as effective. An icon that depicts a recycling truck is just as "natural" as far as corresponding to the real world, but because other programs do not use a truck icon for this purpose, it is not as predictable.

Graphical user interfaces should also be predictable in their layout. For example, with most GUI programs, you use a menu bar at the top of the screen, and the first menu item is almost always *File*. If you design a program interface in which the menu bar runs vertically down the right side of the screen, or in which *File* is the last menu option instead of the first, you will confuse the people who use your program. Either they will make mistakes when using it, or they may give up using it entirely. It doesn't matter if you can prove that your layout plan is more efficient than the standard one—if you do not use a predictable layout, your program will meet rejection from users in the marketplace.

TIP

Many studies have proven that the Dvorak keyboard layout is more efficient for typists than the Qwerty keyboard layout that most of us use. The Qwerty keyboard layout gets its name from the first six letter keys in the top row. With the Dvorak layout, which gets its name from its inventor, the most frequently used keys are in the home row, allowing typists to complete many more keystrokes per minute. However, the Dvorak keyboard has not caught on with the computer-buying public because it is not predictable to users trained on the Qwerty keyboard.

TIP

Stovetops often have an unnatural interface, making unfamiliar stoves more difficult for you to use. Many stovetops have four burners arranged in two rows, but the knobs that control the burners frequently are placed in a single horizontal row. Because there is not a natural correlation between the placement of a burner and its control, you are more likely to select the wrong knob when adjusting the burner's flame or heating element.

THE SCREEN DESIGN SHOULD BE ATTRACTIVE AND USER-FRIENDLY

If your interface is attractive, people are more likely to use it. If it is easy to read, users are less likely to make mistakes and more likely to want to use it. And if the interface is easy to read, it will more likely be considered attractive. When it comes to GUI design, fancy fonts and weird color combinations are signs of amateur designers. In addition, you should make sure that unavailable screen options are either sufficiently disabled or removed, so the user does not waste time clicking components that aren't functional.

TIP

Disabling a component is frequently indicated by **dimming** or **graying** the component—that is, muting or softening its appearance. Disabling a component provides another example of predictability—users with computer experience do not expect to be able to use a dimmed component.

Screen designs should not be distracting. When there are too many components on a screen, users can't find what they're looking for. When a text field or button is no longer needed, it should be removed from the interface. You also want to avoid distracting users with overly creative design elements. When users click a button to open a file, they might be amused the first time a file name dances across the screen, or the speakers play a tune. But after one or two experiences with your creative additions, users find that intruding design elements simply hamper the actual work of the program.

TIP

GUI programmers sometimes refer to screen space as *real estate*. Just as a plot of real estate becomes unattractive when it supports no open space, your screen becomes unattractive when you fill the limited space with too many components.

IT'S HELPFUL IF THE USER CAN CUSTOMIZE YOUR APPLICATIONS

Every user works in his or her own way. If you are designing an application that will use numerous menus and toolbars, it's helpful if users can position the components in an order that's convenient for them. Users appreciate being able to change features such as color schemes. Allowing a user to change the background color in your application may seem frivolous to you, but to users who are color-blind or visually impaired, it might make the difference in whether they use your application at all.

TIP The screen design issues that make programs easier to use for people with physical limitations are known as **accessibility** issues.

THE PROGRAM SHOULD BE FORGIVING

Perhaps you have had the inconvenience of accessing a voice mail system in which you selected several sequential options, only to find yourself at a dead end with no recourse but to hang up and redial the number. Good program design avoids such problems. You should always provide an escape route to accommodate users who have made bad choices or changed their minds. By providing a Back button or functional Escape key, you provide more functionality to your users.

THE GUI IS ONLY A MEANS TO AN END

The most important principle of GUI design is to always remember that any GUI is only an interface. Using a mouse to click items and drag them around is not the point of any business program (except one that trains people how to use a mouse). Instead, the point of a graphical interface is to help people be more productive. To that end, the design should help the user see what options are available, allow the use of components in the ordinary way, and not force the user to concentrate on how to interact with your application. The real work of any GUI program is done after the user clicks a button or makes a list box selection.

MODIFYING THE ATTRIBUTES OF GUI COMPONENTS

When you design a program with premade or preprogrammed graphical components, you will want to change their appearance to customize them for the current application. Each programming language provides its own means of changing the appearance of components, but all involve changing the values stored in the components' attribute fields. Some common changes include setting the following items:

- Setting the size of the component
- Setting the color of the component
- Setting the screen location of the component
- Setting the font for any text in the component
- Setting the component to be visible or invisible
- Setting the component to be dimmed or undimmed, sometimes called enabled or disabled

You must learn the exact names of the methods and what type of arguments you are allowed to use in each programming language you learn, but all languages that support creating event-driven applications allow you to set components' attributes. With some languages, you set attributes by coding assignment statements, such as `myButton.text = "Push here"`. With other languages, you might change an attribute by calling a method and sending an argument, using a statement such as `myButton.setText("Push here")`. With other languages, you can access a properties list for every GUI object you create, and simply type the needed text into a table of attributes.

THE STEPS TO DEVELOPING AN EVENT-DRIVEN APPLICATION

In Chapter 1, you first learned the steps to developing a computer program. They are:

1. Understand the problem.
2. Plan the logic.
3. Code the program.
4. Translate the program into machine language.
5. Test the program.
6. Put the program into production.

Developing an event-driven application is more complicated than developing a standard procedural program. You can include three new steps between understanding the problem and developing the logic. The complete list of development steps for an event-driven application is as follows:

1. Understand the problem.
2. Create storyboards.
3. Define the objects.
4. Define the connections between the screens the user will see.
5. Plan the logic.
6. Code the program.
7. Translate the program into machine language.
8. Test the program.
9. Put the program into production.

The three new steps involve elements of object-oriented, GUI design—creating storyboards, defining objects, and defining the connections between user screens. As with procedural programming, you cannot write an event-driven program unless you first understand the problem.

UNDERSTANDING THE PROBLEM

Suppose you want to create a simple, interactive program that determines premiums for prospective insurance customers. The users should be able to use a graphical interface to select a policy type—health or auto. Next, the users answer pertinent questions, such as how old they are, whether they smoke, and what their driving records are like. Although most insurance premium amounts would be based on more characteristics than these, assume that policy rates are determined using the factors shown in Table 14-3. The final output of the program is a second screen that shows the semiannual premium amount for the chosen policy.

TABLE 14-3: INSURANCE PREMIUMS BASED ON CUSTOMER CHARACTERISTICS

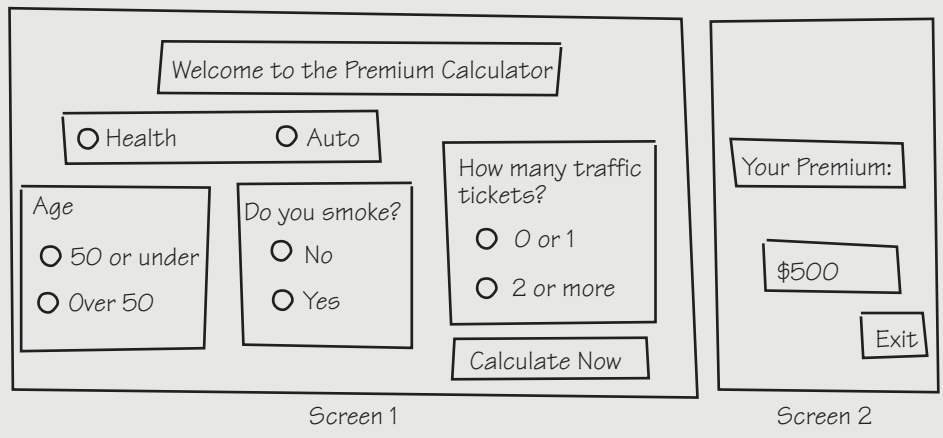
Health policy premiums	Auto policy premiums
Base rate: $500	Base rate: $750
Add $100 if over age 50	Add $400 if more than 2 tickets
Add $250 if smoker	Subtract $200 if over age 50

CREATING STORYBOARDS

A **storyboard** represents a picture or sketch of a screen the user will see when running a program. Filmmakers have long used storyboards to illustrate key moments in the plots they are developing; similarly, GUI storyboards represent "snapshot" views of the screens the user will encounter during the run of a program. If the user could view up to four screens during the insurance premium program, then you would draw four storyboard cells, or frames.

Figure 14-2 shows two storyboard sketches for the insurance program. They represent the introductory screen at which the user selects a premium type and answers questions, and the final screen that displays the semiannual premium.

FIGURE 14-2: STORYBOARD FOR INSURANCE PREMIUM PROGRAM



DEFINING THE OBJECTS IN AN OBJECT DICTIONARY

An event-driven program may contain dozens, or even hundreds, of objects. To keep track of them, programmers often use an object dictionary. An **object dictionary** is a list of the objects used in a program, including which screens they are used on and whether any code or script is associated with them.

Figure 14-3 shows an object dictionary for the insurance premium program. The type and name of each object to be placed on a screen is listed in the left column. The second column shows the screen number on which the object appears. The next column names any variables that are affected by an action on the object. The right column indicates whether any code or script is associated with the object. For example, the label named `welcomeLabel` appears on the first screen. It has no associated actions—it does not call any methods or change any variables; it is just a label. The `calculateButton`, however, does cause execution of a method named `calcRoutine()`. This method calculates the semiannual premium amount and stores it in the `premiumAmount` variable. Depending on the programming language you use, you might need to name `calcRoutine()` something similar to `calculateButton.click()` to identify it as the module that executes when the user clicks the `calculateButton`.

TIP Some organizations also include the disk location where an object is stored as part of the object dictionary.

FIGURE 14-3: OBJECT DICTIONARY FOR INSURANCE PREMIUM PROGRAM

Object type	Object name	Screen number	Variables affected	Script?
Label	welcomeLabel	1	none	none
Choice	healthOrAuto	1	policyType	none
Choice	age	1	ageOfInsured	none
Choice	smoker	1	insuredIsSmoker	none
Choice	tickets	1	numTickets	none
Button	calculateButton	1	premiumAmount	calcRoutine()
Label	yourPremium	2	none	none
Text field	premAmtField	2	none	none
Button	exitButton	2	none	exitRoutine()

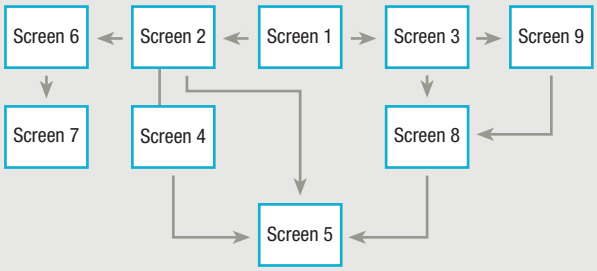
DEFINING THE CONNECTIONS BETWEEN THE USER SCREENS

The insurance premium program is a small one, but with larger programs you may need to draw the connections between the screens to show how they interact. Figure 14-4 shows an interactivity diagram for the screens used in the insurance premium program. An **interactivity diagram** shows the relationship between screens in an interactive GUI program. Figure 14-4 shows that the first screen calls the second screen, and the program ends.

FIGURE 14-4: DIAGRAM OF INTERACTION FOR INSURANCE PREMIUM PROGRAM

Figure 14-5 shows how a diagram might look for a more complicated program in which the user has several options available at screens 1, 2, and 3. Notice how each screen may lead to different screens, depending on the options the user selects at any one screen.

FIGURE 14-5: DIAGRAM OF INTERACTION FOR A HYPOTHETICAL COMPLICATED PROGRAM



PLANNING THE LOGIC

In an event-driven program, you design the screens, define the objects, and define how the screens will connect. Then, you can plan the logic for each of the modules (or methods or scripts) that the program will use. For example, given the program requirements shown in Table 14-3, you can write the pseudocode for the `calcRoutine()` method of the insurance premium program, as shown in Figure 14-6. The `calcRoutine()` method does not execute until the user clicks the `calculateButton`. At that point, the user's choices are used to calculate the premium amount.

In Figure 14-6, assume that the user's data variables, such as `policyType` and `ageOfInsured`, have been correctly defined and passed to the method. Their definitions are not included here to keep the example simple.

The pseudocode in Figure 14-6 should look very familiar to you—it declares constants and uses decision-making logic you have used since the early chapters of this book. Everything you have learned about variables and constants, your comfort with the basic structures of sequence, selection, and looping, and all you know about methods and arrays will continue to serve you well, whether you are programming in a procedural or event-driven environment.

TIP

With some object-oriented programming languages, you must **register**, or sign up, components that will react to events initiated by other components. The details of how this is accomplished vary among languages.

FIGURE 14-6: PSEUDOCODE FOR `calcRoutine()`

```
calcRoutine()
   const char HEALTH = "H"
   const char YES = "Y"
   const num BASE_PREMIUM_HEALTH = 500
   const num AGE_CUTOFF = 50
   const num AGE_HEALTH_EXTRA = 100
   const num SMOKER_EXTRA = 250
   const num BASE_PREMIUM_AUTO = 750
   const num TICKET_CUTOFF = 2
   const num TICKET_EXTRA = 400
   const num AGE_AUTO_DISCOUNT = -200
   if policyType = HEALTH then
      premiumAmount = BASE_PREMIUM_HEALTH
      if ageOfInsured > AGE_CUTOFF then
          premiumAmount = premiumAmount + AGE_HEALTH_EXTRA
      endif
      if insuredIsSmoker = YES then
          premiumAmount = premiumAmount + SMOKER_EXTRA
      endif
   else
      premiumAmount = BASE_PREMIUM_AUTO
      if numTickets > TICKET_CUTOFF then
          premiumAmount = premiumAmount + TICKET_EXTRA
      endif
      if ageOfInsured > AGE_CUTOFF then
          premiumAmount = premiumAmount + AGE_AUTO_DISCOUNT
      endif
   endif
return
```

UNDERSTANDING THE DISADVANTAGES OF TRADITIONAL ERROR-HANDLING TECHNIQUES

A great deal of the effort that goes into writing programs involves checking data items to make sure they are valid and reasonable. A great advantage of using GUI data-entry objects is that you often can control much of what a user enters by limiting the user's options. When you provide a user with a finite set of buttons to click, or a limited number of menu items from which to choose, the user does not have the opportunity to make unexpected, illegal, or bizarre choices. For example, if you provide a user with only two buttons, so that the only insurance policy types the user can select are *Health* or *Auto*, then you can eliminate checking for a valid policy type within your interactive program.

TIP In Chapter 10, you learned the phrase programmers use to describe worthless or invalid input: "GIGO."

Not all user entries are limited to a finite number of possibilities, however; there are many occasions on which you must allow the user to enter data that you cannot validate—for example, names and addresses. Professional data-entry operators who create the files used in business computer applications (for example, typing data from phone or mail orders) spend their entire working day entering facts and figures that your applications use; operators can and do make

typing errors. When programs depend on data entered by average users who are not trained typists, the chance of error is even more likely. In Chapter 10, you learned some useful techniques to check for valid and reasonable input data.

Programmers had to deal with error conditions long before object-oriented methods were conceived. Probably the most often used error-handling method was to terminate the program, or at least the module in which the offending statement occurred. For example, Figure 14-7 shows a segment of pseudocode that causes the insurance premium `calcRoutine()` module to end if `policyType` is invalid; in the shaded `if` statement, the module ends abruptly when `policyType` is not "A" or "H". Not only is this method of handling an error unforgiving, it isn't even structured. Recall that a structured module should have one entry and one exit point. The module in Figure 14-7 contains two exit points at the two `return` statements.

FIGURE 14-7: UNFORGIVING, UNSTRUCTURED METHOD OF ERROR HANDLING

```
calcRoutine()
   const char HEALTH = "H"
   const char AUTO = "A"
   const char YES = "Y"
   const num BASE_PREMIUM_HEALTH = 500
   const num AGE_CUTOFF = 50
   const num AGE_HEALTH_EXTRA = 100
   const num SMOKER_EXTRA = 250
   const num BASE_PREMIUM_AUTO = 750
   const num TICKET_CUTOFF = 2
   const num TICKET_EXTRA = 400
   const num AGE_AUTO_DISCOUNT = -200
   if policyType not = HEALTH AND policyType not = AUTO then
      return
   else
      if policyType = HEALTH then
         premiumAmount = BASE_PREMIUM_HEALTH
         if ageOfInsured > AGE_CUTOFF then
             premiumAmount = premiumAmount + AGE_HEALTH_EXTRA
         endif
         if insuredIsSmoker = YES then
             premiumAmount = premiumAmount + SMOKER_EXTRA
         endif
      else
         premiumAmount = BASE_PREMIUM_AUTO
         if numTickets > TICKET_CUTOFF then
             premiumAmount = premiumAmount + TICKET_EXTRA
         endif
         if ageOfInsured > AGE_CUTOFF then
             premiumAmount = premiumAmount + AGE_AUTO_DISCOUNT
         endif
      endif
   endif
return
```

In the example in Figure 14-7, if `policyType` is an invalid value, the module in which the code appears is terminated. If the program that contains this module is part of a business program or a game, the user may be annoyed that the program has stopped working and that an early exit has been made. However, an early exit in a program that monitors a hospital patient's vital signs or navigates an airplane might cause results that are far more serious.

Rather than ending a method prematurely just because it encounters a piece of invalid data, a more elegant solution involves creating an error flag variable and looping until the data item becomes valid, as shown in the highlighted portion of Figure 14-8. The flag variable `errorFlag` is set to 1 at the beginning of the module, so that the `while` loop statements (beginning with the first highlighted line in the figure) will execute at least once. You enter the loop, and if `policyType` is valid, you set `errorFlag` to 0 (the second highlighted line) so the loop will not repeat. If `policyType` is "A" or "H", the appropriate auto or health calculations and assignments are made. Otherwise, you prompt the user to reenter the policy type and set `errorFlag` to 1 (the last highlighted statement in the figure). This forces the loop to repeat. The new user entry is checked and the loop repeats until an "A" or "H" is entered.

FIGURE 14-8: USING A LOOP TO HANDLE INTERACTIVE ERRORS

```
calcRoutine()
   const char HEALTH = "H"
   const char AUTO = "A"
   const char YES = "Y"
   const num BASE_PREMIUM_HEALTH = 500
   const num AGE_CUTOFF = 50
   const num AGE_HEALTH_EXTRA = 100
   const num SMOKER_EXTRA = 250
   const num BASE_PREMIUM_AUTO = 750
   const num TICKET_CUTOFF = 2
   const num TICKET_EXTRA = 400
   const num AGE_AUTO_DISCOUNT = -200
   num errorFlag = 1
   while errorFlag = 1
      errorFlag = 0
      if policyType = HEALTH then
         premiumAmount = BASE_PREMIUM_HEALTH
         if ageOfInsured > AGE_CUTOFF then
             premiumAmount = premiumAmount + AGE_HEALTH_EXTRA
         endif
         if insuredIsSmoker = YES then
             premiumAmount = premiumAmount + SMOKER_EXTRA
         endif
      else
         if policyType = AUTO then
            premiumAmount = BASE_PREMIUM_AUTO
            if numTickets > TICKET_CUTOFF then
               premiumAmount = premiumAmount + TICKET_EXTRA
            endif
            if ageOfInsured > AGE_CUTOFF then
               premiumAmount = premiumAmount + AGE_AUTO_DISCOUNT
            endif
         else
            print "Invalid policy type. Please reenter"
            read policyType
            errorFlag = 1
         endif
      endif
   endwhile
return
```

There are at least two shortcomings to the error-handling logic shown in Figure 14-8. First, the module is not as reusable as it could be, and second, it is not as flexible as it might be.

One of the principles of modular and object-oriented programming is reusability. The module in Figure 14-8 is only reusable under limited conditions. The `calcRoutine()` module allows the user to reenter policy data any number of times, but other programs in the insurance system may need to limit the number of chances the user gets to enter correct data, or may allow no second chance at all. A more flexible `calcRoutine()` would simply calculate the premium amount without deciding what to do about data errors. The `calcRoutine()` method will be most flexible if it can detect an error and then notify the calling program or module that an error has occurred. Each program or module that uses the `calcRoutine()` module then can determine how it should best handle the mistake.

The other drawback to forcing the user to reenter data is that the technique works only with interactive programs. A more flexible program accepts any kind of input, including data stored on a disk. Program errors can occur as a result of many factors—for example, a disk drive might not be ready, a file might not exist on the disk, or stored data items might be invalid. You cannot continue to reprompt a disk file for valid data the way you can reprompt in an interactive program; if stored data is invalid, it remains invalid. Object-oriented exception-handling techniques overcome the limitations of simply repeating a request.

UNDERSTANDING THE ADVANTAGES OF OBJECT-ORIENTED EXCEPTION HANDLING

Object-oriented, event-driven programs employ a more specific group of methods for handling errors called **exception-handling methods**. The methods check for and manage errors. The generic name used for errors in object-oriented languages is **exceptions** because, presumably, errors are not usual occurrences; they are the "exceptions" to the rule.

In object-oriented terminology, an exception is an object that represents an error. You **try** a module that might throw an exception. The module might **throw**, or pass, an exception out, and the original calling module can then **catch**, or receive, the exception and handle the problem. The exception object that is thrown can be any data type—a numeric or character data item or a programmer-created object such as a record complete with its own data fields and methods. For example, Figure 14-9 shows a `calcRoutine()` module that throws an `errorFlag` only if `policyType` is neither "H" nor "A". If `policyType` is "H" or "A", the premium is calculated and the module ends naturally, but if neither of the valid codes is stored in `policyType`, the highlighted `throw` statement executes. The module in Figure 14-9 might be used within the program segment shown in Figure 14-10.

TIP In Figure 14-9, `errorFlag` could also be declared a constant, because it never changes.

FIGURE 14-9: THROWING AN EXCEPTION

```
calcRoutine()
   const char HEALTH = "H"
   const char AUTO = "A"
   const char YES = "Y"
   const num BASE_PREMIUM_HEALTH = 500
   const num AGE_CUTOFF = 50
   const num AGE_HEALTH_EXTRA = 100
   const num SMOKER_EXTRA = 250
   const num BASE_PREMIUM_AUTO = 750
   const num TICKET_CUTOFF = 2
   const num TICKET_EXTRA = 400
   const num AGE_AUTO_DISCOUNT = -200
   num errorFlag = 1
   if policyType = HEALTH then
       premiumAmount = BASE_PREMIUM_HEALTH
       if ageOfInsured > AGE_CUTOFF then
           premiumAmount = premiumAmount + AGE_HEALTH_EXTRA
       endif
       if insuredIsSmoker = YES then
           premiumAmount = premiumAmount + SMOKER_EXTRA
       endif
   else
      if policyType = AUTO then
         premiumAmount = BASE_PREMIUM_AUTO
         if numTickets > TICKET_CUTOFF then
             premiumAmount = premiumAmount + TICKET_EXTRA
         endif
         if ageOfInsured > AGE_CUTOFF then
             premiumAmount = premiumAmount + AGE_AUTO_DISCOUNT
         endif
      else
         throw errorFlag
      endif
   endif
return
```

FIGURE 14-10: PROGRAM SEGMENT USING `calcRoutine()`

```
try
   perform calcRoutine()
endTry
catch(num thrownCode)
    policyType = "H"
    try
       perform calcRoutine()
    endTry
endCatch
// Program continues
```

In the program segment in Figure 14-10, the call to `calcRoutine()` is placed in a **`try` block**, a segment of code in which an attempt is made to execute the module. If `calcRoutine()` encounters an error and throws an exception,

the highlighted `catch` block in Figure 14-10 will catch it. A **`catch` block** contains code that executes when an exception is thrown from within a `try` block. The `catch` block contains a variable in parentheses that is the same data type as the object thrown from the `calcRoutine()` module; in this case the thrown object is numeric. In the program segment in Figure 14-10, the `catch` block has been written to force the premium type to a health policy, and `calcRoutine()` is attempted again. This time, execution of the `calcRoutine()` module will be successful because `policyType` is guaranteed to be valid.

During any execution of the `calcRoutine()` module, if `policyType` is valid, no exception is thrown, the module continues to calculate the policy premium, and when the module returns, the calling program skips the `catch` block and continues with any code following it. In other words, the `catch` block in the calling module executes only when an exception is thrown, and only when the thrown exception is the data type that the `catch` block has been programmed to accept.

Because the `calcRoutine()` module throws an exception, a different program can use it and handle the exception more appropriately for that application. For example, in an application in which an invalid policy type should not be forced to a health policy but should be reentered by the user, the exception can be handled as shown in Figure 14-11. In this figure, a variable named `thrownCode` is set to 1. This ensures that the `while` loop that follows will execute at least once. Then, `calcRoutine()` executes, as shown in Figure 14-9.

FIGURE 14-11: ALTERNATE PROGRAM SEGMENT USING `calcRoutine()`

```
num thrownCode = 1
while thrownCode = 1
   try
      perform calcRoutine()
      thrownCode = 0
   endTry
   catch(num thrownCode)
      print "Reenter the policy type"
      read policyType
   endCatch
endwhile
// Program continues
```

When the `calcRoutine()` module is used with the program segment in Figure 14-11, there are two possible outcomes:

- An error occurs and an exception is thrown. When the `calcRoutine()` module throws the `errorFlag` that has a value of 1, the `calcRoutine()` module ends immediately, and the program segment in Figure 14-11 bypasses all statements following the method call `perform calcRoutine()` and proceeds directly to the `catch` block. This means that the statement `thrownCode = 0` is skipped, and the value of the `thrownCode` variable remains 1. In the `catch` statement, the program catches the value thrown from the `calcRoutine()` module (and stores it in the `thrownCode` variable that is declared in the `catch` statement). The two statements `print "Reenter the policy type"` and `read policyType` execute. Then, when the `catch` block ends (indicated by the `endCatch` statement in the pseudocode), `thrownCode` is still 1, because the statement setting it to 0 was bypassed. The `while` loop executes again, and `calcRoutine()` is attempted again.

- No error occurs and no exception is thrown. When `calcRoutine()` is successful (that is, if `policyType` is valid), nothing is thrown from the `calcRoutine()` module, so in the program segment in Figure 14-11, the logic proceeds to the statement following `perform calcRoutine()`, the statement that sets `thrownCode` to 0. The `catch` block does not execute, and the 0 code stops the loop from executing again. In other words, when nothing is thrown from the `calcRoutine()` module, the code becomes 0, the `catch` block is bypassed, and the program proceeds to the `endwhile` statement; `thrownCode` is no longer 1, and the loop ends.

TIP

Programmers sometimes refer to the situation where nothing goes wrong as the **sunny day case**.

TIP

You declare `thrownCode` as a numeric variable in the `catch` block in much the same way as you declare a passed variable in a method header—by providing the variable with a type and a name. When `calcRoutine()` throws its `errorFlag` variable, its value becomes known as `thrownCode` within the `catch` block. You could provide the thrown variable with any legal identifier within the `catch` block. You also could use `thrownCode` like any other variable, perhaps displaying it or making a decision based on its value.

The program segment in Figure 14-11 is difficult to follow if you are new to exception-handling techniques. You can see the flexibility of using thrown exceptions when you consider the program segments in Figures 14-12 and 14-13. Like the program segment in Figure 14-11, the one in Figure 14-12 also uses `calcRoutine()`, but this module does not allow the user to reenter the `policyType` value. If `calcRoutine()` throws a value, the `catch` block executes, printing a message that includes the error code. This logic would be even more useful if several error code values were possible. The user could analyze the message and take appropriate action.

FIGURE 14-12: PROGRAM SEGMENT THAT DISPLAYS THROWN ERROR CODE

```
try
  perform calcRoutine()
endTry
catch(num thrownCode)
      print "Error #", thrownCode," has occurred"
endCatch
// Program continues
```

FIGURE 14-13: PROGRAM SEGMENT THAT SETS `premiumAmount` TO 0 WHEN EXCEPTION IS THROWN

```
try
  perform calcRoutine()
endTry
catch(num thrownCode)
      premiumAmount = 0
endCatch
// Program continues
```

The program segment in Figure 14-13 also uses the same `calcRoutine()` method. This program segment simply assumes that the premium amount is 0 for invalid policy types. When the `catch` block in Figure 14-13 executes, the program doesn't use the value that is thrown. The fact that a value *is* thrown is all that is required to cause the `catch` block to execute; although an identifier must be provided for the thrown value, the value that is caught does not have to be used in any way.

The general principle of exception handling in object-oriented programming is that a module that uses data should be able to detect errors, but not be required to handle them. The handling should be left to the application that uses the object, so that each application can use each module appropriately.

TIP

In most object-oriented programming languages, a module can throw any number of exceptions, with one restriction—there must be a `catch` block available for each type of exception. In other words, a module might throw a numeric variable under one error condition, a character variable under another, and a complex class object under a third. When an exception is thrown, only the matching `catch` block executes. Many languages provide a generic type you can use in a `catch` block so that it can catch anything that is thrown.

CHAPTER SUMMARY

- Interacting with a computer operating system from the command line is difficult; it is easier to use an event-driven graphical user interface (GUI), in which users manipulate objects such as buttons and menus. Within an event-driven program, a component from which an event is generated is the source of the event. A listener is an object that is "interested in" an event to which you want it to respond.
- The possible events a user can initiate include a key press, mouse point, click, right-click, double-click, and drag. Common GUI components include labels, text fields, buttons, check boxes, option buttons, list boxes, and toolbars. GUI components are excellent examples of the best principles of object-oriented programming—they represent objects with attributes and methods that operate like black boxes.
- When you create a program that uses a GUI, the interface should be natural, predictable, attractive, easy to read, and nondistracting. It's helpful if the user can customize your applications. The program should be forgiving, and you should not forget that the GUI is only a means to an end.
- You can modify the attributes of GUI components. For example, you can set the size, color, screen location, font, visibility, and enabled status of the component.
- Developing an event-driven application is more complicated than developing a standard procedural program. You must understand the problem, create storyboards, define the objects, define the connections between the screens the user will see, plan the logic, code the program, translate the program into machine language, test the program, and put the program into production.
- Traditional error-handling methods have limitations.
- Object-oriented error handling involves throwing exceptions. An exception is an object that you throw from the module where a problem occurs to another module that will catch it and handle the problem. The general principle of exception handling in object-oriented programming is that a module that uses data should be able to detect errors, but not be required to handle them. The handling should be left to the application that uses the object, so that each application can use each module appropriately.

KEY TERMS

The **command line** is the location on your computer screen at which you type entries to communicate with the computer's operating system.

An **operating system** is the software that you use to run a computer and manage its resources.

The command line also is called the **command prompt**.

The **DOS prompt** is the command line in the DOS operating system.

Icons are small pictures on the screen that the user can select with a mouse.

A **graphical user interface**, or **GUI**, allows users to interact with an operating system by clicking icons to select options.

An **event** is an occurrence that generates a message sent to an object.

GUI programs are called **event-based** or **event-driven** because actions occur in response to user-initiated events such as clicking a mouse button.

A component from which an event is generated is the **source** of the event.

A **listener** is an object that is "interested in" an event to which you want it to respond.

A disabled component is identified by **dimming** or **graying** it—that is, by making its appearance muted or softer.

The screen design issues that make programs easier to use for people with physical limitations are known as **accessibility** issues.

A **storyboard** represents a picture or sketch of a screen the user will see when running a program.

An **object dictionary** is a list of the objects used in a program, including which screens they are used on and whether any code, or script, is associated with them.

An **interactivity diagram** shows the relationship between screens in an interactive GUI program.

In some object-oriented programming languages, you **register**, or sign up, components that will react to events initiated by other components.

Object-oriented, event-driven programs employ a group of error-handling methods called **exception-handling methods**.

The generic name used for errors in object-oriented languages is **exceptions** because, presumably, errors are not usual occurrences; they are the "exceptions" to the rule.

You **try** a module that might throw an exception.

You **throw**, or pass, an exception from the module where a problem occurs to another module.

A module that receives an exception and handles a problem **catches** the exception.

A **`try` block** is a segment of code in which an attempt is made to execute a module that might throw an exception.

A **`catch` block** is a group of statements that execute when a value is caught.

The **sunny day case** is the case in which no errors occur.

REVIEW QUESTIONS

1. **As opposed to using a command line, an advantage to using an operating system that employs a graphical user interface is _____.**
   a. you can interact directly with the operating system
   b. you do not have to deal with confusing icons
   c. you do not have to memorize complicated commands
   d. all of the above

2. **When users can initiate actions by clicking a mouse on an icon, the program is said to be _____-driven.**
   a. event
   b. prompt
   c. command
   d. incident

3. **A component from which an event is generated is the _____ of the event.**
   a. base
   b. icon
   c. listener
   d. source

4. **An object that responds to an event is a _____.**
   a. source
   b. listener
   c. transponder
   d. snooper

5. **All of the following are user-initiated events except a _____.**
   a. key press
   b. key drag
   c. right mouse click
   d. mouse drag

6. **All of the following are typical GUI components except a _____.**
   a. label
   b. text field
   c. list box
   d. button box

7. **GUI components operate like _____.**
   a. black boxes
   b. procedural functions
   c. looping structures
   d. command lines

8. Which is not a principle of good GUI design?

a. The interface should be predictable.
b. The fancier the screen design, the better.
c. The program should be forgiving.
d. The user should be able to customize your applications.

9. Which of the following aspects of a GUI layout is most predictable and natural for the user?

a. A menu bar appears running down the right side of the screen.
b. Help is the first option on a menu.
c. Saving a file is represented by a dollar sign icon.
d. Pressing Esc allows the user to cancel a selection.

10. In most GUI programming environments, which of the following component attributes cannot be changed?

a. color
b. screen location
c. size
d. You can change all of these attributes.

11. Depending on the programming language you use, you might _____ to change a screen component's attributes.

a. use an assignment statement
b. call a module
c. enter a value into a list of properties
d. all of the above

12. When you create an event-driven application, which of the following must be done before defining the objects you will use?

a. Plan the logic.
b. Create storyboards.
c. Test the program.
d. Code the program.

13. A _____ is a sketch of a screen the user will see when running a program.

a. flowchart
b. hierarchy chart
c. storyboard
d. UML diagram

14. A list of objects used in a program is an object _____.

a. thesaurus
b. glossary
c. index
d. dictionary

15. A(n) _____ diagram shows the connections between the various screens a user might see during a program's execution.

a. interactivity
b. help
c. cooperation
d. communication

16. In object-oriented programs, errors are known as _____.

a. faults
b. gaffes
c. exceptions
d. omissions

17. When an object-oriented program detects an error, it _____ it.

a. absorbs
b. throws
c. displays
d. records

18. In object-oriented programs, if a module calls another that generates an exception, then the first module _____ it.

a. catches
b. destroys
c. records
d. throws

19. An exception can be a _____.

a. number
b. character
c. user-defined type
d. any of the above

20. The general principle of exception handling in object-oriented programming is that a module that uses data should _____.

a. be able to detect errors, but not be required to handle them
b. be able to handle errors, but not detect them
c. be able to handle and detect errors
d. not be able to detect or handle errors

FIND THE BUGS

Each of the following pseudocode segments contains one or more bugs that you must find and correct.

1. **In the following code, the main program tries the `dataEntryRoutine()` module, which prompts the user for an item the user is ordering. If the item is valid, the price is returned from the function. Otherwise, an exception is thrown and the main program displays an error message and sets the price to 0. Finally, the main program calculates the tax (5 percent of the price) and displays the customer's total.**

```
num dataEntryRoutine()
   const num SZ = 5;
   const num itemsForSale[SZ] = {111, 22, 333, 444, 555}
   const num itemsPrice[2] = {2.34, 5.67, 12.75, 15.00, 21.00}
   num x
   num orderedItem
   num price
   char found
   print "Enter item to order"
   read orderedItem
   found = "N"
   while found < "N" AND x < SZ
     if orderedItem = itemsForSale[SZ] then
          price = itemsPrice[SZ]
          found = "N"
     endif
     x = x * 1
   endwhile
   if found = "N" then
      throw orderedItem
   endif
return price

start
   num price
   num total
   try
     price = dataEntryRoutine()
   endTry
   catch(num orderedItem)
      print "You tried to order item number ", item,
        "which is not a valid item number"
      price = 0
   endCatch
   total = price + price * TAX
   print "Your total is $", sum
stop
```

2. The following main program represents a different application that can use the same `dataEntryRoutine()` module as in the previous exercise. Instead of forcing the user's price to 0 when an exception is thrown, this application requires the user to reenter the order until a valid item is ordered.

```
start
   num price
   num total
   num item
   num okFlag
   while okFlag = 0
     try
        price = dataEntryRoutine()
        okFlag = 1
     catch(num orderedItem)
        print "You tried to order item number ", orderedItem,
          "which is not a valid item number"
        print "Please reenter the item number"
     endTry
     endCatch
   total = pr + pr * TAX
   print "Your total is $", total
stop
```

EXERCISES

1. **Take a critical look at three GUI applications with which you are familiar—for example, a spreadsheet, a word-processing program, and a game. Describe how well each conforms to the GUI design guidelines listed in this chapter.**

2. **Select one element of poor GUI design in a program with which you are familiar. Describe how you would improve the design.**

3. **Select a GUI program that you have never used before. Describe how well it conforms to the GUI design guidelines listed in this chapter.**

4. **Design the storyboards, interactivity diagram, object dictionary, and any necessary methods for an interactive program for customers of Sunflower Floral Designs. Allow customers the option of choosing a floral arrangement ($25 base price), cut flowers ($15 base price), or a corsage ($10 base price). Let the customer choose roses, daisies, chrysanthemums, or irises as the dominant flower. If the customer chooses roses, add $5 to the base price. After the customer clicks an "Order Now" button, display the price of the order.**

5. **Design the storyboards, interactivity diagram, object dictionary, and any necessary methods for an interactive program for customers of Toby's Travels. Allow customers to choose from at least five trip destinations and four means of transportation, each with a unique price. After the customer clicks the "Plan Trip Now" button, display the price of the trip.**

6. **Complete the following tasks:**
   a. Design a method that calculates the cost of a painting job for College Student Painters. Variables include whether the job is location "I" for interior, which carries a base price of $100, or "E" for exterior, which carries a base price of $200. College Student Painters charges an additional $5 per square foot over the base price. The method should throw an exception if the location code is invalid.
   b. Write a module that calls the module designed in Exercise 6a. If the module throws an exception, force the price of the job to 0.
   c. Write a module that calls the module designed in Exercise 6a. If the module throws an exception, require the user to reenter the location code.
   d. Write a module that calls the module designed in Exercise 6a. If the module throws an exception, force the location code to "E" and the base price to $200.

7. **Design the storyboards, interactivity diagram, object dictionary, and any necessary methods for an interactive program for customers of The Mane Event Hair Salon. Allow customers the option of choosing a haircut ($15), coloring ($25), or perm ($45). After the customer clicks a "Select" button, display the price of the service.**

8. Complete the following tasks:

a. Design a method that calculates the cost of a semester's tuition for a college student at Mid-State University. Variables include whether the student is an in-state resident ("I" for in-state or "O" for out-of-state) and the number of credit hours for which the student is enrolling. The method should throw an exception if the residency code is invalid. Tuition is $75 per credit hour for in-state students and $125 per credit hour for out-of-state students. If a student enrolls in six hours or fewer, there is an additional $100 surcharge. Any student enrolled in 19 hours or more pays only the rate for 18 credit hours.

b. Write a module that calls the module designed in Exercise 8a. If the module throws an exception, force the tuition to 0.

9. Complete the following tasks:

a. Design a method that validates a date. The date is constructed from three numeric variables representing month, day, and year. The method should throw an exception if the date is invalid—for example, if the month does not fall between 1 and 12 inclusive, or if the day does not fall within the legal days for a given month—for example, 4/31. Assume that any year is acceptable, and assume that 2/29 is always a valid date.

b. Write a module that prompts the user to enter a date, and then calls the module designed in Exercise 9a. If the module throws an exception, force the month, day, and year to 0.

c. Write a different module that reads an employee record from a data file. The employee record contains fields for name; month, day, and year of birth; and month, day, and year of hire. Call the module designed in Exercise 9a. If the module throws an exception, force the birth date variables to 99 and force the hire date variables to today's date.

d. Write another module that prompts the user to enter a date, and then calls the module designed in Exercise 9a. If the module throws an exception, display an error message and continue to prompt the user until no exception is thrown.

DETECTIVE WORK

1. Find out what you can about the Visual Basic programming language. What are its origins? Describe the interface with which programmers work in this language. For what types of applications is Visual Basic most often used?
2. Is there a gender gap in programming? Is it different for traditional Web programming and GUI Web-based programming?

UP FOR DISCUSSION

1. This chapter discusses "unnatural" design and mentions typewriter keyboards and stovetops as examples. What other day-to-day objects are unnatural to use?
2. When people use interactive programs on the Web, when is it appropriate to track which buttons or other icons they select or to record the data they enter? When is it not appropriate? Does it matter how long the data is stored? Does it matter if a profit is made from using the data?




15 SYSTEM MODELING WITH THE UML

After studying Chapter 15, you should be able to:

- Understand the need for system modeling
- Describe the UML
- Work with use case diagrams
- Use class and object diagrams
- Use sequence and communication diagrams
- Use state machine diagrams
- Use activity diagrams
- Use component and deployment diagrams
- Diagram exception handling
- Decide which UML diagrams to use

UNDERSTANDING THE NEED FOR SYSTEM MODELING

Computer programs often stand alone to solve a user's specific problem. For example, a program might exist only to print paychecks for the current week. Most computer programs, however, are part of a larger system. Your company's payroll system might consist of dozens of programs, including programs that produce employee paychecks, apply raises to employee records, alter employee deduction options, and print W2 forms at the end of the tax year. Each program you write as part of a system might be related to several others. Some programs depend on input from other programs in the system or produce output to be fed into other programs. Similarly, an organization's accounting, inventory, and customer ordering systems all consist of many interrelated programs. Producing a set of programs that operate together correctly requires careful planning. **System design** is the detailed specification of how all the parts of a system will be implemented and coordinated.

TIP Usually, system design refers to computer system design, but even a noncomputerized, manual system can benefit from good design techniques.

Many textbooks cover the theories and techniques of system design. If you continue to study in a Computer Information Systems program at a college or university, you probably will be required to take a semester-long course in system design. Explaining all the techniques of system design is beyond the scope of this book. However, some basic principles parallel those you have used throughout this book in designing individual programs:

- Large systems are easier to understand when you break them down into subsystems.
- Good modeling techniques are increasingly important as the size and complexity of systems increase.
- Good models promote communication among technical and nontechnical workers while ensuring good business solutions.

In other words, developing a model for a single program or an entire business system requires organization and planning. In this chapter, you learn the basics of one popular design tool, the UML, which is based on these principles. The UML, or Unified Modeling Language, allows you to envision systems with an object-oriented perspective, breaking a system into subsystems, focusing on the big picture, and hiding the implementation details. In addition, the UML provides a means for programmers and businesspeople to communicate about system design. It also provides a way to plan to divide responsibilities for large systems. Understanding the UML's principles helps you design a variety of system types and talk about systems with the people who will use them.

TIP In addition to modeling a system before creating it, system analysts sometimes model an existing system to get a better picture of its operation. Creating a model for an existing system is called **reverse engineering**.

WHAT IS UML?

The **UML** is a standard way to specify, construct, and document systems that use object-oriented methods. (The UML is a modeling language, not a programming language. The systems you develop using the UML probably will be implemented later in object-oriented programming languages such as Java, C++, C#, or Visual Basic.) As with flowcharts, pseudocode, hierarchy charts, and class diagrams, the UML has its own notation that consists of a set of specialized shapes and conventions. You can use the UML's shapes to construct different kinds of software diagrams and model different kinds of systems. Just as you can use a flowchart or hierarchy chart to diagram real-life activities, organizational relationships, or computer programs, you also can use the UML for many purposes, including modeling business activities, organizational processes, or software systems.

TIP

The UML was created at Rational Software by Grady Booch, Ivar Jacobson, and Jim Rumbaugh. The Object Management Group (OMG) adopted the UML as a standard for software modeling in 1997. The OMG includes more than 800 software vendors, developers, and users who seek a common architectural framework for object-oriented programming. The UML is in its second version, known as UML 2.0. You can view or download the entire UML specification and usage guidelines from the OMG at *www.uml.org*.

TIP

You can purchase compilers for most programming languages from a variety of manufacturers. Similarly, you can purchase a variety of tools to help you create UML diagrams, but the UML itself is vendor-independent.

When you draw a flowchart or write pseudocode, your purpose is to illustrate the individual steps in a process. When you draw a hierarchy chart, you use more of a "big picture" approach. As with a hierarchy chart, you use the UML to create top-view diagrams of business processes that let you hide details and focus on functionality. This approach lets you start with a generic view of an application and introduce details and complexity later. UML diagrams are useful as you begin designing business systems, when customers who are not technically oriented must accurately communicate with the technical staff members who will create the actual systems. The UML was intentionally designed to be nontechnical so that developers, customers, and implementers (programmers) could all "speak the same language." If business and technical people can agree on what a system should do, the chances improve that the final product will be useful.

The UML is very large; its documentation is more than 800 pages. The UML provides 13 diagram types that you can use to model systems. Each of the diagram types lets you see a business process from a different angle, and appeals to a different type of user. Just as an architect, interior designer, electrician, and plumber use different diagram types to describe the same building, different computer users appreciate different perspectives. For example, a business user most values a system's use case diagrams because they illustrate who is doing what. On the other hand, programmers find class and object diagrams more useful because they help explain details of how to build classes and objects into applications.

The UML superstructure defines six structure diagrams, three behavior diagrams, and four interaction diagrams. The 13 UML diagram types are:

- **Structure diagrams**
  - Class diagrams
  - Object diagrams
  - Component diagrams
  - Composite structure diagrams
  - Package diagrams
  - Deployment diagrams
- **Behavior diagrams**
  - Use case diagrams
  - Activity diagrams
  - State machine diagrams
- **Interaction diagrams**
  - Sequence diagrams
  - Communication diagrams
  - Timing diagrams
  - Interaction overview diagrams

TIP

You can categorize UML diagrams as those that illustrate the dynamic, or changing, aspects of a system and those that illustrate the static, or steady, aspects of a system. Dynamic diagrams include use case, sequence, communication, state machine, and activity diagrams. Static diagrams include class, object, component, and deployment diagrams.

TIP

In UML 1.5, communication diagrams were called collaboration diagrams, and state machine diagrams were called statechart diagrams.

Each of the UML diagram types supports multiple variations, and explaining them all would require an entire textbook. This chapter presents an overview and simple examples of several diagram types, which provides a good foundation for further study of the UML.

TIP

The UML Web site, at *www.uml.org*, provides links to several UML tutorials.

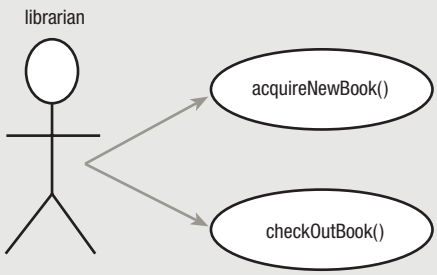
USING USE CASE DIAGRAMS

The **use case diagram** shows how a business works from the perspective of those who approach it from the outside, or those who actually use the business. This category includes many types of users—for example, employees, customers, and suppliers. Although users can also be governments, private organizations, machines, or other systems, it is easiest to think of them as people, so users are called actors and are represented by stick figures in use case diagrams. The actual use cases are represented by ovals.

Use cases do not necessarily represent all the functions of a system; they are the system functions or services that are visible to the system's actors. In other words, they represent the cases by which an actor uses and presumably benefits from the system. Determining all the cases for which users interact with systems helps you divide a system logically into functional parts.

Establishing use cases usually follows from analyzing the main events in a system. For example, from a librarian's point of view, two main events are `acquireNewBook()` and `checkOutBook()`. Figure 15-1 shows a use case diagram for these two events.

FIGURE 15-1: USE CASE DIAGRAM FOR LIBRARIAN



TIP

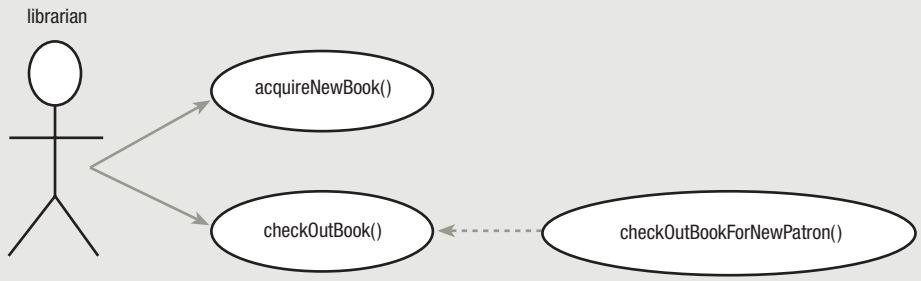
Many system developers would use the standard English form to describe activities in their UML diagrams—for example, `check out book` instead of `checkOutBook()`, which looks like a programming method call. Because you are used to seeing method names in camel casing and with trailing parentheses throughout this book, this discussion of the UML continues with the same format.

In many systems, there are variations in use cases. The three possible types of variations are:

- Extend
- Include
- Generalization

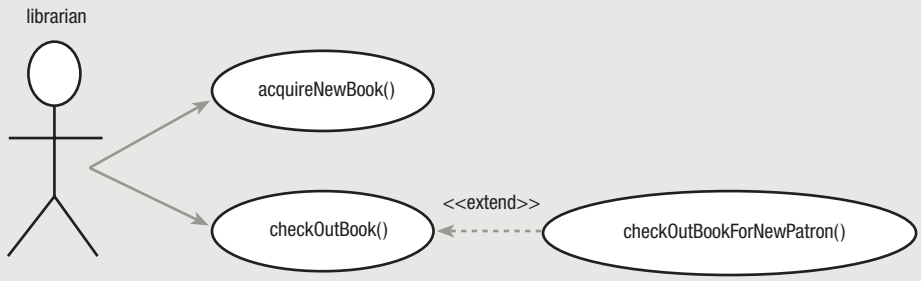
An **extend variation** is a use case variation that shows functions beyond those found in a base case. In other words, an extend variation is usually an optional activity. For example, checking out a book for a new library patron who doesn't have a library card is slightly more complicated than checking out a book for an existing patron. Each variation in the sequence of actions required in a use case is a **scenario**. Each use case has at least one main scenario, but might have several more that are extensions or variations of the main one. Figure 15-2 shows how you would diagram the relationship between the use case `checkOutBook()` and the more specific scenario `checkOutBookForNewPatron()`. Extended use cases are shown in an oval with a dashed arrow pointing to the more general base case.

FIGURE 15-2: USE CASE DIAGRAM FOR LIBRARIAN, WITH SCENARIO EXTENSION



For clarity, you can add "<<extend>>" near the line that shows a relationship extension. Such a feature, which adds to the UML vocabulary of shapes to make them more meaningful for the reader, is called a **stereotype**. Figure 15-3 includes a stereotype.

FIGURE 15-3: USE CASE DIAGRAM FOR LIBRARIAN, USING STEREOTYPE



In addition to extend relationships, use case diagrams also can show include relationships. You use an **include variation** when a case can be part of multiple use cases. This concept is very much like that of a subroutine or submodule. You show an include use case in an oval with a dashed arrow pointing to the subroutine use case. For example, `issueLibraryCard()` might be a function of `checkOutBook()`, which is used when the patron checking out a book is new, but it might also be a function of `registerNewPatron()`, which occurs when a patron registers at the library but does not want to check out books yet. See Figure 15-4.

You use a **generalization variation** when a use case is less specific than others, and you want to be able to substitute the more specific case for a general one. For example, a library has certain procedures for acquiring new materials, whether they are videos, tapes, CDs, hardcover books, or paperbacks. However, the procedures might become more specific during a particular acquisition—perhaps the librarian must procure plastic cases for circulating videos or assign locked storage locations for CDs. Figure 15-5 shows the generalization `acquireNewItem()` with two more specific situations: acquiring videos and acquiring CDs. The more specific scenarios are attached to the general scenario with open-headed dashed arrows.

FIGURE 15-4: USE CASE DIAGRAM FOR LIBRARIAN, USING INCLUDE RELATIONSHIP

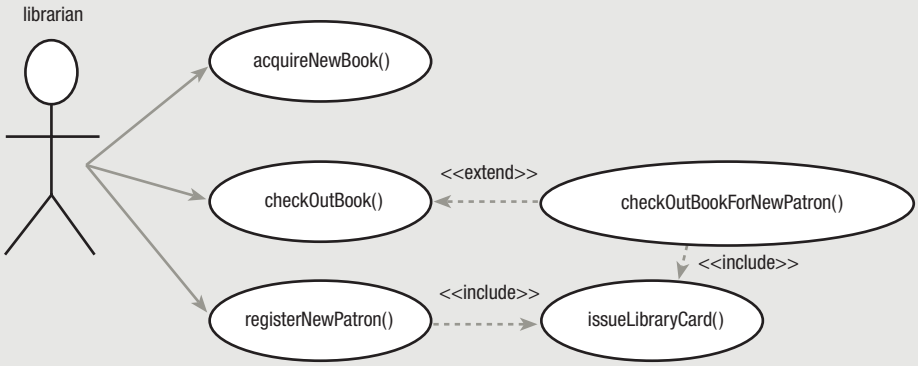
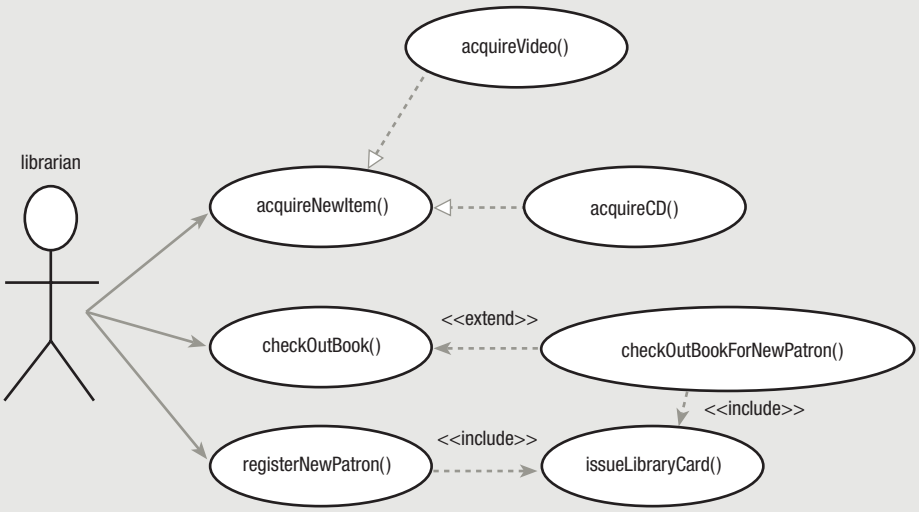
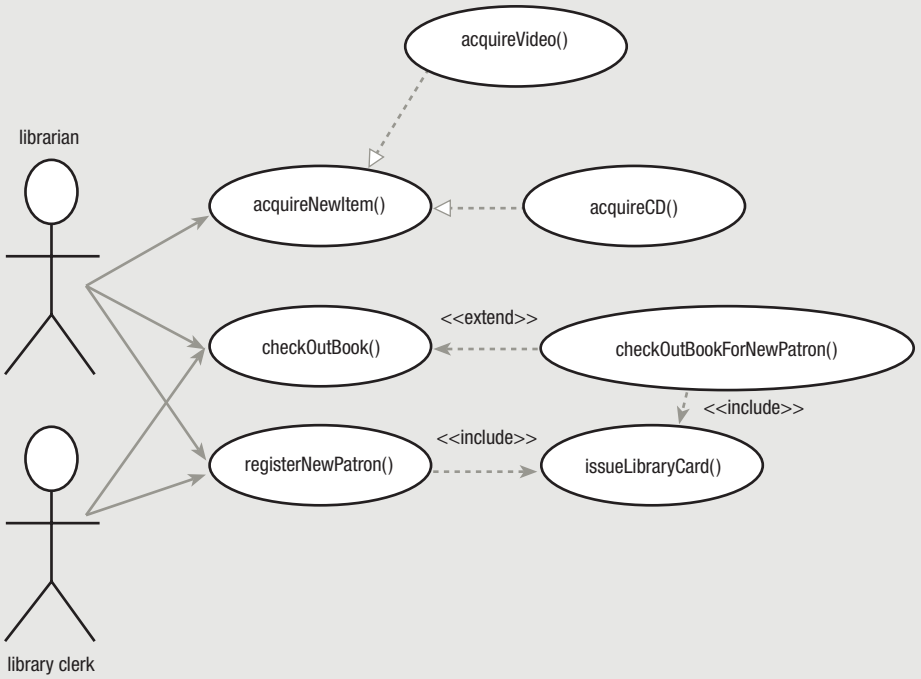


FIGURE 15-5: USE CASE DIAGRAM FOR LIBRARIAN, WITH GENERALIZATIONS



Many use case diagrams show multiple actors. For example, Figure 15-6 shows that a library clerk cannot perform as many functions as a librarian; the clerk can check out books and register new patrons but cannot acquire new materials.

FIGURE 15-6: USE CASE DIAGRAM FOR LIBRARIAN, WITH MULTIPLE ACTORS



While designing an actual library system, you could add many more use cases and actors to the use case diagram. The purpose of such a diagram is to encourage discussion between the system developer and the library staff. Library staff members do not need to know any of the technical details of the system that the analysts will eventually create, and they certainly do not need to understand computers or programming. However, by viewing the use cases, the library staff can visualize activities they perform while doing their jobs and correct the system developer if inaccuracies exist. The final software products developed for such a system are far more likely to satisfy users than those developed without this design step.

A use case diagram is only a tool to aid communication. No single "correct" use case diagram exists; you might correctly represent a system in several ways. For example, you might choose to emphasize the actors in the library system, as shown in Figure 15-7, or to emphasize system requirements, as shown in Figure 15-8. Diagrams that are too crowded are neither visually pleasing nor very useful. Therefore, the use case diagram in Figure 15-7 shows all the specific actors and their relationships, but purposely omits more specific system functions, whereas Figure 15-8 shows many actions that are often hidden from users but purposely omits more specific actors. For example, the activities carried out to `manageNetworkOutage()`, if done properly, should be invisible to library patrons checking out books.

FIGURE 15-7: USE CASE DIAGRAM EMPHASIZING ACTORS

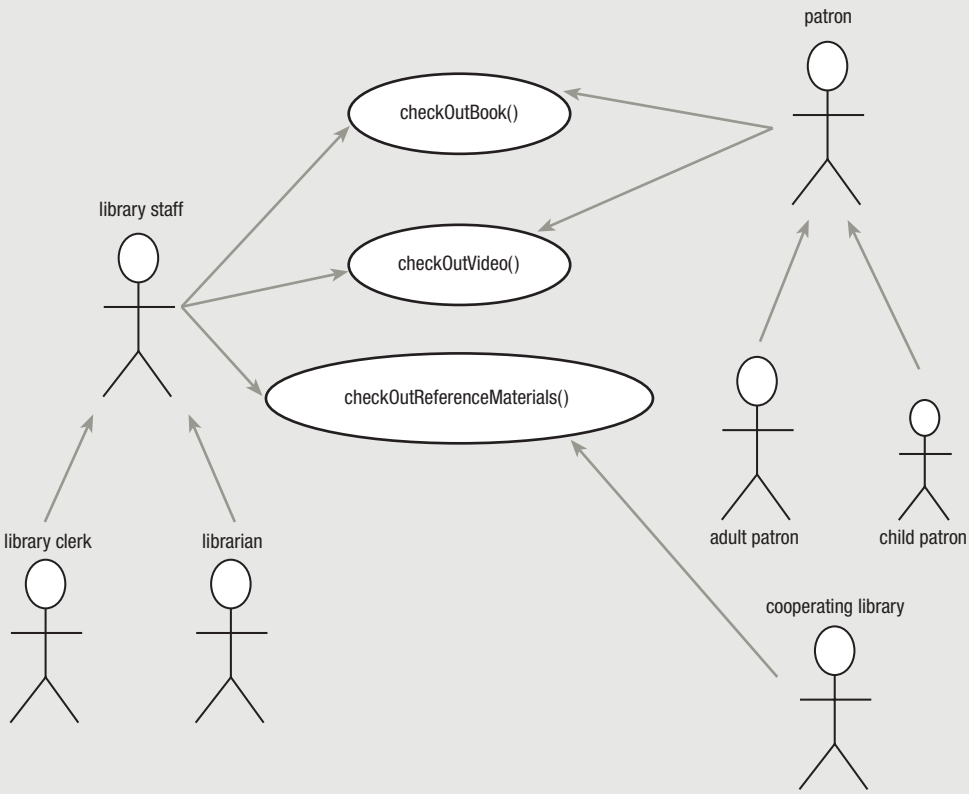
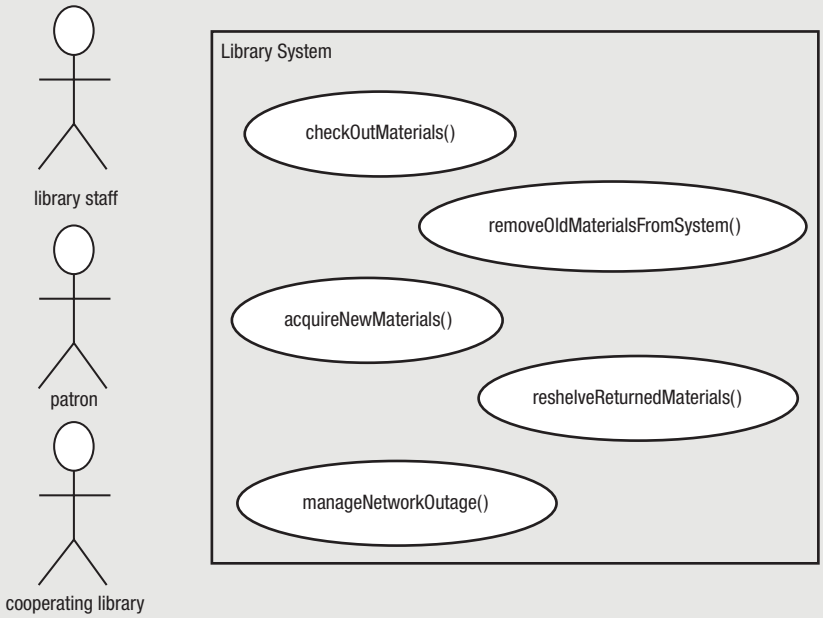


FIGURE 15-8: USE CASE DIAGRAM EMPHASIZING SYSTEM REQUIREMENTS



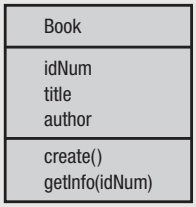
In Figure 15-8, the relationship lines between the actors and use cases have been removed because the emphasis is on the system requirements, and too many lines would make the diagram confusing. When system developers omit parts of diagrams for clarity, they refer to the missing parts as **elided**. For the sake of clarity, eliding extraneous information is perfectly acceptable. The main purpose of UML diagrams is to facilitate clear communication.

USING CLASS AND OBJECT DIAGRAMS

You use a class diagram to illustrate the names, attributes, and methods of a class or set of classes. Class diagrams are more useful to a system's programmers than to its users because they closely resemble code the programmers will write. A class diagram illustrating a single class contains a rectangle divided into three sections: the top section contains the name of the class, the middle section contains the names of the attributes, and the bottom section contains the names of the methods. Figure 15-9 shows the class diagram for a `Book` class. Each `Book` object contains an `idNum`, `title`, and `author`. Each `Book` object also contains methods to create a `Book` when it is acquired and to retrieve or get `title` and `author` information when the `Book` object's `idNum` is supplied.

TIP You first used class diagrams in Chapter 13.

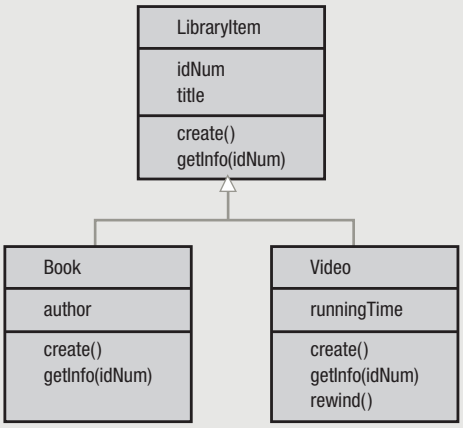
FIGURE 15-9: `Book` CLASS DIAGRAM



In the preceding section, you learned how to use generalizations with use case diagrams to show general and more specific use cases. With use case diagrams, you drew an open-headed arrow from the more specific case to the more general one. Similarly, you can use generalizations with class diagrams to show more general (or parent) classes and more specific (or child) classes that inherit attributes from parents. For example, Figure 15-10 shows `Book` and `Video` classes that are more specific than the general `LibraryItem` class. All `LibraryItem` objects contain an `idNum` and `title`, but each `Book` item also contains an `author`, and each `Video` item also contains a `runningTime`. In addition, `Video` items contain a `rewind()` method not found in the more general `LibraryItem` class. Child classes contain all the attributes of their parents and usually contain additional attributes not found in the parent.

TIP You first learned about inheritance and parent and child classes in Chapter 13. There, you learned that the `create()` and `getInfo()` methods in the `Book` and `Video` classes override the version in the `LibraryItem` class.

FIGURE 15-10: `LibraryItem` CLASS DIAGRAM SHOWING GENERALIZATION



Class diagrams can include symbols that show the relationships between objects. You can show two types of relationships:

- An association relationship
- A whole-part relationship

An **association relationship** describes the connection or link between objects. You represent an association relationship between classes with a straight line. Frequently, you include information about the arithmetical relationship or ratio (called **cardinality** or **multiplicity**) of the objects. For example, Figure 15-11 shows the association relationship between a `Library` and the `LibraryItem`s it lends. Exactly one `Library` object exists, and it can be associated with any number of `LibraryItem`s from 0 to infinity, which is represented by an asterisk. Figure 15-12 adds the `Patron` class to the diagram and shows how you indicate that any number of `Patron`s can be associated with the `Library`, but that each `Patron` can borrow only up to five `LibraryItem`s at a time, or currently might not be borrowing any. In addition, each `LibraryItem` can be associated with at most one `Patron`, but at any given time might not be on loan.

FIGURE 15-11: CLASS DIAGRAM WITH ASSOCIATION RELATIONSHIP

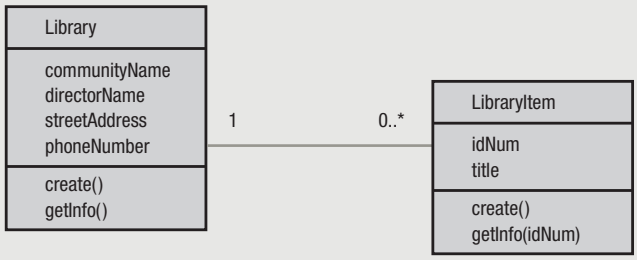
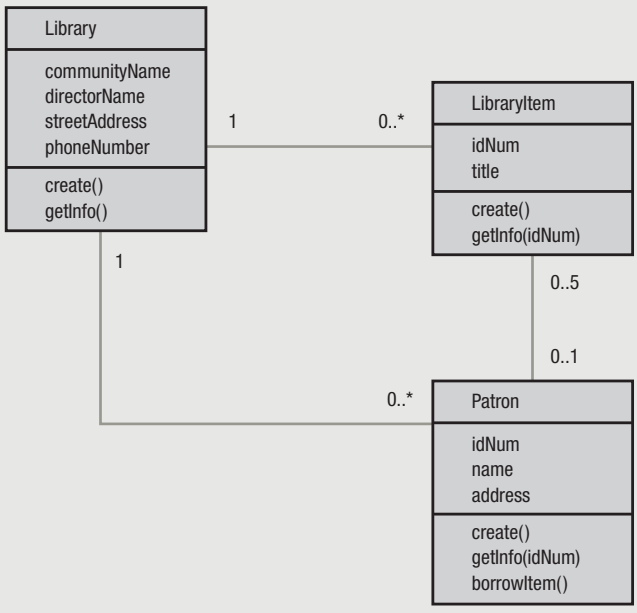
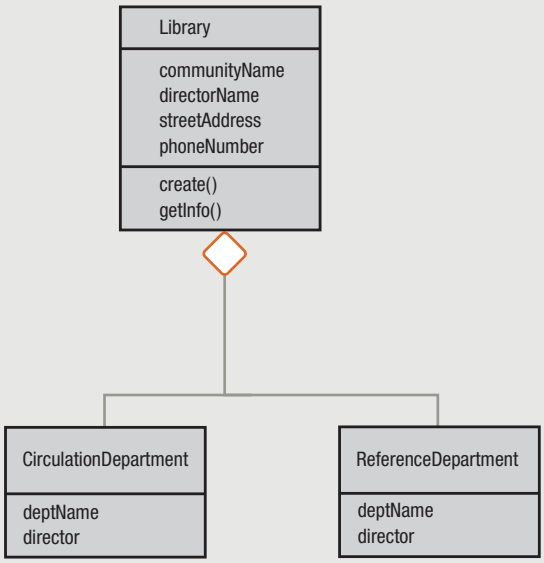


FIGURE 15-12: CLASS DIAGRAM WITH SEVERAL ASSOCIATION RELATIONSHIPS



A **whole-part relationship** describes an association in which one or more classes make up the parts of a larger whole class. For example, 50 states "make up" the United States, and 10 departments might "make up" a company. This type of relationship is also called an **aggregation** and is represented by an open diamond at the "whole part" end of the line that indicates the relationship. You also can call a whole-part relationship a **has-a relationship** because the phrase describes the association between the whole and one of its parts; for example, "The library has a Circulation Department." Figure 15-13 shows a whole-part relationship for a `Library`.

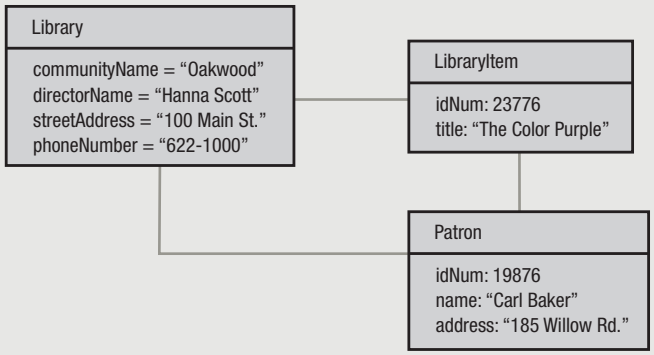
FIGURE 15-13: CLASS DIAGRAM WITH WHOLE-PART RELATIONSHIP



Object diagrams are similar to class diagrams, but they model specific instances of classes. You use an object diagram to show a snapshot of an object at one point in time, so you can more easily understand its relationship to other objects. Imagine looking at the travelers in a major airport. If you try to watch them all at once, you see a flurry of activity, but it is hard to understand all the tasks (buying a ticket, checking luggage, and so on) a traveler must accomplish to take a trip. However, if you concentrate on one traveler and follow his or her actions through the airport from arrival to takeoff, you get a clearer picture of the required activities. An object diagram serves the same purpose; you concentrate on a specific instance of a class to better understand how a class works.

Figure 15-14 contains an object diagram showing the relationship between one `Library`, `LibraryItem`, and `Patron`. Notice the similarities between Figures 15-12 and 15-14. If you need to describe the relationship between three classes, you can use either model—a class diagram or an object diagram—interchangeably. You simply use the model that seems clearer to you and your intended audience.

FIGURE 15-14: OBJECT DIAGRAM FOR `Library`

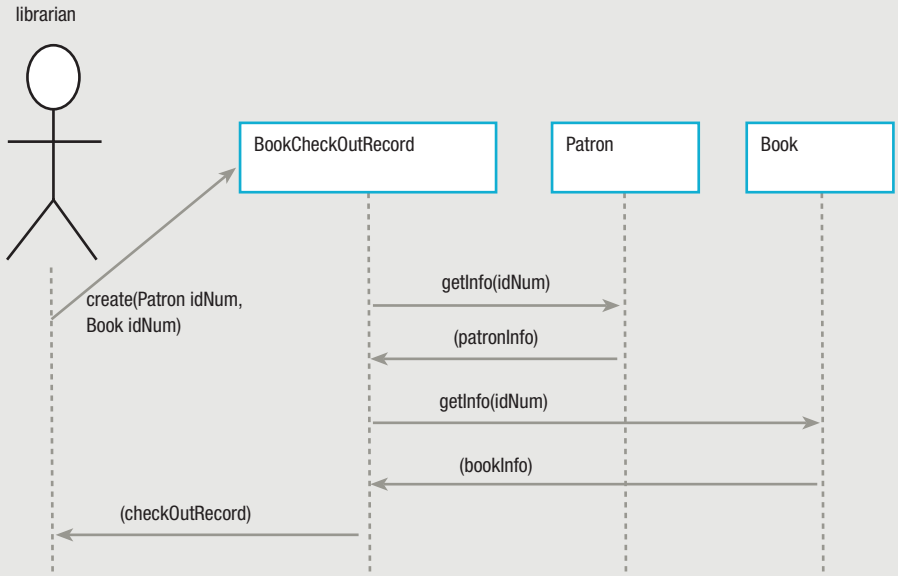


USING SEQUENCE AND COMMUNICATION DIAGRAMS

You use a **sequence diagram** to show the timing of events in a single use case. A sequence diagram makes it easier to see the order in which activities occur. The horizontal axis (x-axis) of a sequence diagram represents objects, and the vertical axis (y-axis) represents time. You create a sequence diagram by placing objects that are part of an activity across the top of the diagram along the x-axis, starting at the left with the object or actor that begins the action. Beneath each object on the x-axis, you place a vertical dashed line that represents the period of time the object exists. Then, you use horizontal arrows to show how the objects communicate with each other over time.

For example, Figure 15-15 shows a sequence diagram for a scenario that a librarian can use to create a book check-out record. The librarian begins a `create()` method with `Patron idNum` and `Book idNum` information. The `BookCheckOutRecord` object requests additional `Patron` information (such as `name` and `address`) from the `Patron` object with the correct `Patron idNum`, and additional `Book` information (such as `title` and `author`) from the `Book` object with the correct `Book idNum`. When `BookCheckOutRecord` contains all the data it needs, a completed record is returned to the librarian.

FIGURE 15-15: SEQUENCE DIAGRAM FOR CHECKING OUT A `Book` FOR A `Patron`

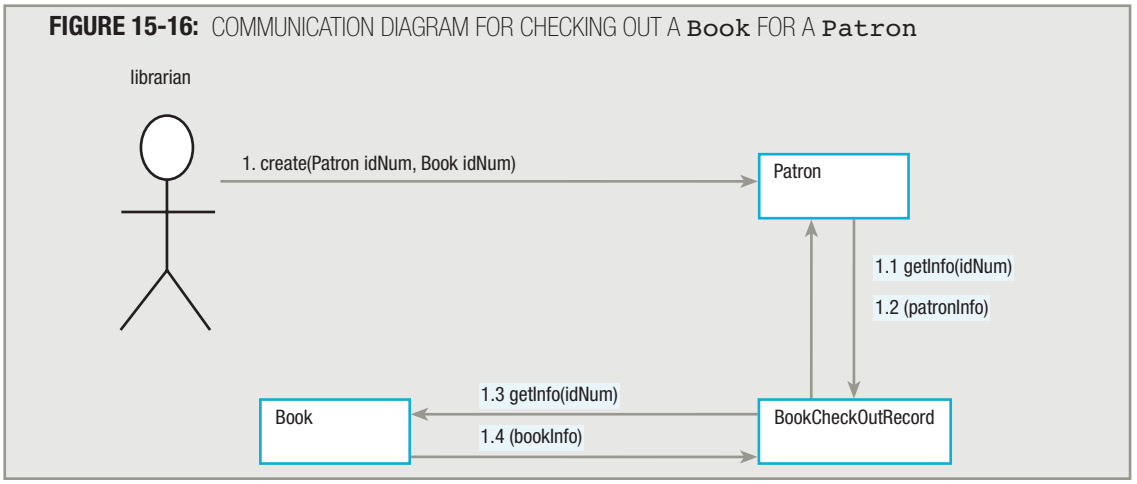


TIP

In Figures 15-15 and 15-16, `patronInfo` and `bookInfo` represent group items that contain all of a `Patron`'s and `Book`'s data. For example, `patronInfo` might contain `idNum`, `lastName`, `firstName`, `address`, and `phoneNumber`, all of which have been defined as attributes of that class.

A **communication diagram** emphasizes the organization of objects that participate in a system. It is similar to a sequence diagram, except that it contains sequence numbers to represent the precise order in which activities occur. Communication diagrams focus on object roles instead of the times that messages are sent. Figure 15-16 shows the same sequence of events as Figure 15-15, but the steps to creating a `BookCheckOutRecord` are clearly numbered (see the shaded sections of the figure). Decimal numbered steps (1.1, 1.2, and so on) represent substeps of the main steps. Checking out a library book is a fairly straightforward event, so a sequence diagram sufficiently illustrates the process. Communication diagrams become more useful with more complicated systems.

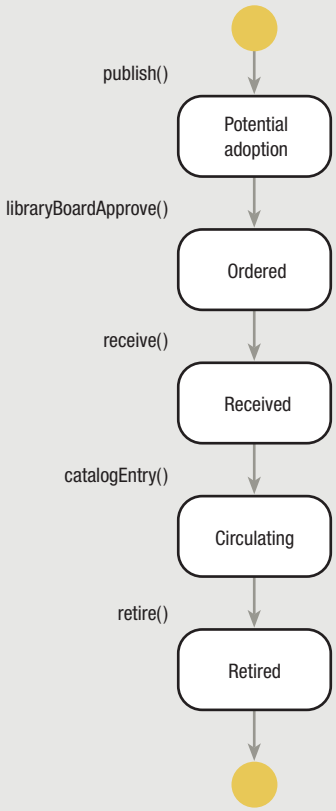
FIGURE 15-16: COMMUNICATION DIAGRAM FOR CHECKING OUT A `Book` FOR A `Patron`



USING STATE MACHINE DIAGRAMS

A **state machine diagram** shows the different statuses of a class or object at different points in time. You use a state machine diagram to illustrate aspects of a system that show interesting changes in behavior as time passes. Conventionally, you use rounded rectangles to represent each state and labeled arrows to show the sequence in which events affect the states. A solid dot indicates the start and stop states for the class or object. Figure 15-17 contains a state machine diagram you can use to describe the states of a `Book`.

FIGURE 15-17: STATE MACHINE DIAGRAM FOR `Book` CLASS



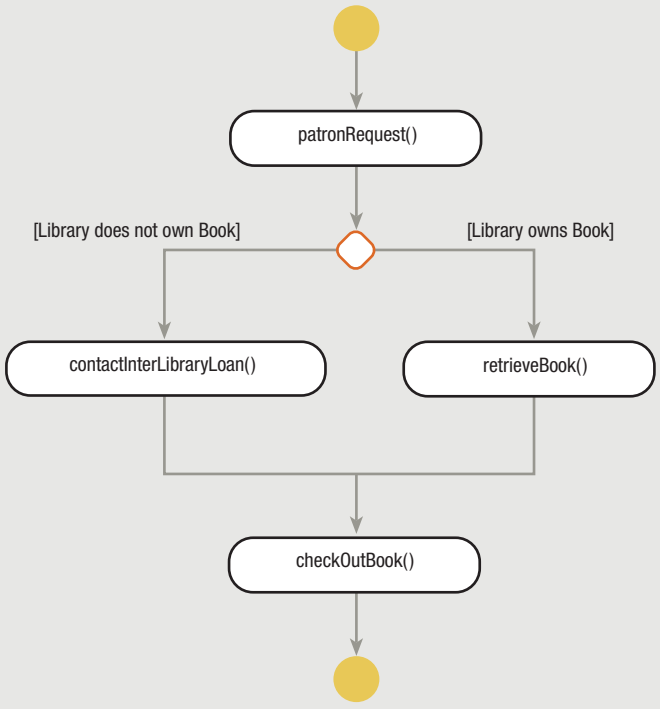
TIP

So that your diagrams are clear, you should use the correct symbol in each UML diagram you create, just as you should use the correct symbol in each program flowchart. However, if you create a flowchart and use a rectangle for an input or output statement where a parallelogram is conventional, others will still understand your meaning. Similarly, with UML diagrams, the exact shape you use is not nearly as important as the sequence of events and relationships between objects.

USING ACTIVITY DIAGRAMS

The UML diagram that most closely resembles a conventional flowchart is an activity diagram. In an **activity diagram**, you show the flow of actions of a system, including branches that occur when decisions affect the outcome. Conventionally, activity diagrams use flowchart start and stop symbols (called lozenges) to describe actions and solid dots to represent start and stop states. Like flowcharts, activity diagrams use diamonds to describe decisions. Unlike the diamonds in flowcharts, the diamonds in UML activity diagrams usually are empty; the possible outcomes are documented along the branches emerging from the decision symbol. As an example, Figure 15-18 shows a simple activity diagram with a single branch.

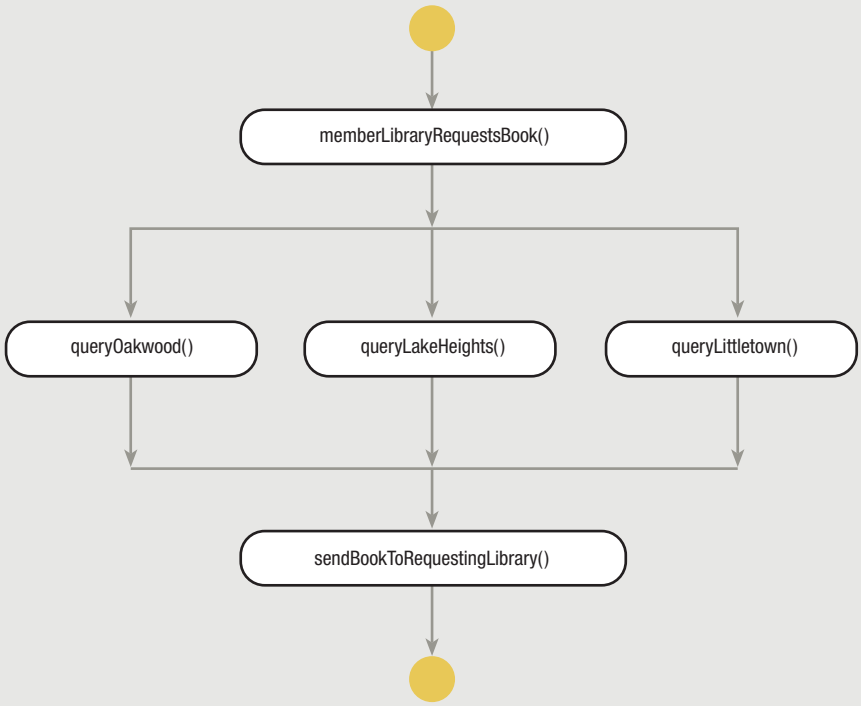
FIGURE 15-18: ACTIVITY DIAGRAM SHOWING BRANCH



TIP In the first version of the UML (UML 1.0), each lozenge was an activity. In the second version (UML 2.0), each lozenge is an action and a group of actions is an activity.

Many real-life systems contain actions that are meant to occur simultaneously. For example, when you apply for a home mortgage with a bank, a bank officer might perform a credit or background check while an appraiser determines the value of the house you are buying. When both actions are complete, the loan process continues. UML activity diagrams use forks and joins to show simultaneous activities. A fork is similar to a decision, but whereas the flow of control follows only one path after a decision, a fork defines a branch in which all paths are followed simultaneously. A join, as its name implies, reunites the flow of control after a fork. You indicate forks and joins with thick straight lines. Figure 15-19 shows how you might model the way an interlibrary loan system processes book requests. When a request is received, simultaneous searches begin at three local libraries that are part of the library system.

FIGURE 15-19: ACTIVITY DIAGRAM SHOWING FORK AND JOIN

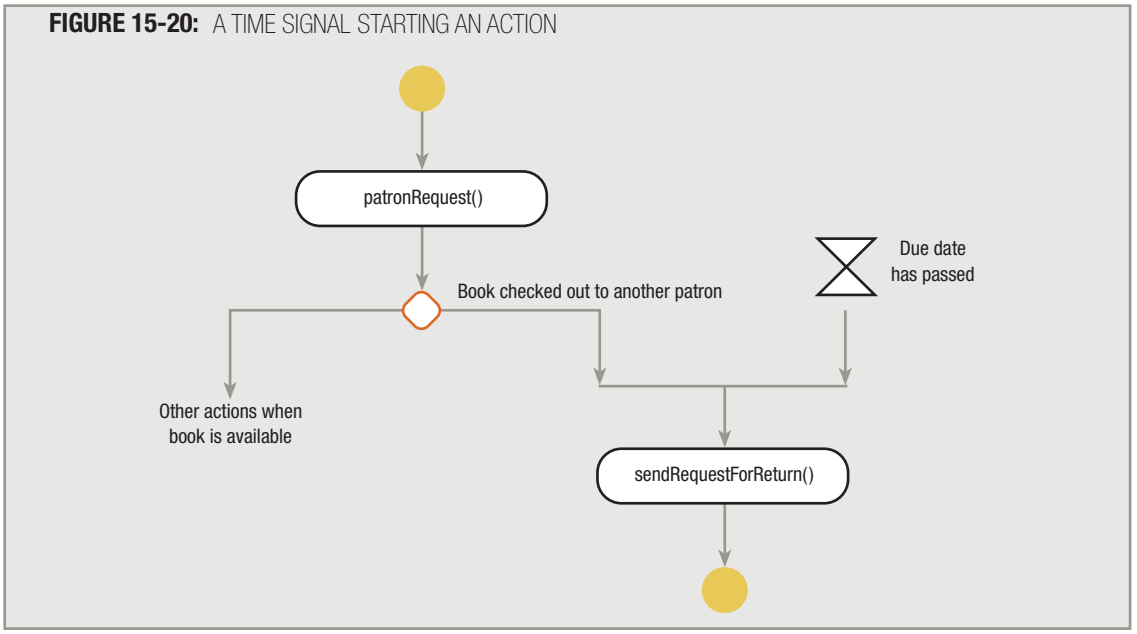


TIP A fork does not have to indicate strictly simultaneous activity. The actions in the branches for a fork might only be concurrent or interleaved.

An activity diagram can contain a time signal. A **time signal** indicates that a specific amount of time has passed before an action is started. The time signal looks like two stacked triangles (resembling the shape of an hourglass). Figure 15-20 shows a time signal indicating that if a patron requests a book, and the book is checked out to another patron, then only if the book's due date has passed should a request to return the book be issued. In activity diagrams for other systems, you might see explanations at time signals, such as "10 hours have passed" or "at least January 1st". If an action is time-dependent, whether by a fraction of a second or by years, using a time signal is appropriate.

TIP The time signal is a new feature in UML 2.0.

FIGURE 15-20: A TIME SIGNAL STARTING AN ACTION



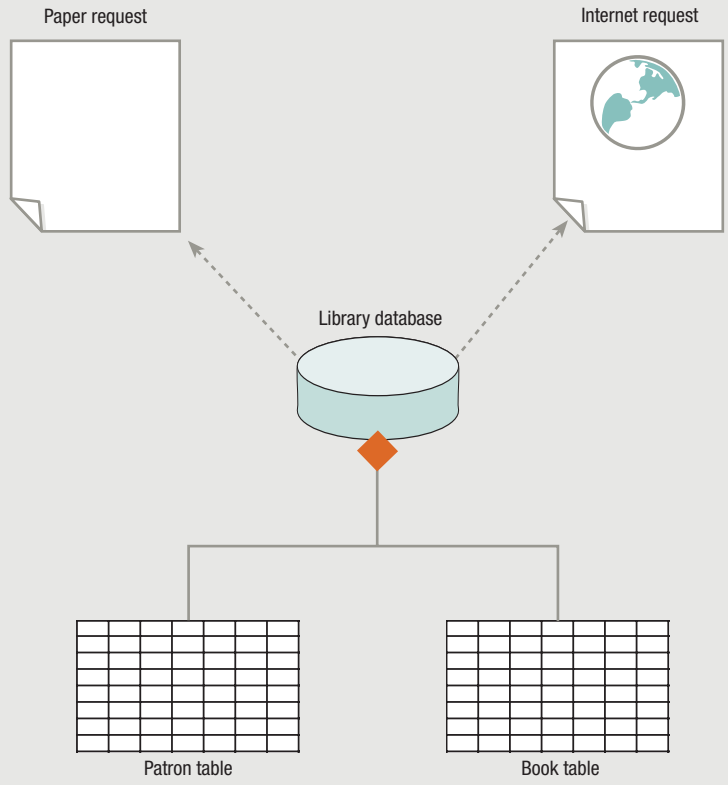
TIP

The connector is a recently introduced symbol to the UML. It is a small circle used to connect diagrams that are continued on a new page. It is identical to the flowchart connector symbol you learned about in Chapter 1.

USING COMPONENT AND DEPLOYMENT DIAGRAMS

Component and deployment diagrams model the physical aspects of systems. You use a **component diagram** when you want to emphasize the files, database tables, documents, and other components that a system's software uses. You use a **deployment diagram** when you want to focus on a system's hardware. You can use a variety of icons in each type of diagram, but each icon must convey meaning to the reader. Figures 15-21 and 15-22 show component and deployment diagrams that illustrate aspects of a library system. Figure 15-21 contains icons that symbolize paper and Internet requests for library items, the library database, and two tables that constitute the database. Figure 15-22 shows some commonly used icons that represent hardware components.

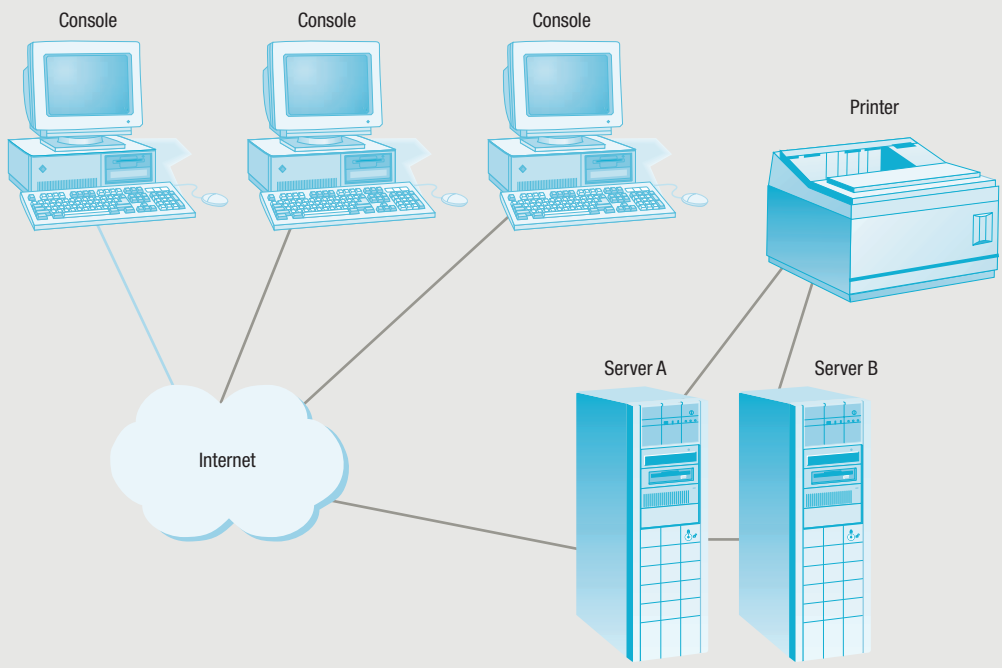
FIGURE 15-21: COMPONENT DIAGRAM



TIP

In Figure 15-21, notice the filled diamond connecting the two tables to the database. Just as it does in a class diagram, the diamond aggregation symbol shows the whole-part relationship of the tables to the database. You use an open diamond when a part might belong to several wholes (for example, `Door` and `Wall` objects belong to many `House` objects), but you use a filled diamond when a part can belong to only one whole at a time (the `Patron` table can belong only to the `Library` database). You can use most UML symbols in multiple types of diagrams.

FIGURE 15-22: DEPLOYMENT DIAGRAM



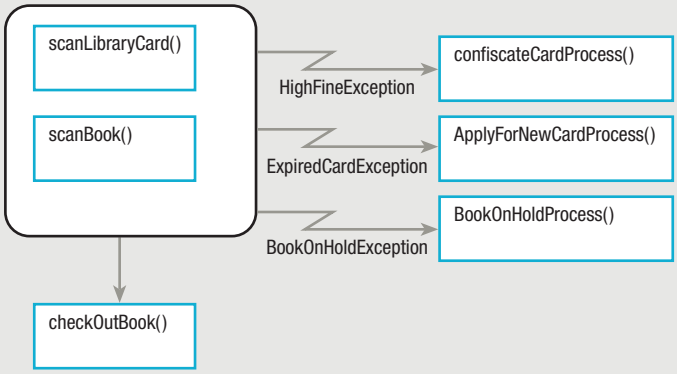
DIAGRAMMING EXCEPTION HANDLING

Exception handling is a set of the object-oriented techniques used to handle program errors. In Chapter 14, you learned that when a segment of code might cause an error, you can place that code in a `try` block. If the error occurs, an object called an exception is thrown, or sent, to a `catch` block where appropriate action can be taken. For example, depending on the application, a `catch` block might display a message, assign a default value to a field, or prompt the user for direction.

In the UML, a `try` block is called a **protected node** and a `catch` block is a **handler body node**. In a UML diagram, a protected node is enclosed in a rounded rectangle and any exceptions that might be thrown are listed next to lightning-bolt-shaped arrows that extend to the appropriate handler body node.

Figure 15-23 shows an example of an activity that uses exception handling. When a library patron tries to check out a book, the patron's card is scanned and the book is scanned. These actions might cause three errors—the patron owes fines, and so cannot check out new books; the patron's card has expired, requiring a new card application; or the book might be on hold for another patron. If no exceptions occur, the activity proceeds to the `checkOutBook()` process.

FIGURE 15-23: EXCEPTIONS IN THE BOOK CHECK-OUT ACTIVITY



DECIDING WHICH UML DIAGRAMS TO USE

Each of the UML diagram types provides a different view of a system. Just as a portrait artist, psychologist, and neurosurgeon each prefer a different conceptual view of your head, the users, managers, designers, and technicians of computer and business systems each prefer specific system views. Very few systems require diagrams of all 13 types; you can illustrate the objects and activities of many systems by using a single diagram, or perhaps one that is a hybrid of two or more basic types. No view is superior to the others; you can achieve the most complete picture of any system by using several views. The most important reason you use any UML diagram is to communicate clearly and efficiently with the people for whom you are designing a system.

CHAPTER SUMMARY

- System design is the detailed specification of how all the parts of a system will be implemented and coordinated. Good designs make systems easier to understand. The UML (Unified Modeling Language) provides a means for programmers and businesspeople to communicate about system design.
- The UML is a standard way to specify, construct, and document systems that use object-oriented methods. The UML has its own notation, with which you can construct software diagrams that model different kinds of systems. The UML provides 13 diagram types that you use at the beginning of the design process.
- A use case diagram shows how a business works from the perspective of those who approach it from the outside, or those who actually use the business. The diagram often includes actors, represented by stick figures, and use cases, represented by ovals. Use cases can include variations such as extend relationships, include relationships, and generalizations.
- You use a class diagram to illustrate the names, attributes, and methods of a class or set of classes. A class diagram of a single class contains a rectangle divided into three sections: the name of the class, the names of the attributes, and the names of the methods. Class diagrams can show generalizations and the relationships between objects. Object diagrams are similar to class diagrams, but they model specific instances of classes at one point in time.
- You use a sequence diagram to show the timing of events in a single use case. The horizontal axis (x-axis) of a sequence diagram represents objects, and the vertical axis (y-axis) represents time. A communication diagram emphasizes the organization of objects that participate in a system. It is similar to a sequence diagram, except that it contains sequence numbers to represent the precise order in which activities occur.
- A state machine diagram shows the different statuses of a class or object at different points in time.
- In an activity diagram, you show the flow of actions of a system, including branches that occur when decisions affect the outcome. UML activity diagrams use forks and joins to show simultaneous activities.
- You use a component diagram when you want to emphasize the files, database tables, documents, and other components that a system's software uses. You use a deployment diagram when you want to focus on a system's hardware.
- Each of the UML diagram types provides a different view of a system. Very few systems require diagrams of all 13 types; the most important reason to use any UML diagram is to communicate clearly and efficiently with the people for whom you are designing a system.

KEY TERMS

System design is the detailed specification of how all the parts of a system will be implemented and coordinated.

Reverse engineering is the process of creating a model of an existing system.

The **UML** is a standard way to specify, construct, and document systems that use object-oriented methods. UML is an acronym for Unified Modeling Language.

The **use case diagram** is a UML diagram that shows how a business works from the perspective of those who approach it from the outside, or those who actually use the business.

An **extend variation** is a use case variation that shows functions beyond those found in a base case.

Each variation in the sequence of actions required in a use case is a **scenario**.

A feature that adds to the UML vocabulary of shapes to make them more meaningful for the reader is called a **stereotype**.

An **include variation** is a use case variation that you use when a case can be part of multiple use cases in a UML diagram.

You use a **generalization variation** in a UML diagram when a use case is less specific than others, and you want to be able to substitute the more specific case for a general one.

When system developers omit parts of UML diagrams for clarity, they refer to the missing parts as **elided**.

An **association relationship** describes the connection or link between objects in a UML diagram.

Cardinality and **multiplicity** refer to the arithmetic relationships between objects.

A **whole-part relationship** describes an association in which one or more classes make up the parts of a larger whole class. This type of relationship is also called an **aggregation**. You also can call a whole-part relationship a **has-a relationship** because the phrase describes the association between the whole and one of its parts.

Object diagrams are UML diagrams that are similar to class diagrams, but they model specific instances of classes.

A **sequence diagram** is a UML diagram that shows the timing of events in a single use case.

A **communication diagram** is a UML diagram that emphasizes the organization of objects that participate in a system.

A **state machine diagram** is a UML diagram that shows the different statuses of a class or object at different points in time.

An **activity diagram** is a UML diagram that shows the flow of actions of a system, including branches that occur when decisions affect the outcome.

A **time signal** is a UML diagram symbol that indicates that a specific amount of time has passed before an action is started.

A **component diagram** is a UML diagram that emphasizes the files, database tables, documents, and other components that a system's software uses.

A **deployment diagram** is a UML diagram that focuses on a system's hardware.

A **protected node** is the UML diagram name for an exception-throwing `try` block.

A **handler body node** is the UML diagram name for an exception-handling `catch` block.

REVIEW QUESTIONS

1. **The detailed specification of how all the parts of a system will be implemented and coordinated is called _____.**
   a. programming
   b. paraphrasing
   c. system design
   d. structuring

2. **The primary purpose of good modeling techniques is to _____.**
   a. promote communication
   b. increase functional cohesion
   c. reduce the need for structure
   d. reduce dependency between modules

3. **The Unified Modeling Language provides standard ways to do all of the following to business systems except to _____ them.**
   a. construct
   b. document
   c. describe
   d. destroy

4. **The UML is commonly used to model all of the following except _____.**
   a. computer programs
   b. business activities
   c. organizational processes
   d. software systems

5. **The UML was intentionally designed to be _____.**
   a. low-level, detail-oriented
   b. used with Visual Basic
   c. nontechnical
   d. inexpensive

6. **The UML diagrams that show how a business works from the perspective of those who actually use the business, such as employees or customers, are _____ diagrams.**
   a. communication
   b. use case
   c. state machine
   d. class

7. Which of the following is an example of a relationship that would be portrayed as an extend relationship in a use case diagram for a hospital?

a. the relationship between the head nurse and the floor nurses
b. admitting a patient who has never been admitted before
c. serving a meal
d. scheduling the monitoring of patients' vital signs

8. The people shown in use case diagrams are called _____.

a. workers
b. clowns
c. actors
d. relatives

9. One aspect of use case diagrams that makes them difficult to learn about is that _____.

a. they require programming experience to understand
b. they use a technical vocabulary
c. there is no single right answer for any case
d. all of the above

10. The arithmetic association relationship between a college student and college courses would be expressed as _____.

a. 1 0
b. 1 1
c. 1 0..*
d. 0..* 0..*

11. In the UML, object diagrams are most similar to _____ diagrams.

a. use case
b. activity
c. class
d. sequence

12. In any given situation, you should choose the type of UML diagram that is _____.

a. shorter than others
b. clearer than others
c. more detailed than others
d. closest to the programming language you will use to implement the system

13. A whole-part relationship can be described as a(n) _____ relationship.

a. parent-child
b. is-a
c. has-a
d. creates-a

14. The timing of events is best portrayed in a(n) _____ diagram.

a. sequence
b. use case
c. communication
d. association

15. A communication diagram is closest to a(n) _____ diagram.

a. activity
b. use case
c. deployment
d. sequence

16. A(n) _____ diagram shows the different statuses of a class or object at different points in time.

a. activity
b. state machine
c. sequence
d. deployment

17. The UML diagram that most closely resembles a conventional flowchart is a(n) _____ diagram.

a. activity
b. state machine
c. sequence
d. deployment

18. You use a _____ diagram when you want to emphasize the files, database tables, documents, and other components that a system's software uses.

a. state machine
b. component
c. deployment
d. use case

19. The UML diagram that focuses on a system's hardware is a(n) _____ diagram.

a. deployment
b. sequence
c. activity
d. use case

20. When using the UML to describe a single system, most designers would use _____.

a. a single type of diagram
b. at least three types of diagrams
c. most of the available types of diagrams
d. all 13 types of diagrams

FIND THE BUGS

Because of the nature of this chapter, there are no debugging exercises.

EXERCISES

1. **Complete the following tasks:**
   a. Develop a use case diagram for a convenience food store. Include an actor representing the store manager and use cases for `orderItem()`, `stockItem()`, and `sellItem()`.
   b. Add more use cases to the diagram you created in Exercise 1a. Include two generalizations for `stockItem()`: `stockPerishable()` and `stockNonPerishable()`. Also include an extension to `sellItem()` called `checkCredit()` for when a customer purchases items using a credit card.
   c. Add a customer actor to the use case diagram you created in Exercise 1b. Show that the customer participates in `sellItem()`, but not in `orderItem()` or `stockItem()`.
2. **Develop a use case diagram for a department store credit card system. Include at least two actors and four use cases.**
3. **Develop a use case diagram for a college registration system. Include at least three actors and five use cases.**
4. **Develop a class diagram for a `Video` class that describes objects a video store customer can rent. Include at least four attributes and three methods.**
5. **Develop a class diagram for a `Shape` class. Include generalizations for child classes `Rectangle`, `Circle`, and `Triangle`.**
6. **Develop a class diagram for a `BankLoan` class. Include generalizations for child classes `Mortgage`, `CarLoan`, and `EducationLoan`.**
7. **Develop a class diagram for a college registration system. Include at least three classes that cooperate to achieve student registration.**
8. **Develop a sequence diagram that shows how a clerk at a mail-order company places a customer `Order`. The `Order` accesses `Inventory` to check availability. Then, the `Order` accesses `Invoice` to produce a customer invoice that returns to the clerk.**
9. **Develop a state machine diagram that shows the states of a `CollegeStudent` from `PotentialApplicant` to `Graduate`.**
10. **Develop a state machine diagram that shows the states of a `Book` from `Concept` to `Publication`.**
11. **Develop an activity diagram that illustrates how to build a house.**
12. **Develop an activity diagram that illustrates how to prepare dinner.**

13. **Develop the UML diagram of your choice that illustrates some aspect of your life.**

14. **Complete the following tasks:**

    a. Develop the UML diagram of your choice that best illustrates some aspect of a place you have worked.
    b. Develop a different UML diagram type that illustrates the same functions as the diagram you created in Exercise 14a.

DETECTIVE WORK

1. **What are the education requirements for a career in system design? What are the job prospects and average salaries?**

2. **Find any discussion you can on the advantages and disadvantages of the UML as a system design tool. Summarize your findings.**

UP FOR DISCUSSION

1. **Which do you think you would enjoy doing more on the job—designing large systems that contain many programs, or writing the programs themselves? Why?**

2. **In Chapter 11, you considered ethical dilemmas in writing a program that selects candidates for organ transplants. Are the ethical responsibilities of a system designer different from those of a programmer? If so, how?**

16 USING RELATIONAL DATABASES

After studying Chapter 16, you should be able to:

- Understand relational database fundamentals
- Create databases and table descriptions
- Identify primary keys
- Understand database structure notation
- Understand the principles of adding, deleting, updating, and sorting records within a table
- Write queries
- Understand relationships between tables and functional dependence between columns
- Recognize poor table design
- Understand anomalies, normal forms, and the normalization process
- Understand the performance and security issues connected to database administration

UNDERSTANDING RELATIONAL DATABASE FUNDAMENTALS

When you store data items for use within computer systems, they are often stored in what is known as a data hierarchy, where the smallest usable unit of data is the character, often a letter or number. Characters are grouped together to form fields, such as `firstName`, `lastName`, and `socialSecurityNumber`. Related fields are often grouped together to form records—groups of fields that go together because they represent attributes of some entity, such as an employee, a customer, an inventory item, or a bank account. Files are composed of related records; for example, a file might contain a record for each employee in a company or each account at a bank.

TIP You first learned about the data hierarchy in Chapter 1 of this book. The terms *character*, *field*, *record*, and *file* were defined there, and you have been using these terms throughout this book.

Most organizations store many files that contain the data they need to operate their businesses; for example, businesses often need to maintain files containing data about employees, customers, inventory items, and orders. Many organizations use database software to organize the information in these files. A **database** holds a group of files that an organization needs to support its applications. In a database, the files often are called **tables** because you can arrange their contents in rows and columns. Real-life examples of database-like tables abound. For example, consider the listings in a telephone book. Each listing in a city directory might contain four columns, as shown in Figure 16-1—last name, first name, street address, and phone number. Although your local phone directory might not store its data in the rigid columnar format shown in the figure, it could. You can see that each column represents a field and that each row represents one record. You can picture a table within a database in the same way.

FIGURE 16-1: A TELEPHONE BOOK TABLE

Last name	First name	Address	Phone
Abbott	William	123 Oak Lane	490-8920
Ackerman	Kimberly	467 Elm Drive	787-2781
Adams	Stanley	8120 Pine Street	787-0129
Adams	Violet	347 Oak Lane	490-8912
Adams	William	12 Second Street	490-3667

TIP One record or row is also sometimes called an **entity**; however, many definitions of "entity" exist in database texts. One column (field) can also be called an **attribute**.

Figure 16-1 includes five records, each representing a unique person. It is relatively easy to scan this short list of names to find a person's phone number; of course, telephone books contain many more records. Some telephone book users, such as telemarketers or even the phone company, might prefer to look up a number in a book in which the records are organized in telephone-number order. Others, such as door-to-door salespeople, might prefer a telephone book in which the records are organized in street-address order. Most people, however, prefer a telephone book in

which the records are organized as shown, in alphabetical order by last name. It is most convenient for different users when computerized databases can sort records in various orders based on the contents of different columns.

Unless you are reading a telephone book for a very small town, a last name alone often is not sufficient to identify a person. In the example in Figure 16-1, three people have the last name of Adams. For these records, you need to examine the first name before you can determine the correct phone number. In a large city, many people might have the same first and last names; in that case, you might also need to examine the street address to identify a person. As with the telephone book, in most computerized database tables, it is important to have a way to uniquely identify each record, even if it means using multiple columns. A value that uniquely identifies a record is called a **primary key**, or a **key** for short. Key fields often are defined as a single table column, but as with the telephone book, keys can be constructed from multiple columns; a key constructed from multiple columns is a **compound key**.

TIP You learn more about key fields and compound keys later in this chapter. Compound keys also are known as **composite keys**.

Telephone books are republished periodically because changes have occurred—new people have moved into the city and become telephone customers, and others have left, canceled service, or changed phone numbers. With computerized database tables, you also need to add, delete, and modify records, although usually far more frequently than phone books are published.

Telephone books often contain thousands of records. Computerized database tables also frequently contain thousands of records, or rows, and each row might contain entries in dozens of columns. Handling and organizing all the data contained in an organization's tables requires sophisticated software. **Database management software** is a set of programs that allows users to:

- Create table descriptions.
- Identify keys.
- Add, delete, and update records within a table.
- Arrange records within a table so they are sorted by different fields.
- Write questions that select specific records from a table for viewing.
- Write questions that combine information from multiple tables. This is possible because the database management software establishes and maintains relationships between the columns in the tables. A group of database tables from which you can make these connections is a **relational database**.
- Create reports that allow users to easily interpret your data, and create forms that allow users to view and enter data using an easy-to-manage interactive screen.
- Keep data secure by employing sophisticated security measures.

If you have used different word-processing or spreadsheet programs, you know that each version works a little differently, although each carries out the same types of tasks. Like other computer programs, each database management software package operates differently; however, with each, you need to perform the same types of tasks.

CREATING DATABASES AND TABLE DESCRIPTIONS

Creating a useful database requires a lot of planning and analysis. You must decide what data will be stored, how that data will be divided between tables, and how the tables will interrelate. Before you create any tables, you must create the database itself. With most database software packages, creating the database that will hold the tables requires nothing more than providing a name for the database and indicating the physical location, perhaps a hard disk drive, where the database will be stored. When you save a table, it is conventional to provide it with a name that begins with the prefix "tbl"—for example, `tblCustomers`. Your databases often become filled with a variety of objects—tables, forms that users can use for data entry, reports that organize the data for viewing, queries that select subsets of data for viewing, and so on. Using naming conventions, such as beginning each table name with a prefix that identifies it as a table, helps you to keep track of the various objects in your system.

TIP

Many database management programs suggest that you use a generic name such as Table1 when you save a table description. Usually, a more descriptive name is more useful to you as you continue to create objects.

Before you can enter any data into a database table, you must design the table. At minimum, this involves two tasks:

- You must decide what columns your table needs, and provide names for them.
- You must provide a data type for each column.

For example, assume you are designing a customer database table. Figure 16-2 shows some column names and data types you might use.

FIGURE 16-2: CUSTOMER TABLE DESCRIPTION

Column	Data type
customerID	text
lastName	text
firstName	text
streetAddress	text
balanceOwed	numeric

TIP

A table description closely resembles the record descriptions you have used with data files throughout this book.

TIP

It is important to think carefully about the original design of a database. After the database has been created and data has been entered, it could be difficult and time-consuming to make changes.

The table description in Figure 16-2 uses just two data types—text and numeric. Text columns can hold any type of characters—letters or digits. Numeric columns can hold numbers only. Depending on the database management software you use, you might have many more sophisticated data types at your disposal. For example, some database software divides the numeric data type into several subcategories such as integer (whole number only) values and double-precision numbers (numbers that contain decimals). Other options might include special categories for currency numbers (representing dollars and cents), dates, and Boolean columns (representing true or false). At the least, all database software recognizes the distinction between text and numeric data.

TIP

You have been aware of the distinction that computers make between character and numeric data throughout this book. Because of the way computers handle data, every type of software observes this distinction. Throughout this book, the term "char" has been used to describe text fields. The term "text" is used in this chapter only because it is the term that popular database packages use.

TIP

Unassigned variables within computer programs might be empty (containing a null value), or might contain unknown or garbage values. Similarly, columns in database tables might also contain null or unknown values. When a field in a database contains a null value, it does not mean that the field holds a 0 or a space; it means that no data has been entered for the field at all. Although "null" and "empty" are used synonymously by many database developers, the terms have slightly different meanings to Visual Basic programmers.

The table description in Figure 16-2 uses one-word column names and camel casing, in the same way that variable names have been defined throughout this book. Many database software packages do not require that data column names be single words without embedded spaces, but many database table designers prefer single-word names because they resemble variable names in programs. In addition, when you write programs that access a database table, the single-word field names can be used "as is," without special syntax to indicate the names that represent a single field. As a further advantage, when you use a single word to label each database column, it is easier to understand whether just one column is being referenced, or several.

The `customerID` column in Figure 16-2 is defined as a text field or text column. If `customerID` numbers are composed entirely of digits, this column could also be defined as numeric. However, many database designers feel that columns should be defined as numeric only if they need to be—that is, only if they might be used in arithmetic calculations. The description in Figure 16-2 follows this convention by declaring `customerID` to be a text column.

Many database management software packages allow you to add a narrative description of each data column to a table. This allows you to make comments that become part of the table. These comments do not affect the way the table operates; they simply serve as documentation for those who are reading a table description. For example, you might want to make a note that `customerID` should consist of five digits, or that `balanceOwed` should not exceed a given limit. Some software allows you to specify that values for a certain column are required—the user cannot create a record without providing data for these columns. In addition, you might be able to indicate value limits for a column—high and low numbers between which the column contents must fall.

IDENTIFYING PRIMARY KEYS

In most tables you create for a database, you want to identify a column, or possibly a combination of columns, as the table's key column or field, also called the primary key. The primary key in a table is the column that makes each record different from all others. For example, in the customer table in Figure 16-2, the logical choice for a primary key is the `customerID` column—each customer record that is entered into the customer table has a unique value in this column. Many customers might have the same first name or last name (or both), and multiple customers also might have the same street address or balance due. However, each customer possesses a unique ID number.

Other typical examples of primary keys include:

- A student ID number in a table that contains college student information
- A part number in a table that contains inventory items
- A Social Security number in a table that contains employee information

In each of these examples, the primary key uniquely identifies the row. For example, each student has a unique ID number assigned by the college. Other columns in a student table would not be adequate keys—many students have the same last name, first name, hometown, or major.

TIP It is no coincidence that each of the preceding examples of a key is a number, such as a student ID number or item number. Usually, assigning a number to each row in a table is the simplest and most efficient method of obtaining a useful key. However, it is possible that a table's key could be a text field.

The primary key is important for several reasons:

- You can configure your database software to prevent multiple records from containing the same value in this column, thus avoiding data-entry errors.
- You can sort your records in this order before displaying or printing them.
- You use this column when setting up relationships between this table and others that will become part of the same database.
- In addition, you need to understand the concept of the primary key when you normalize a database—a concept you will learn more about later in this chapter.

TIP In some database software packages, such as Microsoft Access, you indicate a primary key simply by selecting a column name and clicking a button that is labeled with a key icon.

In some tables, when no identifying number has been assigned to the rows, more than one column is required to construct a primary key. A multicolumn key is a compound key. For example, consider Figure 16-3, which might be used by a residence hall administrator to store data about students living on a university campus. Each room in a building has a number and two students, each assigned to either bed A or bed B.

FIGURE 16-3: TABLE CONTAINING RESIDENCE HALL STUDENT RECORDS

hall	room	bed	lastName	firstName	major
Adams	101	A	Fredricks	Madison	Chemistry
Adams	101	B	Garza	Lupe	Psychology
Adams	102	A	Liu	Jennifer	CIS
Adams	102	B	Smith	Crystal	CIS
Browning	101	A	Patel	Sarita	CIS
Browning	101	B	Smith	Margaret	Biology
Browning	102	A	Jefferson	Martha	Psychology
Browning	102	B	Bartlett	Donna	Spanish
Churchill	101	A	Wong	Cheryl	CIS
Churchill	101	B	Smith	Madison	Chemistry
Churchill	102	A	Patel	Jennifer	Psychology
Churchill	102	B	Jones	Elizabeth	CIS

In Figure 16-3, no single column can serve as a primary key. Many students live in the same residence hall, and the same room numbers exist in the different residence halls. In addition, some students have the same last name, first name, or major. It is even possible that two students with the same first name, last name, or major are assigned to the same room. In this case, the best primary key is a multicolumn key that combines residence hall, room number, and bed number (`hall`, `room`, and `bed`). "Adams 101 A" identifies a single room and student, as does "Churchill 102 B".

TIP

A primary key should be **immutable**, meaning that a value does not change during normal operation. In other words, in Figure 16-3, "Adams 102 A" will always pertain to a fixed location, even though the resident or her major might change. Of course, the school might choose to change the name of a residence hall—for example, to honor a benefactor—but that action would fall outside the range of "normal operation." (In object-oriented programming, a class is immutable if it contains no methods that allow changes to its attributes after construction.)

TIP

Sometimes, there are several columns that could serve as the key. For example, if an employee record contains both a company-assigned employee ID and a Social Security number, then both columns are **candidate keys**. After you choose a primary key from among candidate keys, the remaining candidate keys become **alternate keys**.

TIP

Even if there were only one student named Smith, for example, or only one Psychology major in the table in Figure 16-3, those fields still would not be good primary key candidates because of the potential for future Smiths and Psychology majors within the database. Analyzing existing data is not a foolproof way to select a good key; you must also consider likely future data.

TIP

As an alternative to selecting three columns to create the compound key for the table in Figure 16-3, many database designers prefer to simply add a new column containing a bed location ID number that would uniquely identify each row. Many database designers feel that a primary key should be short to minimize the amount of storage required for it in all the tables that refer to it.

Usually, after you have identified the necessary fields and their data types, and identified the primary key, you are ready to save your table description and begin to enter data.

UNDERSTANDING DATABASE STRUCTURE NOTATION

A shorthand way to describe a table is to use the table name followed by parentheses containing all the field names, with the primary key underlined. Thus, when a table is named `tblStudents` and contains columns named `idNumber`, `lastName`, `firstName`, and `gradePointAverage`, and `idNumber` is the key, you can reference the table using the following notation:

```
tblStudents(idNumber, lastName, firstName, gradePointAverage)
```

Although this shorthand notation does not provide you with information about data types or range limits on values, it does provide you with a quick overview of the structure of a table.

TIP

Some database designers insert an asterisk after the key instead of underlining it.

TIP

The key does not have to be the first attribute listed in a table reference, but frequently it is.

ADDING, DELETING, AND UPDATING RECORDS WITHIN TABLES

Entering data into an already created table is not difficult, but it requires a good deal of time and accurate typing. Depending on the application, the contents of the tables might be entered over the course of many months or years by any number of data-entry personnel. Entering data of the wrong type is not allowed by most database software. In addition, you might have set up your table to prevent duplicate data in specific fields, or to prevent data entry outside of specified bounds in other fields. With some database software, you type data into rows representing each record, and columns representing each field in each record, much as you would enter data into a spreadsheet. With other software, you can create on-screen forms to make data entry more user-friendly. Some software does not allow you to enter a partial record; that is, you might not be allowed to leave any fields blank.

TIP

Computer professionals use the acronym GIGO, which stands for "garbage in, garbage out." It means that if you enter invalid input data into an application, the output results will be worthless. You first learned this expression in Chapter 10.

Deleting records from and modifying records within a database table are also relatively easy tasks. In most organizations, most of the important data is in a constant state of change. Maintaining the data records so they are up to date is a vital part of any database management system.

TIP

In many database systems, some "deleted" records are not physically removed. Instead, they are just marked as deleted so they will not be used to process active records. For example, a company might want to retain data about former employees, but not process them with current personnel reports. On the other hand, an employee record that was entered by mistake would be permanently removed from the database.

SORTING THE RECORDS IN A TABLE

Database management software generally allows you to sort a table based on any column, letting you view your data in the way that is most useful to you. For example, you might want to view inventory items in alphabetical order, or from the most to the least expensive. You also can sort by multiple columns—for example, you might sort employees by first name within last name (so that Aaron Black is listed before Andrea Black), or by department within first name within last name (so that Aaron Black in Department 1 is listed before another Aaron Black in Department 6).

TIP

When performing sorts on multiple fields, the software sorts first by a primary sort—for example, last name. After all those with the same primary sort key are grouped, the software sorts by the secondary key—for example, first name.

After rows are sorted, they usually can be grouped. For example, you might want to sort customers by their zip code, or employees by the department in which they work; in addition, you might want counts or subtotals at the end of each group. Database software provides the means to create displays in the formats that suit your present information needs.

TIP

When a database program includes counts or totals at the end of each sorted group, it is creating a control break report. You learned about control break reports in Chapter 7.

CREATING QUERIES

Data tables often contain hundreds or thousands of rows; making sense out of that much information is a daunting task. Frequently, you want to cull subsets of data from a table you have created. For example, you might want to view only those customers with an address in a specific state, only those inventory items whose quantity in stock has fallen below the normal reorder point, or only those employees who participate in an insurance plan. Besides limiting records, you might also want to limit the columns that you view. For example, student records might contain dozens of fields, but a school administrator might only be interested in looking at names and grade point averages. The questions that cause the database software to extract the appropriate records from a table and specify the fields to be viewed are called queries; a **query** is simply a question asked using the syntax that the database software can understand.

Depending on the software you use, you might create a query by filling in blanks (a process called **query by example**) or by writing statements similar to those in many programming languages. The most common language that database administrators use to access data in their tables is **Structured Query Language**, or **SQL**. The basic form of the SQL command that retrieves selected records from a table is **SELECT-FROM-WHERE**. The `SELECT–FROM–WHERE` SQL statement:

- Selects the columns you want to view
- From a specific table
- Where one or more conditions are met

TIP "SQL" frequently is pronounced "sequel"; however, several SQL product Web sites insist that the official pronunciation is "S-Q-L." Similarly, some people pronounce GUI as "gooey" and others insist that it should be "G-U-I." In general, a preferred pronunciation evolves in an organization. The TLA, or three-letter abbreviation, is the most popular type of abbreviation in technical terminology.

For example, suppose a customer table named `tblCustomer` contains data about your business customers and that the structure of the table is `tblCustomer(custId, lastName, state)`. Then, a statement such as:

```
SELECT custId, lastName FROM tblCustomer WHERE state = "WI"
```

would display a new table containing two columns—`custId` and `lastName`—and only as many rows as needed to hold those customers whose state column contains "WI". Besides using = to mean "equal to," you can use the comparison conditions > (greater than), < (less than), >= (greater than or equal to), and <= (less than or equal to). As you have already learned from working with programming variables throughout this book, text field values are always contained within quotes, whereas numeric values are not.

TIP Conventionally, SQL keywords such as SELECT appear in all uppercase; this book follows that convention.

TIP In database management systems, a particular way of looking at a database is sometimes called a **view**. Typically, a view arranges records in some order and makes only certain fields visible. The different views provided by database software are virtual; that is, they do not affect the physical organization of the database.

To select all fields for each record in a table, you can use the asterisk as a wildcard; a wildcard is a symbol that means "any" or "all." For example, `SELECT * from tblCustomer WHERE state = "WI"` would select all columns for every customer whose state is "WI", not just specifically named columns. To select all customers from a table, you can omit the `WHERE` clause in a `SELECT-FROM-WHERE` statement. In other words, `SELECT * FROM tblCustomer` selects all columns for all customers.

You learned about making selections in computer programs much earlier in this book, and you have probably noticed that `SELECT-FROM-WHERE` statements serve the same purpose as programming decisions. As with decision statements in programs, when using SQL, you can create compound conditions using `AND` or `OR` operators. In addition, you can precede any condition with a `NOT` operator to achieve a negative result. In summary, Figure 16-4 shows a database table named `tblInventory` with the following structure: `tblInventory(itemNumber, description, quantityInStock, price)`. The table contains five records. Figure 16-5 lists several typical SQL `SELECT` statements you might use with `tblInventory`, and explains each.

FIGURE 16-4: THE `tblInventory` TABLE

itemNumber	description	quantityInStock	price
144	Pkg 12 party plates	250	$14.99
231	Helium balloons	180	$2.50
267	Paper streamers	68	$1.89
312	Disposable tablecloth	20	$6.99
383	Pkg 20 napkins	315	$2.39

FIGURE 16-5: SAMPLE SQL STATEMENTS AND EXPLANATIONS

SQL statement	Explanation
`SELECT itemNumber, price FROM tblInventory`	Shows only the item number and price for all five records.
`SELECT * FROM tblInventory WHERE price > 5.00`	Shows all fields from only those records where price is over $5.00—items 144 and 312.
`SELECT itemNumber FROM tblInventory WHERE quantityInStock > 200 AND price > 10.00`	Shows item number 144—the only record that has a quantity greater than 200 as well as a price greater than $10.00.
`SELECT description, price FROM tblInventory WHERE description = "Pkg 20 napkins" OR itemNumber < 200`	Shows the description and price fields for the package of 12 party plates and the package of 20 napkins. Each selected record must satisfy only one of the two criteria.
`SELECT itemNumber FROM tblInventory WHERE NOT price < 14.00`	Shows the item number for the only record where the price is not less than $14.00—item 144.

UNDERSTANDING TABLE RELATIONSHIPS

Most database applications require many tables, and these applications also require that the tables be related. The connection between two tables is a **relationship**, and the database containing the relationships is called a relational database. Connecting two tables based on the values in a common column is called a **join operation**, or more simply, a **join**; the column on which they are connected is the **join column**. A virtual, or imaginary, table that is displayed as the result of the query takes some of its data from each joined table. For example, in Figure 16-6, the `customerNumber` column is the join column that could produce a virtual image when a user makes a query. When a user asks to see the

name of a customer associated with a specific order number, or a list of all the names of customers who have ordered a specific item, then a joined table is produced. The three types of relationships that can exist between tables are:

- One-to-many
- Many-to-many
- One-to-one

FIGURE 16-6: SAMPLE CUSTOMERS AND ORDERS

tblCustomers

customerNumber	customerName
214	Kowalski
215	Jackson
216	Lopez
217	Thompson
218	Vitale

tblOrders

orderNumber	customerNumber	orderQuantity	orderItem	orderDate
10467	215	2	HP203	10/15/2007
10468	218	1	JK109	10/15/2007
10469	215	4	HP203	10/16/2007
10470	216	12	ML318	10/16/2007
10471	214	4	JK109	10/16/2007
10472	215	1	HP203	10/16/2007
10473	217	10	JK109	10/17/2007

UNDERSTANDING ONE-TO-MANY RELATIONSHIPS

A **one-to-many relationship** is one in which one row in a table can be related to many rows in another table. It is the most common type of relationship between tables. Consider the following tables:

```
tblCustomers(customerNumber, customerName)
tblOrders(orderNumber, customerNumber, orderQuantity, orderItem, orderDate)
```

The `tblCustomers` table contains one row for each customer, and `customerNumber` is the primary key. The `tblOrders` table contains one row for each order, and each order is assigned an `orderNumber`, which is the primary key in this table.

In most businesses, a single customer can place many orders. For example, in the sample data in Figure 16-6, customer 215 has placed three orders. One row in the `tblCustomers` table can correspond to, and can be related to, many rows in the `tblOrders` table. This means there is a one-to-many relationship between the two tables `tblCustomers` and `tblOrders`. The "one" table (`tblCustomers`) is the **base table** in this relationship, and the "many" table (`tblOrders`) is the **related table**.

When two tables are related in a one-to-many relationship, the relationship occurs based on the values in one or more columns in the tables. In this example, the column, or attribute, that links the two tables together is the `customerNumber` attribute. In the `tblCustomers` table, `customerNumber` is the primary key, but in the `tblOrders` table, `customerNumber` is not a key—it is a **non-key attribute**. When a column that is not a key in a

table contains an attribute that is a key in a related table, the column is called a **foreign key**. When a base table is linked to a related table in a one-to-many relationship, it is always the primary key of the base table that is related to the foreign key in the related table. In this example, `customerNumber` in the `tblOrders` table is a foreign key.

TIP A key in a base table and the foreign key in the related table do not need to have the same name; they only need to contain the same type of data. Some database management software programs automatically create a relationship for you if the columns in two tables you select have the same name and data type. However, if this is not the case (for example, if the column is named `customerNumber` in one table and `custID` in another), you can explicitly instruct the software to create the relationship.

UNDERSTANDING MANY-TO-MANY RELATIONSHIPS

Another example of a one-to-many relationship is depicted with the following tables:

```
tblItems(itemNumber, itemName, itemPurchaseDate, itemPurchasePrice,
   itemCategoryId)
tblCategories(categoryId, categoryName, categoryInsuredAmount)
```

Assume you are creating these tables to keep track of all the items in your household for insurance purposes. You want to store data about items such as your sofa, stereo, refrigerator, and so on. The `tblItems` table contains the name, purchase date, and purchase price of each item. In addition, this table contains the ID number of the item category (Appliance, Jewelry, Antique, and so on) to which the item belongs. You need the category of each item because your insurance policy has specific coverage limits for different types of property. For example, with many insurance policies, antiques might have a different coverage limit than appliances, or jewelry might have a different limit than furniture. Sample data for these tables is shown in Figure 16-7.

The primary key of the `tblItems` table is `itemNumber`, a unique identifying number that you have assigned to each item that you own. (You might even prepare labels with these numbers and stick a label on each item in an inconspicuous place.) The `tblCategories` table contains the category names and the maximum insured amounts for the specific categories. For example, one row in this table may have a `categoryName` of "Jewelry" and a `categoryInsuredAmount` of $15,000. The primary key for the `tblCategories` table is `categoryId`, which is simply a uniquely assigned value for each property category.

The two tables in Figure 16-7 have a one-to-many relationship. Which is the "one" table and which is the "many" table? Or, asked in another way, which is the base table and which is the related table? You have probably determined that the `tblCategories` table is the base table (the "one" table) because one category can describe many items that you own. Therefore, the `tblItems` table is the related table (the "many" table); that is, there are many items that fall into each category. The two tables are linked with the `categoryId` attribute, which is the primary key in the base table (`tblCategories`) and a foreign key in the related table (`tblItems`).

FIGURE 16-7: SAMPLE ITEMS AND CATEGORIES: A ONE-TO-MANY RELATIONSHIP

tblItems

itemNumber	itemName	itemPurchaseDate	itemPurchasePrice	itemCategoryId
1	Sofa	1/13/2001	$6,500	5
2	Stereo	2/10/2003	$1,200	6
3	Refrigerator	5/12/2003	$750	1
4	Diamond ring	2/12/2004	$42,000	2
5	TV	7/11/2004	$285	6
6	Rectangular pine coffee table	4/21/2005	$300	5
7	Round pine end table	4/21/2005	$200	5

tblCategories

categoryId	categoryName	categoryInsuredAmount
1	Appliance	$30,000
2	Jewelry	$15,000
3	Antique	$10,000
4	Clothing	$25,000
5	Furniture	$5,000
6	Electronics	$2,500
7	Miscellaneous	$5,000

In the tables in Figure 16-7, one row in the `tblCategories` table relates to multiple items you own. The opposite is not true—that is, one item in the `tblItems` table cannot relate to multiple categories in the `tblCategories` table. The row in the `tblItems` table that describes the "rectangular pine coffee table" relates to one specific category in the `tblCategories` table—the Furniture category. However, what if you own a rectangular pine coffee table that has a built-in DVD player, or a diamond ring that is an antique, or a stereo that could also be worn as a hat on a rainy day? Even though this last example is humorous, it does bring up an important consideration.

The structure of the tables shown in Figure 16-7 and the relationship between those tables are designed to support a particular application—keeping track of possessions for insurance purposes. If you acquired a sofa with a built-in CD player and speakers, what would you do? For guidance, you probably would call your insurance agent. If the agent said, "Well, for insurance purposes that item is considered a piece of furniture," then the existing table structures and relationships are adequate.

However, if the insurance agent said, "Well, actually a sofa with a CD player is considered a special type of hybrid item, and that category of property has a specific maximum insured amount," then you could simply create a new row in the `tblCategories` table to describe this special hybrid category—perhaps Electronic Furniture. This new category would acquire a category number, and then you could associate the CD-sofa to the new category using the foreign key in the `tblItems` table.

However, what if your insurance agent said, "You know, that's a good question. We've never had that come up before—a sofa with a CD player. What we would probably do if you filed a claim because the sofa was damaged is to take a look at it to try to determine whether the sofa is mostly a piece of furniture or mostly a piece of electronics." This answer presents a problem to your database. You may want to categorize your new sofa as both a furniture item *and* an electronic item. The existing table structures, with their one-to-many relationship, would not support this because the current design limits any specific item to one and only one category. When you insert a row into the `tblItems` table to describe the new CD-sofa, you can assign the Furniture code to the foreign key `itemCategory`, or you can assign the Electronics code, but not both.

If you want to assign the new CD-sofa to both categories (Furniture and Electronics), you have to change the design of the table structures and relationships, because there is no longer a one-to-many relationship between the two tables. Now, there is a **many-to-many relationship**—one in which multiple rows in each table can correspond to multiple rows in the other. That is, in this example, one row in the `tblCategories` table (for example, Furniture) can relate to many rows in the `tblItems` table (for example, sofa and coffee table), *and* one row in the `tblItems` table (for example, the sofa with the built-in CD player) can relate to multiple rows in the `tblCategories` table.

The `tblItems` table contains a foreign key named `itemCategoryId`. If you want to change the application so that one specific row in the `tblItems` table can link to many rows (and, therefore, many `categoryIds`) in the `tblCategories` table, you cannot continue to maintain the foreign key `itemCategoryId` in the `tblItems` table, because one item may be assigned to many categories. You could change the structure of the `tblItems` table so that you can assign multiple `itemCategoryIds` to one specific row in that table, but as you will learn later in this chapter, that approach leads to many problems using the data. Therefore, it is not an option.

The simplest way to support a many-to-many relationship between the `tblItems` and `tblCategories` tables is to remove the `itemCategoryId` attribute (what was once the foreign key) from the `tblItems` table, producing:

```
tblItems(itemNumber, itemName, itemPurchaseDate, itemPurchasePrice)
```

The `tblCategories` table structure remains the same:

```
tblCategories(categoryId, categoryName, categoryInsuredAmount)
```

With just the preceding two tables, there is no way to know that any specific row(s) in the `tblItems` table link(s) to any specific row(s) in the `tblCategories` table, so you create a new table called `tblItemsCategories` that contains the primary keys from the two tables that you want to link in a many-to-many relationship. This table is depicted as:

```
tblItemsCategories(itemNumber, categoryId)
```

Notice that this new table contains a compound primary key—both `itemNumber` and `categoryId` are underlined. The `itemNumber` value of 1 might be associated with many `categoryId`s. Therefore, `itemNumber` alone cannot be the primary key because the same value may occur in many rows. Similarly, a `categoryId` might relate to many different `itemNumber`s; this would disallow using just the `categoryId` as the primary key.

However, a combination of the two attributes `itemNumber` and `categoryId` results in a unique primary key value for each row of the `tblItemsCategories` table.

The purpose of all this is to create a many-to-many relationship between the `tblItems` and `tblCategories` tables. The `tblItemsCategories` table contains two attributes; together, these attributes are the primary key. In addition, each of these attributes separately is a foreign key to one of the two original tables. The `itemNumber` attribute in the `tblItemsCategories` table is a foreign key that links to the primary key of the `tblItems` table. The `categoryId` attribute in the `tblItemsCategories` table links to the primary key of the `tblCategories` table. Now, there is a one-to-many relationship between the `tblItems` table (the "one," or base table) and the `tblItemsCategories` table (the "many," or related table) and a one-to-many relationship between the `tblCategories` table (the "one," or base table) and the `tblItemsCategories` table (the "many," or related table). This, in effect, implies a many-to-many relationship between the two base tables (`tblItems` and `tblCategories`).

Figure 16-8 shows the new tables holding a few items. The sofa (`itemNumber` 1) in the `tblItems` table is associated with the Furniture category (`categoryId` 5) in the `tblCategories` table because the first row of the `tblItemsCategories` table contains a 1 and a 5. Similarly, the stereo (`itemNumber` 2) in the `tblItems` table is associated with the Electronics category (`categoryId` 6) in the `tblCategories` table because in the `tblItemsCategories` table there is a row containing the values 2, 6.

FIGURE 16-8: SAMPLE ITEMS, CATEGORIES, AND ITEM CATEGORIES: A MANY-TO-MANY RELATIONSHIP

tblItems

itemNumber	itemName	itemPurchaseDate	itemPurchasePrice
1	Sofa	1/13/2001	$6,500
2	Stereo	2/10/2003	$1,200
3	Sofa with CD player	5/24/2005	$8,500
4	Table with DVD player	6/24/2005	$12,000
5	Granpa's pocket watch	12/24/1927	$100

tblItemsCategories

itemNumber	categoryId
1	5
2	6
3	5
3	6
4	5
4	6
5	2
5	3

tblCategories

categoryId	categoryName	categoryInsuredAmount
1	Appliance	$30,000
2	Jewelry	$15,000
3	Antique	$10,000
4	Clothing	$25,000
5	Furniture	$5,000
6	Electronics	$2,500
7	Miscellaneous	$5,000

The fancy sofa with the built-in CD player (`itemNumber` 3 in the `tblItems` table) occurs in two rows in the `tblItemsCategories` table, once with a `categoryId` of 5 (Furniture) and once with a `categoryId` of 6 (Electronics). Similarly, the table with the DVD player and Grandpa's pocket watch both belong to multiple categories. It is the `tblItemsCategories` table, then, that allows the establishment of a many-to-many relationship between the two base tables, `tblItems` and `tblCategories`.

UNDERSTANDING ONE-TO-ONE RELATIONSHIPS

In a **one-to-one relationship**, a row in one table corresponds to exactly one row in another table. This type of relationship is easy to understand, but is the least frequently encountered. When one row in a table corresponds to a row in another table, the columns could be combined into a single table. A common reason you create a one-to-one relationship is security. For example, Figure 16-9 shows two tables, `tblEmployees` and `tblSalaries`. Each employee in the `tblEmployees` table has exactly one salary in the `tblSalaries` table. The salaries could have been added to the `tblEmployees` table as an additional column; the salaries are separate only because you want some clerical workers to be allowed to view only names, addresses, and other nonsensitive data, so you give them permission to access only the `tblEmployees` table. Others who work in payroll or administration can create queries that allow them to view joined tables that include the salary information.

FIGURE 16-9: EMPLOYEES AND SALARIES TABLES: A ONE-TO-ONE RELATIONSHIP

tblEmployees

empId	empLast	empFirst	empDept	empHireDate
101	Parker	Laura	3	4/07/1998
102	Walters	David	4	1/19/1999
103	Shannon	Ewa	3	2/28/2003

tblSalaries

empId	empSalary
101	$42,500
102	$28,800
103	$36,000

TIP Another reason to create tables with one-to-one relationships is to avoid lots of empty columns, or **nulls**, if a certain subset of columns is applicable only to specific types of rows in the main table.

TIP You learn more about security issues later in this chapter.

RECOGNIZING POOR TABLE DESIGN

As you create database tables that will hold the data an organization needs, you will encounter many occasions when the table design, or structure, is inadequate to support the needs of the application. In other words, even if a table contains all the attributes required by a specific application, the structural design of the table may make the application cumbersome to use (you will see examples of this later) and prone to data errors.

For example, assume that you have been hired by an Internet-based college to design a database to keep track of its students. After meeting with the college administrators, you determine that you need to know the following information:

- Students' names
- Students' addresses
- Students' cities
- Students' states
- Students' zip codes
- ID numbers for classes in which students are enrolled
- Titles for classes in which students are enrolled

TIP Of course, in a real-life example you could probably think of many other data requirements for the college, in addition to those listed here. The number of attributes is small here for simplicity.

Figure 16-10 contains the `Students` table. Assume that because the Internet-based college is new, only three students have already enrolled. Besides the columns you identified as being necessary, notice the addition of the `studentId` attribute. Given the earlier discussions, you probably recognize that this is the best choice to use as a primary key, because many students can have the same names and even the same addresses. Although the table in Figure 16-10 contains a column for each of the data requirements decided upon with the college administration, the table is poorly designed and will create many problems for the users of the database.

FIGURE 16-10: `Students` TABLE BEFORE NORMALIZATION PROCESS

studentId	name	address	city	state	zip	class	classTitle
1	Rodriguez	123 Oak	Schaumburg	IL	60193	CIS101	Computer Literacy
						PHI150	Ethics
						BIO200	Genetics
2	Jones	234 Elm	Wild Rose	WI	54984	CHM100	Chemistry
						MTH200	Calculus
3	Mason	456 Pine	Dubuque	IA	52004	HIS202	World History

What if a college administrator wanted to view a list of courses offered by the Internet-based college? Can you answer that question by reviewing the table? Well, you can see six courses listed for the three students, so you can assume that at least six courses are offered. But, is it possible that there is also a Psychology course, or a class whose code is CIS102? You can't determine this from the table because no students have enrolled in those classes. Wouldn't it be nice to know all the classes that are offered by your institution, regardless of whether any students have enrolled in them?

Consider another potential problem: What if student Mason withdraws from the school, and, therefore, his row is deleted from the table? You would lose some valuable information that really has nothing to do specifically with student

Mason, but that is very important for running the college. For instance, if Mason's row is deleted from the table, you no longer know, from the remaining data in the table, whether the college offers any History classes, because Mason was the only student enrolled in the HIS202 class.

Why is it so important to discuss the deficiencies of the existing table structure? You have probably heard the saying, "Pay me now or pay me later." This is especially true as it relates to table design. If you do not take the time to ensure well-designed table structures when you are initially designing your database, then you (or the users of your database) will surely spend lots of time later fixing data errors, typing the same information multiple times, and being frustrated by the inability to cull important subsets of information from the database. If you were really hired to create this database and this table structure was your solution to the college's needs, then it is unlikely you would be hired for future database projects.

UNDERSTANDING ANOMALIES, NORMAL FORMS, AND THE NORMALIZATION PROCESS

Database management programs can maintain all the relationships you need. As you add records to, delete records from, and modify records within your database tables, the software keeps track of all the relationships you have established, so that you can view any needed joins any time you want. The software, however, can only maintain useful relationships if you have planned ahead to create a set of tables that supports all the applications you will need. The process of designing and creating a set of database tables that satisfies the users' needs and avoids many potential problems is **normalization**.

The normalization process helps you reduce data redundancies and anomalies. **Data redundancy** is the unnecessary repetition of data. An **anomaly** is an irregularity in a database's design that causes problems and inconveniences. Three common types of anomalies are:

- Update anomalies
- Delete anomalies
- Insert anomalies

If you look ahead to the college database table in Figure 16-11, you will see an example of an **update anomaly**, or a problem that occurs when the data in a table needs to be altered. Because the table contains redundant data, if student Rodriguez moves to a new residence, you have to change the values stored as address, city, state, and zip in more than one location. Of course, this table example is small; imagine if additional data were stored about Rodriguez, such as birth date, e-mail address, major field of study, and previous schools attended.

The database table in Figure 16-10 contains a **delete anomaly**, or a problem that occurs when a row is deleted. If student Jones withdraws from the college, and his entries are deleted from the table, important data regarding the classes CHM100 and MTH200 are lost.

With an **insert anomaly**, problems occur when new rows are added to a table. In the table in Figure 16-10, if a new student named Ramone has enrolled in the college, but has not yet registered for any specific classes, then you can't insert a complete row for student Ramone; the only way to do so would be to "invent" at least one phony class for him.

It would certainly be valuable to the college to be able to maintain data on all enrolled students, regardless of whether those students have registered for specific classes—for example, the college might want to send catalogs and registration information to these students.

TIP In some databases, you might be able to enter an incomplete row for a student.

When you normalize a database table, you walk through a series of steps that allows you to remove redundancies and anomalies. The normalization process involves altering a table so that it satisfies one or more of three **normal forms**, or sets of rules for constructing a well-designed database. The three normal forms are:

- **First normal form**, also known as **1NF**, in which you eliminate repeating groups
- **Second normal form**, also known as **2NF**, in which you eliminate partial key dependencies
- **Third normal form**, also known as **3NF**, in which you eliminate transitive dependencies

Each normal form is structurally better than the one preceding it. In any well-designed database, you almost always want to convert all tables to 3NF.

TIP In a 1970 paper titled "A Relational Model of Data for Large Shared Data Banks," Dr. E.F. Codd listed seven normal forms. For business applications, 3NF is usually sufficient, and so only 1NF through 3NF are discussed in this chapter.

FIRST NORMAL FORM

A table that contains repeating groups is **unnormalized**. A **repeating group** is a subset of rows in a database table that all depend on the same key. A table in 1NF contains no repeating groups of data.

The table in Figure 16-10 violates this 1NF rule. The `class` and `classTitle` attributes repeat multiple times for some of the students. For example, student Rodriguez is taking three classes; her `class` attribute contains a repeating group. To remedy this situation, and to transform the table to 1NF, you simply repeat the rows for each repeating group of data. Figure 16-11 contains the revised table.

FIGURE 16-11: `Students` TABLE IN 1NF

studentId	name	address	city	state	zip	class	classTitle
1	Rodriguez	123 Oak	Schaumburg	IL	60193	CIS101	Computer Literacy
1	Rodriguez	123 Oak	Schaumburg	IL	60193	PHI150	Ethics
1	Rodriguez	123 Oak	Schaumburg	IL	60193	BIO200	Genetics
2	Jones	234 Elm	Wild Rose	WI	54984	CHM100	Chemistry
2	Jones	234 Elm	Wild Rose	WI	54984	MTH200	Calculus
3	Mason	456 Pine	Dubuque	IA	52004	HIS202	World History

The repeating groups have been eliminated from the table in Figure 16-11. However, as you look at the table, you will notice a problem—the primary key, `studentId`, is no longer unique for each row in the table. For example, the table

in Figure 16-11 now contains three rows in which `studentId` equals 1. You can fix this problem, and create a primary key, by simply adding the `class` attribute to the primary key, creating a compound key. (Other problems still exist, as you will see later in this chapter.) The table's key then becomes a combination of `studentId` and `class`. By knowing the `studentId` *and* `class`, you can identify one, and only one, row in the table—for example, a combination of `studentId` 1 and `class` BIO200 identifies a single row. Using the notation discussed earlier in this chapter, the table in Figure 16-11 can be described as:

```
tblStudents(studentId, name, address, city, state, zip, class, classTitle)
```

Both the `studentId` and `class` attributes are underlined, showing that they are both part of the key.

TIP When you combine two columns to create a compound key, you are **concatenating the columns**.

The table in Figure 16-11 is now in 1NF because there are no repeating groups and the primary key attributes are defined. Satisfying the "no repeating groups" condition is also called making the columns **atomic attributes**; that is, making them as small as possible, containing an undividable piece of data. In 1NF, all values for an intersection of a row and column must be atomic. Recall the table in Figure 16-10 in which the class attribute for `studentId` 1 (Rodriguez) contained three entries: CIS101, PHI150, and BIO200. This violated the 1NF atomicity rule because these three classes represented a set of values rather than one specific value. The table in Figure 16-11 does not repeat this problem because, for each row in the table, the class attribute contains one and only one value. The same is true for the other attributes that were part of the repeating group.

TIP Database developers also refer to operations or transactions as **atomic transactions** when they appear to execute completely or not at all.

Now, think back to the earlier discussion about why we want to normalize tables in the first place. Look at Figure 16-11. Are there still redundancies? Are there still anomalies? Yes to both questions. Recall that you want to have your tables in 3NF before actually defining them to the database. Currently, the table in Figure 16-11 is only in 1NF.

In Figure 16-11, notice that Student 1, Rodriguez, is taking three classes. If you were the college employee who was responsible for typing the data into this table, would you want to type this student's name, address, city, state, and zip code for each of the three classes Rodriguez is taking? It is very probable that you may, for one of her classes, type her name as "Rodrigues" instead of "Rodriguez." Or, you might misspell the city of "Schaumburg" as "Schamburg" for one of Rodriguez's classes. A college administrator looking at the table might not know whether Rodriguez's correct city of residence is Schaumburg or Schamburg. If you queried the database to select or count the number of classes being taken by students residing in "Schaumburg," one of Rodriguez's classes would be missed.

TIP Misspelling the student name "Rodriguez" is an example of a data integrity error. You learn more about this type of error later in this chapter.

Consider the student Jones, who is taking two classes. If Jones changes his residence, how many times will you need to retype his new address, state, city, and zip code? What if Jones is taking six classes?

SECOND NORMAL FORM

To improve the design of the table and bring the table in Figure 16-11 to 2NF, you need to eliminate all **partial key dependencies**; that is, no column should depend on only part of the key. Restated, this means that for a table to be in 2NF, it must be in 1NF and all non-key attributes must be dependent on the entire primary key.

In the table in Figure 16-11, the key is a combination of `studentId` and `class`. Consider the `name` attribute. Does the `name` "Rodriguez" depend on the entire primary key? In other words, do you need to know that the `studentId` is 1 *and* that the `class` is CIS101 to determine that the `name` is "Rodriguez"? No, it is sufficient to know that the `studentId` is 1 to know that the `name` is "Rodriguez." Therefore, the `name` attribute is only partially dependent on the primary key, and so the table violates 2NF. The same is true for the other attributes of `address`, `city`, `state`, and `zip`. If you know, for example, that `studentId` is 3, then you also know that the student's `city` is "Dubuque"; you do not need to know any class codes.

Similarly, examine the `classTitle` attribute in the first row in the table in Figure 16-11. This attribute has a value of "Computer Literacy". In this case, you do not need to know both the `studentId` and the `class` to predict the `classTitle` "Computer Literacy". Rather, just the `class` attribute, which is only part of the compound key, is required. Looked at in another way, class "PHI150" will always have the associated `classTitle` "Ethics", regardless of the particular students who are taking that class. So, `classTitle` represents a partial key dependency.

You bring a table into 2NF by eliminating the partial key dependencies. To accomplish this, you create multiple tables so that each non-key attribute of each table is dependent on the *entire* primary key for the specific table within which the attribute occurs. If the resulting tables are still in 1NF and there are no partial key dependencies, then those tables will also be in 2NF.

Figure 16-12 contains three tables: `tblStudents`, `tblClasses`, and `tblStudentClasses`. To create the `tblStudents` table, you simply take those attributes from the original table that depend on the `studentId` attribute, and group them into a new table; name, address, city, state, and zip code all can be determined by the `studentId` alone. The primary key to the `tblStudents` table is `studentId`. Similarly, you can create the `tblClasses` table by simply grouping the attributes from the 1NF table that depend on the `class` attribute. In this application, only one attribute from the original table, the `classTitle` attribute, depends on the `class` attribute. The first two Figure 16-12 tables can be notated as:

```
tblStudents(studentId, name, address, city, state, zip)
tblClasses(class, classTitle)
```

FIGURE 16-12: `Students` TABLE IN 2NF

tblStudents

studentId	name	address	city	state	zip
1	Rodriguez	123 Oak	Schaumburg	IL	60193
2	Jones	234 Elm	Wild Rose	WI	54984
3	Mason	456 Pine	Dubuque	IA	52004

tblClasses

class	classTitle
CIS101	Computer Literacy
PHI150	Ethics
BIO200	Genetics
CHM100	Chemistry
MTH200	Calculus
HIS202	World History

tblStudentClasses

studentId	class
1	CIS101
1	PHI150
1	BIO200
2	CHM100
2	MTH200
3	HIS202

The `tblStudents` and `tblClasses` tables contain all the attributes from the original table. Remember the prior redundancies and anomalies. Several improvements have occurred:

- You have eliminated the update anomalies. The name "Rodriguez" occurs just once in the `tblStudents` table. The same is true for Rodriguez's address, city, state, and zip code. The original table contained three rows for student Rodriguez. By eliminating the redundancies, you have fewer anomalies. If Rodriguez changes her residence, you only need to update one row in the `tblStudents` table.
- You have eliminated the insert anomalies. With the new configuration, you can insert a complete row into the `tblStudents` table even if the student has not yet enrolled in any classes. Similarly, you can add a complete row for a new class offering to the `tblClasses` table even though no students are currently taking the class.
- You have eliminated the delete anomalies. Recall from the original table that student Mason was the only student taking HIS202. This caused a delete anomaly because the HIS202 class would disappear if student Mason was removed. Now, if you delete Mason from the `tblStudents` table in Figure 16-12, the HIS202 class remains in the `tblClasses` list.

If you create the first two tables shown in Figure 16-12, you have eliminated many of the problems associated with the original version. However, if you have those two tables alone, you have lost some important information that you originally had while at 1NF—specifically, which students are taking which classes or which classes are being taken by which students. When breaking up a table into multiple tables, you need to consider the type of relationship among the resulting tables—you are designing a *relational* database, after all.

You know that the Internet-based college application requires that you keep track of which students are taking which classes. This implies a relationship between the `tblStudents` and `tblClasses` tables. Your job is to determine what type of relationship exists between the two tables. Recall from earlier in the chapter that the two most common types of relationships are one-to-many and many-to-many. This specific application requires that one specific student can enroll in many different classes, and that one specific class can be taken by many different students. Therefore, there is a many-to-many relationship between the tables `tblStudents` and `tblClasses`.

As you learned in the earlier example of categorizing insured items, you create a many-to-many relationship between two tables by creating a third table that contains the primary keys from the two tables that you want to relate. In this case, you create the `tblStudentClasses` table in Figure 16-12 as:

```
tblStudentClasses(studentId, class)
```

If you examine the rows in the `tblStudentClasses` table, you can see that the student with `studentId` 1, Rodriguez, is enrolled in three classes; `studentId` 2, Jones, is taking two classes; and `studentId` 3, Mason, is enrolled in only one class. Finally, the table requirements for the Internet-based college have been fulfilled.

Or have they? Earlier, you saw the many redundancies and anomalies that were eliminated by structuring the tables into 2NF, and it is certainly true that the 2NF table structures result in a much "better" database than the 1NF structures. But look again at the `tblStudents` table in Figure 16-12. What if, as the college expands, you need to add 50 new students to this table, and all of the new students reside in Schaumburg, IL? If you were the data-entry person, would you want to type the city of "Schaumburg", the state of "IL", and the zip code of "60193" 50 times? This data is redundant, and you can improve the design of the tables to eliminate this redundancy.

THIRD NORMAL FORM

3NF requires that a table be in 2NF and that it have no transitive dependencies. A **transitive dependency** occurs when the value of a non-key attribute determines, or predicts, the value of another non-key attribute. Clearly, the `studentId` attribute of the `tblStudents` table in Figure 16-12 is a determinant—if you know a particular `studentId` value, you can also know that student's `name`, `address`, `city`, `state`, and `zip`. But this is not considered a transitive dependency because the `studentId` attribute is the primary key for the `tblStudents` table, and, after all, the primary key's job is to determine the values of the other attributes in the row.

There is a problem, however, if a non-key attribute determines another non-key attribute. In the Figure 16-12 `tblStudents` table, there are five non-key attributes: `name`, `address`, `city`, `state`, and `zip`.

The name is a non-key attribute. If you know the value of `name` is "Rodriguez", do you also know the one specific address where Rodriguez resides? In other words, is this a transitive dependency? No, it isn't. Even though only one student is named "Rodriguez" now, there may be many more in the future. So, though it may be tempting to consider that the `name` attribute is a determinant of `address`, it isn't. Looked at another way, if your boss said, "Look at the `tblStudents` table and tell me Jones' address," you wouldn't be able to do so if you had 10 students named "Jones".

The `address` attribute is a non-key attribute. Does it predict anything? If you know the value of `address` is "20 N. Main Street", can you, for instance, determine the name of the student who is associated with that address? No, because in the

future, you might have many students who live at "20 N. Main Street," but they might live in different cities, or you might have two students who live at the same address in the same city. Therefore, `address` does not cause a transitive dependency.

Similarly, the `city` and `state` attributes are not keys, but they also are not determinants because knowing their values alone is not sufficient to predict another non-key attribute value. You might argue that if you know a city's name, you know the state, but many states contain cities named, for example, Union or Springfield.

But what about the non-key attribute `zip`? If you know, for example, that the zip code is 60193, can you determine the value of any other non-key attributes? Yes, a zip code of 60193 indicates that the `city` is Schaumburg and the `state` is IL. This is the "culprit" that is causing the redundancies with regard to the `city` and `state` attributes. The attribute `zip` is a determinant because it determines `city` and `state`; therefore, the `tblStudents` table contains a transitive dependency and is not in 3NF.

To convert the `tblStudents` table to 3NF, simply remove the attributes that depend on, or are **functionally dependent** on, the `zip` attribute. For example, if attribute `zip` determines attribute `city`, then attribute `city` is considered to be functionally dependent on attribute `zip`. So, as Figure 16-13 shows, the new `tblStudents` table is defined as:

```
tblStudents(studentId, name, address, zip)
```

FIGURE 16-13: THE COMPLETE `Students` DATABASE

tblStudents

studentId	name	address	zip
1	Rodriguez	123 Oak	60193
2	Jones	234 Elm	54984
3	Mason	456 Pine	52004

tblZips

zip	city	state
60193	Schaumburg	IL
54984	Wild Rose	WI
52004	Dubuque	IA

tblClasses

class	classTitle
CIS101	Computer Literacy
PHI150	Ethics
BIO200	Genetics
CHM100	Chemistry
MTH200	Calculus
HIS202	World History

tblStudentClasses

studentId	class
1	CIS101
1	PHI150
1	BIO200
2	CHM100
2	MTH200
3	HIS202

TIP A functionally dependent relationship is sometimes written using an arrow that extends from the depended-upon attribute to the dependent attribute—for example, `zip` ⟶ `city`.

Figure 16-13 also shows the `tblZips` table, which is defined as:

```
tblZips(zip, city, state)
```

The new tblZips table is related to the tblStudents table by the zip attribute. Using the two tables together, you can determine, for example, that studentId 3, Mason, in the tblStudents table resides in the city of Dubuque and the state of IA, attributes stored in the tblZips table. When you encounter a table with a functional dependence, you almost always can reduce data redundancy by creating two tables, as in Figure 16-13. With the new configuration, a data-entry operator must still type a zip code for each student, but the drudgery of typing and the possibility of introducing data-entry errors in city and state names for each student is eliminated.

Is the students-to-zip-codes relationship a one-to-many relationship, a many-to-many relationship, or a one-to-one relationship? You know that one row in the tblZips table can relate to many rows in the tblStudents table—that is, many students can reside in zip code 60193. However, the opposite is not true—one row in the tblStudents table (a particular student) cannot relate to many rows in the tblZips table, because a particular student can only reside in one zip code. Therefore, there is a one-to-many relationship between the base table, tblZips, and the related table tblStudents. The link to the relationship is the zip attribute, which is a primary key in the tblZips table and a foreign key in the tblStudents table.

This was a lot of work, but it was worth it. The tables are in 3NF, and the redundancies and anomalies that would have contributed to an unwieldy, error-prone, inefficient database design have been eliminated.

Recall that the definition of 3NF is 2NF plus no transitive dependencies. What if you were considering changing the structure of the tblStudents table by adding an attribute to hold the students' Social Security numbers (ssn)? If you know a specific ssn value, you also know a particular student name, address, and so on; in other words, a specific value for ssn determines one and only one row in the tblStudents table. No two students have the same Social Security number (ruling out identity theft, of course). However, studentId is the primary key; ssn is a non-key determinant, which, by definition, seems to violate the requirements of 3NF. However, if you add ssn to the tblStudents table, the table is still in 3NF because a determinant is allowed in 3NF if the determinant is also a candidate key. Recall that a candidate key is an attribute that could qualify as the primary key but has not been used as the primary key. In the example concerning the zip attribute of the tblStudents table (Figure 16-11), zip was a determinant of the city and state attributes. Therefore, the tblStudents table was not in 3NF because many rows in the tblStudents table can have the same value for zip, meaning zip is not a candidate key. The situation with the ssn column is different because ssn could be used as a primary key for the tblStudents table.

TIP

In general, you try to create a database in the highest normal form. However, when data items are stored in multiple tables, it takes longer to access related information than when it is all stored in a single table. So, sometimes, for performance, you might **denormalize** a table, or reduce it to a lower normal form, by placing some repeated information back into the table. Deciding on the best form in which to store a body of data is a sophisticated art.

In summary:

- A table is in first normal form when there are no repeating groups.
- A table is in second normal form if it is in first normal form and no non-key column depends on just part of the primary key.
- A table is in third normal form if it is in second normal form and the only determinants are candidate keys.

TIP

Not every table starts out denormalized. For example, a table might already be in third normal form when you first encounter it. On the other hand, a table might not be normalized, but after you put it in 1NF, you may find that it also satisfies the requirements for 2NF and 3NF.

DATABASE PERFORMANCE AND SECURITY ISSUES

Frequently, a company's database is its most valuable resource. If buildings, equipment, or inventory items are damaged or destroyed, they can be rebuilt or re-created. However, the information contained in a database is often irreplaceable. A company that has spent years building valuable customer profiles cannot re-create them at the drop of a hat; a company that loses billing or shipment information might not simply lose the current orders—it might also lose the affected customers forever as they defect to competitors who can serve them better. Keeping an organization's data secure is often the most economically valuable responsibility in the company.

You can study entire books to learn all the details involved in data security. The major issues include:

- Providing data integrity
- Recovering lost data
- Avoiding concurrent update problems
- Providing authentication and permissions
- Providing encryption

PROVIDING DATA INTEGRITY

Database software provides the means to ensure that data integrity is enforced; a database has **data integrity** when it follows a set of rules that makes the data accurate and consistent. For example, you might indicate that a quantity in an inventory record can never be negative, or that a price can never be higher than a predetermined value. In addition, you can enforce integrity between tables; for example, you might prohibit entering an insurance plan code for an employee if the insurance plan code is not one of the types offered by the organization.

RECOVERING LOST DATA

An organization's data can be destroyed in many ways—legitimate users can make mistakes, hackers or other malicious users can enter invalid data, and hardware problems can wipe out records or entire databases. **Recovery** is the process of returning the database to a correct form that existed before an error occurred.

Periodically making a backup copy of a database and keeping a record of every transaction together provide one of the simplest approaches to recovery. When an error occurs, you can replace the database with an error-free version that was saved at the last backup. Usually, there have also been changes to the database, called transactions, since the last backup; if so, you must then reapply those transactions.

TIP

Many organizations keep a copy of their data off-site (sometimes hundreds or thousands of miles away) so that if a disaster such as a fire or flood destroys data, the remotely stored copy can serve as a backup.

AVOIDING CONCURRENT UPDATE PROBLEMS

Large databases are accessible by many users at a time. The database is stored on a central computer, and users work at terminals in diverse locations. For example, several order takers might be able to update customer and inventory tables concurrently. A **concurrent update problem** occurs when two database users need to make changes to the same record at the same time. Suppose two order processors take a phone order for item number 101 in an inventory file. Each gets a copy of the quantity in stock—for example, 25—loaded into the memory of her terminal. Each accepts her customer's order and subtracts 1 from inventory. Now, in each local terminal, the quantity is 24. One order gets written to the central database, then the other, and the final inventory is 24, not 23 as it should be.

Several approaches can be used to avoid this problem. With one approach, a lock can be placed on one record the moment it is accessed. A **lock** is a mechanism that prevents changes to a database for a period of time. While one order taker makes a change, the other cannot access the record. Potentially, a customer on the phone with the second order taker could be inconvenienced while the first order taker maintains the lock, but the data in the inventory table would remain accurate.

TIP A **persistent lock** is a long-term database lock required when users want to maintain a consistent view of their data while making modifications over a long transaction.

Another approach to preventing the concurrent update problem is to not allow the users to update the original database at all, but to have them store transactions, which then can be applied to the database all at once, or in a **batch**, at a later time—perhaps once or twice a day or after business hours. The problem with this approach is that as soon as the first transaction occurs and until the batch processing takes place, the original database is out of date. For example, if several order takers place orders for the same item, the item might actually be out of stock. However, none of the order takers will realize the item is unavailable because the database will not reflect the orders until it is updated with the current batch of transactions.

PROVIDING AUTHENTICATION AND PERMISSIONS

Most database software can authenticate that those who are attempting to access an organization's data are legitimate users. **Authentication techniques** include storing and verifying passwords or even using physical characteristics, such as fingerprints or voice recognition, before users can view data. When a user is authenticated, the user typically receives authorization to all or part of the database. The **permissions** assigned to a user indicate which parts of the database the user can view, and which parts he or she can change or delete. For example, an order taker might not be allowed to view or update personnel data, whereas a clerk in the personnel office might not be allowed to alter inventory data.

PROVIDING ENCRYPTION

Database software can be used to encrypt data. **Encryption** is the process of coding data into a format that human beings cannot read. If unauthorized users gain access to database files, the data will be in a coded format that is useless to them. Only authorized users see the data in a readable format.

CHAPTER SUMMARY

- A database holds a group of files that an organization needs to support its applications. In a database, the files often are called tables because you can arrange their contents in rows and columns. A value that uniquely identifies a record is called a primary key, a key field, or a key for short. Database management software is a set of programs that allows users to create table descriptions; identify keys; add records to, delete records from, and update records within a table; arrange records so they are sorted by different fields; write questions that select specific records from a table for viewing; write questions that combine information from multiple tables; create reports and forms; and keep data secure by employing sophisticated security measures.

- Creating a useful database requires a lot of planning and analysis. You must decide what data will be stored, how that data will be divided between tables, and how the tables will interrelate.

- In most tables you create for a database, you want to identify a column, or possibly a combination of columns, as the table's key column or field, also called the primary key. The primary key is important because you can configure your software to prevent multiple records from containing the same value in this column, thus avoiding data-entry errors. In addition, you can sort your records in primary key order before displaying or printing them, and you need to use this column when setting up relationships between the table and others that will become part of the same database.

- A shorthand way to describe a table is to use the table name followed by parentheses containing all the field names, with the primary key underlined.

- Entering data into an already created table requires a good deal of time and accurate typing. Depending on the application, the contents of the tables might be entered over the course of many months or years by any number of data-entry personnel. Deleting records from and modifying records within a database table are relatively easy tasks. In most organizations, most of the important data is in a constant state of change.

- Database management software generally allows you to sort a table based on any column, letting you view your data in the way that is most useful to you. After rows are sorted, they usually can be grouped.

- Frequently, you want to cull subsets of data from a table you have created. The questions that cause the database software to extract the appropriate records from a table and specify the fields to be viewed are called queries. Depending on the software you use, you might create a query by filling in blanks, a process called query by example, or by writing statements similar to those in many programming languages. The most common language that database administrators use to access data in their tables is Structured Query Language, or SQL.
- Most database applications require many tables, and these applications also require that the tables be related. The three types of relationships are one-to-many, many-to-many, and one-to-one.
- As you create database tables that will hold the data an organization needs, you will encounter many situations in which the table design, or structure, is inadequate to support the needs of the application.
- Normalization is the process of designing and creating a set of database tables that satisfies the users' needs and avoids many potential problems. The normalization process helps you reduce data redundancies, update anomalies, delete anomalies, and insert anomalies. The normalization process involves altering a table so that it satisfies one or more of three normal forms, or rules, for constructing a well-designed database. The three normal forms are first normal form, also known as 1NF, in which you eliminate repeating groups; second normal form, also known as 2NF, in which you eliminate partial key dependencies; and third normal form, also known as 3NF, in which you eliminate transitive dependencies.
- Frequently, a company's database is its most valuable resource. Major security issues include providing data integrity, recovering lost data, avoiding concurrent update problems, providing authentication and permissions, and providing encryption.

KEY TERMS

A **database** holds a group of files, or tables, that an organization needs to support its applications.

A database **table** contains data in rows and columns.

An **entity** is one record or row in a database table.

An **attribute** is one field or column in a database table.

A **primary key**, or **key** for short, is a field or column that uniquely identifies a record.

A **compound key**, also known as a **composite key**, is a key constructed from multiple columns.

Database management software is a set of programs that allows users to create table descriptions; identify key fields; add records to, delete records from, and update records within a table; arrange records so they are sorted by different fields; write questions that select specific records from a table for viewing; write questions that combine information from multiple tables; create reports and forms; and keep data secure by employing sophisticated security measures.

A **relational database** contains a group of tables from which you can make connections to produce virtual tables.

Immutable means not changing during normal operation.

Candidate keys are columns or attributes that could serve as a primary key in a table.

After you choose a primary key from among candidate keys, the remaining candidate keys become **alternate keys**.

A **query** is a question asked using syntax that the database software can understand. Its purpose is often to display a subset of data.

Query by example is the process of creating a query by filling in blanks.

Structured Query Language, or **SQL**, is a commonly used language for accessing data in database tables.

The **SELECT-FROM-WHERE** SQL statement is the command that selects the fields you want to view from a specific table where one or more conditions are met.

A **view** is a particular way of looking at a database.

A **relationship** is a connection between two tables.

A **join operation**, or a **join**, connects two tables based on the values in a common column.

A **join column** is the column on which two tables are connected.

A **one-to-many relationship** is one in which one row in a table can be related to many rows in another table. It is the most common type of relationship among tables.

The **base table** in a one-to-many relationship is the “one” table.

The **related table** in a one-to-many relationship is the “many” table.

A **non-key attribute** is any column in a table that is not a key.

A **foreign key** is a column that is not a key in a table, but contains an attribute that is a key in a related table.

A **many-to-many relationship** is one in which multiple rows in each of two tables can correspond to multiple rows in the other.

In a **one-to-one relationship**, a row in one table corresponds to exactly one row in another table.

In a database, empty columns are **nulls**.

Normalization is the process of designing and creating a set of database tables that satisfies the users’ needs and avoids redundancies and anomalies.

Data redundancy is the unnecessary repetition of data.

An **anomaly** is an irregularity in a database's design that causes problems and inconveniences.

An **update anomaly** is a problem that occurs when the data in a table needs to be altered; the result is repeated data.

A **delete anomaly** is a problem that occurs when a row in a table is deleted; the result is loss of related data.

An **insert anomaly** is a problem that occurs when new rows are added to a table; the result is incomplete rows.

Normal forms are rules for constructing a well-designed database.

First normal form, also known as **1NF**, is the normalization form in which you eliminate repeating groups.

Second normal form, also known as **2NF**, is the normalization form in which you eliminate partial key dependencies.

Third normal form, also known as **3NF**, is the normalization form in which you eliminate transitive dependencies.

An **unnormalized** table contains repeating groups.

A **repeating group** is a subset of rows in a database table that all depend on the same key.

To **concatenate columns** is to combine columns to produce a compound key.

Atomic attributes or columns are as small as possible so as to contain an undividable piece of data.

Atomic transactions appear to execute completely or not at all.

A **partial key dependency** occurs when a column in a table depends on only part of the table's key.

A **transitive dependency** occurs when the value of a non-key attribute determines, or predicts, the value of another non-key attribute.

An attribute is **functionally dependent** on another if it can be determined by the other attribute.

You might **denormalize** a table, or place it in a lower normal form, by placing some repeated information back into it.

A database has **data integrity** when it follows a set of rules that makes the data accurate and consistent.

Recovery is the process of returning the database to a correct form that existed before an error occurred.

A **concurrent update problem** occurs when two database users need to make changes to the same record at the same time.

A **lock** is a mechanism that prevents changes to a database for a period of time.

A **persistent lock** is a long-term database lock required when users want to maintain a consistent view of their data while making modifications over a long transaction.

A **batch** is a group of transactions applied all at once.

Authentication techniques include storing and verifying passwords or even using physical characteristics, such as fingerprints or voice recognition, before users can view data.

The **permissions** assigned to a user indicate which parts of the database the user can view, and which parts he or she can change or delete.

Encryption is the process of coding data into a format that human beings cannot read.

REVIEW QUESTIONS

1. **A field or column that uniquely identifies a row in a database table is a(n) _____.**
   a. variable
   b. identifier
   c. principal
   d. key

2. **Which of the following is *not* a feature of most database management software?**
   a. sorting records in a table
   b. creating reports
   c. preventing poorly designed tables
   d. relating tables

3. **Before you can enter any data into a database table, you must do all of the following except _____.**
   a. determine the attributes the table will hold
   b. provide names for each attribute
   c. provide data types for each attribute
   d. determine maximum and minimum values for each attribute

4. **Which of the following is the best key for a table containing a landlord's rental properties?**
   a. `numberOfBedrooms`
   b. `amountOfMonthlyRent`
   c. `streetAddress`
   d. `tenantLastName`

5. **A table's notation is:** `tblClients(socialSecNum, lastName, firstName, clientNumber, balanceDue)`. **You know that** _____.
   a. the primary key is `socialSecNum`
   b. the primary key is `clientNumber`
   c. there are four candidate keys
   d. there is at least one numeric attribute

6. **You can extract subsets of data from database tables using a(n)** _____.
   a. query
   b. sort
   c. investigation
   d. subroutine

7. **A database table has the structure** `tblPhoneOrders(orderNum, custName, custPhoneNum, itemOrdered, quantity)`. **Which SQL statement could be used to extract all attributes for orders for item AB3333?**
   a. `SELECT * FROM tblPhoneOrders WHERE itemOrdered = "AB3333"`
   b. `SELECT tblPhoneOrders WHERE itemOrdered = "AB3333"`
   c. `SELECT itemOrdered FROM tblPhoneOrders WHERE = "AB3333"`
   d. Two of these are correct.

8. **Connecting two database tables based on the value of a column (producing a virtual view of a new table) is a** _____ **operation.**
   a. merge
   b. concatenate
   c. join
   d. met

9. **Heartland Medical Clinic maintains a database to keep track of patients. One table can be described as:** `tblPatients(patientId, name, address, primaryPhysicianCode)`. **Another table contains physician codes along with other physician data; it is described as** `tblPhysicians(physicianCode, name, officeNumber, phoneNumber, daysOfWeekInOffice)`. **In this example, the relationship is** _____.
   a. one-to-one
   b. one-to-many
   c. many-to-many
   d. impossible to determine

10. Edgerton Insurance Agency sells life, home, health, and auto insurance policies. The agency maintains a database containing a table that holds customer data—each customer's name, address, and types of policies purchased. For example, customer Michael Robertson holds life and auto policies. Another table contains information on each type of policy the agency sells—coverage limits, term, and so on. In this example, the relationship is _____.

a. one-to-one
b. one-to-many
c. many-to-many
d. impossible to determine

11. Kratz Computer Repair maintains a database that contains a table that holds job information about each repair job the company agrees to perform. The jobs table is described as: `tblJobs(jobId, dateStarted, customerId, technicianId, feeCharged)`. Each job has a unique ID number that serves as a key to this table. The `customerId` and `technicianId` columns in the table each link to other tables where customer information, such as name, address, and phone number, and technician information, such as name, office extension, and hourly rate, are stored. When the `tblJobs` and `tblCustomers` tables are joined, which is the base table?

a. `tblJobs`
b. `tblCustomers`
c. `tblTechnicians`
d. a combination of two tables

12. When a column that is not a key in a table contains an attribute that is a key in a related table, the column is called a _____.

a. foreign key
b. merge column
c. internal key
d. primary column

13. The most common reason to construct a one-to-one relationship between two tables is _____.

a. to save money
b. to save time
c. for security purposes
d. so that neither table is considered "inferior"

14. The process of designing and creating a set of database tables that satisfies the users' needs and avoids many potential problems is _____.

a. purification
b. normalization
c. standardization
d. structuring

15. The unnecessary repetition of data is called data _____.

a. amplification
b. echoing
c. redundancy
d. mining

16. Problems with database design are caused by irregularities known as _____.

a. glitches
b. anomalies
c. bugs
d. abnormalities

17. When you place a table into first normal form, you have eliminated _____.

a. transitive dependencies
b. partial key dependencies
c. repeating groups
d. all of the above

18. When you place a table into third normal form, you have eliminated _____.

a. transitive dependencies
b. partial key dependencies
c. repeating groups
d. all of the above

19. If a table contains no repeating groups, but a column depends on part of the table's key, the table is in _____ normal form.

a. first
b. second
c. third
d. fourth

20. Which of the following is not a database security issue?

a. providing data integrity
b. recovering lost data
c. providing normalization
d. providing encryption

FIND THE BUGS

1. Create tables as needed so the following employee table is in 3NF.

empID	lastName	firstName	dept	floor	supervisor	payRate
123	Henderson	Robert	HR	1	Rollings	11.00
124	Barker	Anne	MKTG	2	Jenkins	23.50
145	Lee	Benjamin	MFG	3	Liu	15.00
157	Davis	Robert	MFG	3	Liu	14.75
178	Nance	Cody	MKTG	2	Jenkins	24.00
184	Rice	Paula	HR	1	Rollings	12.45
189	Lee	Anne	MFG	3	Liu	15.55
243	Saunders	Marcie	MKTG	2	Jenkins	25.75
256	Freize	Michael	MFG	3	Liu	15.00

2. Suppose you have started a collection of old records. You want to store them in a database so you can select records by title, artist, or condition of the recording. Create tables as needed so the following record collection table is in 3NF.

idNum	title	artists	condition
11	Ebony and Ivory	Paul McCartney Stevie Wonder	Good
12	Yesterday	Paul McCartney John Lennon	Excellent
13	Just a Gigolo	Louis Prima	Fair
14	I've Got You Under My Skin	Peggy Lee	Fair
15	I've Got You Under My Skin	Louis Prima Keely Smith	Excellent

EXERCISES

1. **The Lucky Dog Grooming Parlor maintains data about each of its clients in a table named `tblClients`. Attributes include each dog's name, breed, and owner's name, all of which are text attributes. The only numeric attributes are an ID number assigned to each dog and the balance due on services. The table structure is `tblClients(dogID, name, breed, owner, balanceDue)`. Write the SQL statement that would select each of the following:**

   a. names and owners of all Great Danes
   b. owners of all dogs with balance due over $100
   c. all attributes of dogs named "Fluffy"
   d. all attributes of poodles whose balance is no greater than $50

2. **Consider the following table with the structure `tblRecipes(recipeName, timeToPrepare, ingredients)`. If necessary, redesign the table so it satisfies each of the following:**

   a. 1NF
   b. 2NF
   c. 3NF

recipeName	timeToPrepare	ingredients
Baked lasagna	1 hour	1 pound lasagna noodles ½ pound ground beef 16 ounces tomato sauce ½ pound ricotta cheese ½ pound parmesan cheese 1 onion
Fruit salad	10 minutes	1 apple 1 banana 1 bunch grapes 1 pint blueberries
Marinara sauce	30 minutes	16 ounces tomato sauce ¼ pound parmesan cheese 1 onion

3. Consider the following table with the structure `tblFriends(lastName, firstName, address, birthday, phoneNumbers, emailAddresses)`**. If necessary, redesign the table so it satisfies each of the following:**

a. 1NF
b. 2NF
c. 3NF

lastName	firstName	address	birthday	phoneNumbers	emailAddresses
Gordon	Alicia	34 Second St.	3/16	222-4343 349-0012	agordon@mail.com
Washington	Edward	12 Main St.	12/12	222-7121	ewash@mail.com coolguy@earth.com
Davis	Olivia	55 Birch Ave.	10/3	222-9012 333-8788 834-0112	olivia@abc.com

4. **You have created the following table to keep track of your DVD collection. The structure is `tblDVDs(movie, year, stars)`. If necessary, redesign the table so it satisfies each of the following:**

   a. 1NF
   b. 2NF
   c. 3NF

movie	year	stars
Jerry McGuire	1996	Tom Cruise Renee Zellweger
Chicago	2002	Renee Zellweger Catherine Zeta-Jones Richard Gere
Risky Business	1983	Tom Cruise Rebecca DeMornay

5. **The Midtown Ladies Auxiliary is sponsoring a scholarship for local high-school students. They have constructed a table with the structure `tblScholarshipApplicants(appId, lastName, hsAttended, hsAddress, gpa, honors, clubsActivities)`. The `hsAttended` and `hsAddress` attributes represent high school attended and its street address, respectively. The `gpa` attribute is a grade point average. The `honors` attribute holds awards received, and the `clubsActivities` attribute holds the names of clubs and activities in which the student participated. If necessary, redesign the table so it satisfies each of the following:**

   a. 1NF
   b. 2NF
   c. 3NF

appId	lastName	hsAttended	hsAddress	gpa	honors	clubsActivities
1	Wong	Central	1500 Main	3.8	Citizenship award Class officer Soccer MVP	Future teachers Model airplane Newspaper
2	Jefferson	Central	1500 Main	4.0	Valedictorian Citizenship award Homecoming court Football MVP	Pep Yearbook
3	Mitchell	Highland	200 Airport	3.6	Class officer Homecoming court	Pep Future teachers
4	O'Malley	St. Joseph	300 Fourth	4.0	Valedictorian	Pep Chess
5	Abel	Central	1500 Main	3.7	Citizenship award Class officer	Yearbook

6. Assume you want to create a database to store information about your music collection. You want to be able to query the database for each of the following attributes:

- ☐ A particular title (for example, *Tapestry* or Beethoven's Fifth Symphony)
- ☐ Artist (for example, Carole King or the Chicago Symphony Orchestra)
- ☐ Format of the recording (for example, CD or tape)
- ☐ Style of music (for example, rock or classical)
- ☐ Year recorded
- ☐ Year acquired as part of your collection
- ☐ Recording company
- ☐ Address of the recording company

Design the tables you would need so they are all in third normal form. Create at least five sample data records for each table you create.

7. **Design a group of database tables for the St. Charles Riding Academy. The Academy teaches students to ride by starting them on horses that have been ranked as to their manageability, using a numeric score from 1 to 4. The data you need to store includes the following attributes:**

   - ☐ Student's last name
   - ☐ Student's first name
   - ☐ Student's address
   - ☐ Student's age
   - ☐ Student's emergency contact information—name and phone number
   - ☐ Student's riding level—1, 2, 3, or 4
   - ☐ Each horse's name
   - ☐ Horse's age
   - ☐ Horse's color
   - ☐ Horse's manageability level—1, 2, 3, or 4
   - ☐ Horse's veterinarian's name
   - ☐ Horse's veterinarian's phone number

   Design the tables you would need so they are all in third normal form. Create at least five sample data records for each table you create.

DETECTIVE WORK

1. **What is data mining? Is it a good or bad thing?**
2. **How many free databases can you locate on the Web? What types of data do they offer?**
3. **What organization uses the world's most heavily used database system?**

UP FOR DISCUSSION

1. In this chapter, a phone book was mentioned as an example of a database you use frequently. Name some other examples.

2. Suppose you have authority to browse your company's database. The company keeps information on each employee's past jobs, health insurance claims, and any criminal record. Also suppose that there is an employee at the company whom you want to ask out on a date. Should you use the database to obtain information about the person? If so, are there any limits on the data you should use? If not, should you be allowed to pay a private detective to discover similar data?

3. The FBI's National Crime Information Center (NCIC) is a computerized database of criminal justice information (for example, data on criminal histories, fugitives, stolen property, and missing persons). It is available to federal, state, and local law enforcement and other criminal justice agencies 24 hours a day, 365 days a year. It is almost inevitable that such large systems will contain some inaccuracies. Various studies have indicated that perhaps less than half the records in this database are complete, accurate, and unambiguous. Do you approve of this system or object to it? Would you change your mind if there were no inaccuracies? Is there a level of inaccuracy you would find acceptable to realize the benefits such a system provides?

4. What type of data might be useful to a community in the wake of a natural disaster? Who should pay for the expense of gathering, storing, and maintaining this data?

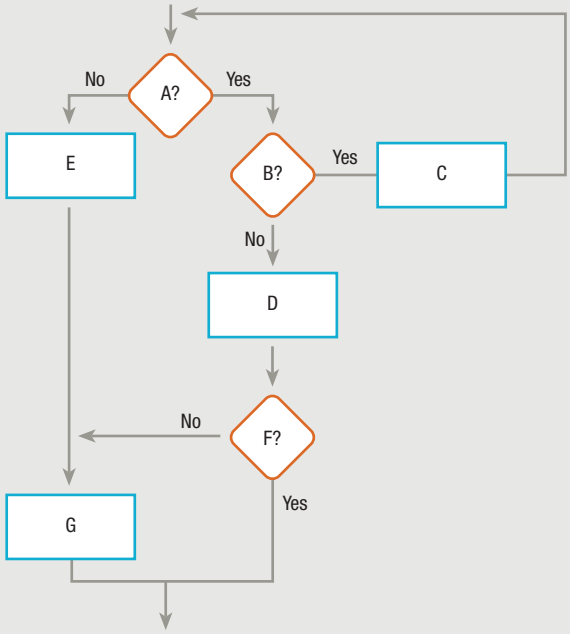
APPENDIX A

SOLVING DIFFICULT STRUCTURING PROBLEMS

In Chapter 2, you learned that you can solve any logical problem using only the three standard structures—sequence, selection, and looping. Often it is a simple matter to modify an unstructured program to make it adhere to structured rules. Sometimes, however, it is a challenge to structure a more complicated program. Still, no matter how complicated, large, or poorly structured a problem is, the same tasks can *always* be accomplished in a structured manner.

Consider the flowchart segment in Figure A-1. Is it structured?

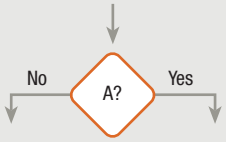
FIGURE A-1: UNSTRUCTURED FLOWCHART SEGMENT



No, it's not. To straighten out the flowchart segment, making it structured, you can use the "spaghetti" method. Using this method, you untangle each path of the flowchart as if you were attempting to untangle strands of spaghetti in a bowl. The objective is to create a new flowchart segment that performs exactly the same tasks as the first, but using only the three structures—sequence, selection, and loop.

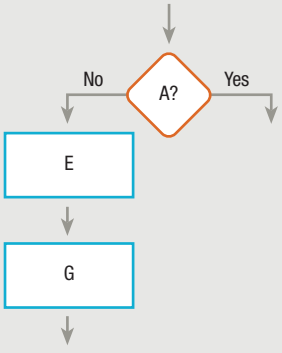
To begin to untangle the unstructured flowchart segment, you start at the beginning with the decision labeled A, shown in Figure A-2. This step must represent the beginning of either a selection or a loop, because a sequence would not contain a decision.

FIGURE A-2: STRUCTURING, STEP 1



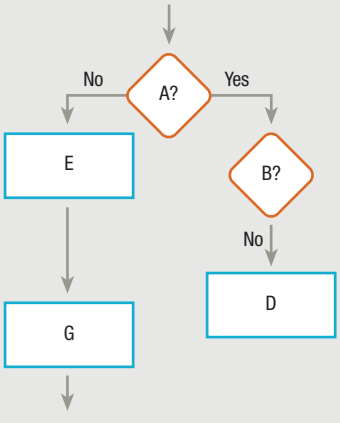
If you follow the logic on the No, or left, side of the question in the original flowchart, you can pull up on the left branch of the decision. You encounter process E, followed by G, followed by the end, as shown in Figure A-3. Compare the "No" actions after Decision A in the first flowchart (Figure A-1) with the actions after Decision A in Figure A-3; they are identical.

FIGURE A-3: STRUCTURING, STEP 2



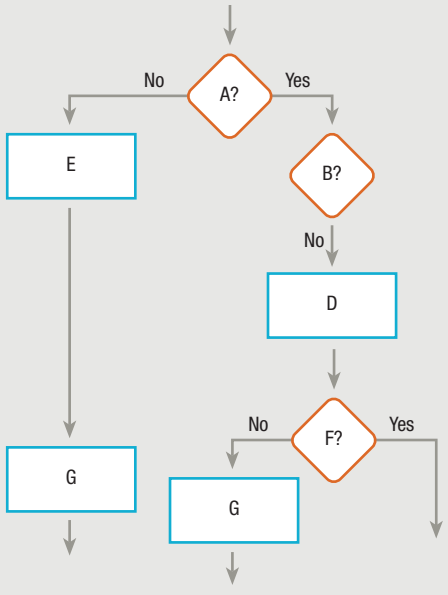
Now continue on the right, or Yes, side of Decision A in Figure A-1. When you follow the flowline, you encounter a decision symbol, labeled B. Pull on B's left side, and a process, D, comes up next. See Figure A-4.

FIGURE A-4: STRUCTURING, STEP 3



After Step D in the original diagram, a decision labeled F comes up. Pull on its left, or No, side and you get a process, G, and then the end. When you pull on F's right, or Yes, side in the original flowchart, you simply reach the end, as shown in Figure A-5. Notice in Figure A-5 that the G process now appears in two locations. When you improve unstructured flowcharts so that they become structured, you often must repeat steps. This eliminates crossed lines and difficult-to-follow spaghetti logic.

FIGURE A-5: STRUCTURING, STEP 4



The biggest problem in structuring the original flowchart segment from Figure A-1 follows the right, or Yes, side of the B decision. When the answer to B is Yes, you encounter process C, as shown in both Figures A-1 and A-6. The structure that begins with Decision C looks like a loop because it doubles back, up to Decision A. However, the rules of a structured loop say that it must have the appearance shown in Figure A-7: a question, followed by a structure, returning right back to the question. In Figure A-1, if the path coming out of C returned right to B, there would be no problem; it would be a simple, structured loop. However, as it is, Question A must be repeated. The spaghetti technique says if things are tangled up, start repeating them. So repeat an A decision after C, as Figure A-6 shows.

FIGURE A-6: STRUCTURING, STEP 5

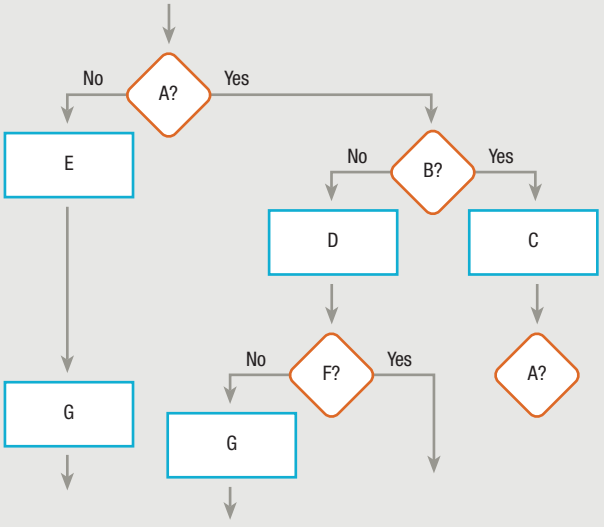
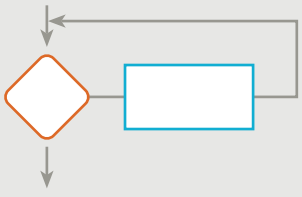
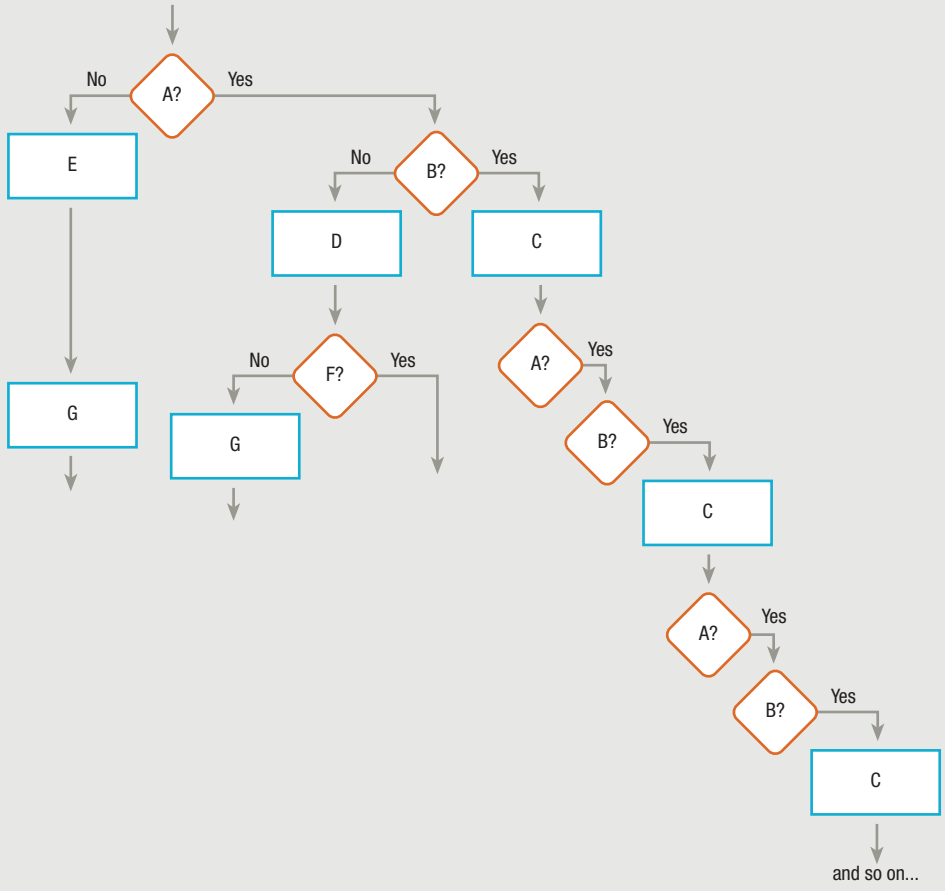


FIGURE A-7: A STRUCTURED LOOP



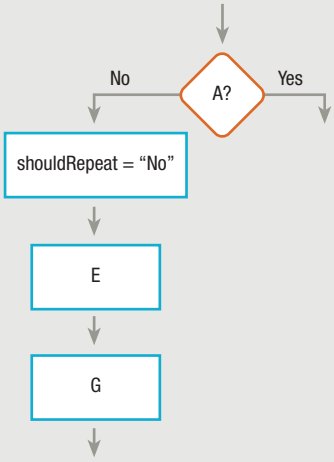
In the original flowchart segment in Figure A-1, when A is Yes, Question B always follows. So, in Figure A-8, after A is Yes, B is Yes, Step C executes, and A is asked again; when A is Yes, B repeats. In the original, when B is Yes, C executes, so in Figure A-8, on the right side of B, C repeats. After C, A occurs. On the right side of A, B occurs. On the right side of B, C occurs. After C, A should occur again, and so on. Soon you should realize that, in order to follow the steps in the same order as in the original flowchart segment, you will repeat these same steps forever. See Figure A-8.

FIGURE A-8: STRUCTURING, STEP 6, WHICH NEVER ENDS



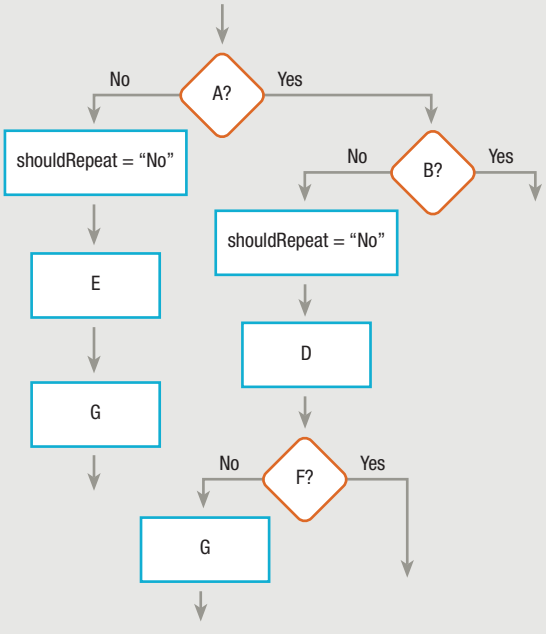
If you continue with Figure A-8, you will never be able to end; every C is always followed by another A, B, and C. Sometimes, in order to make a program segment structured, you have to add an extra flag variable to get out of an infinite mess. A flag is a variable that you set to indicate a true or false state. Typically, a variable is called a flag when its only purpose is to tell you whether some event has occurred. You can create a flag variable named `shouldRepeat` and set the value of `shouldRepeat` to "Yes" or "No," depending on whether it is appropriate to repeat Decision A. When A is No, the `shouldRepeat` flag should be set to "No" because, in this situation, you never want to repeat Question A again. See Figure A-9.

FIGURE A-9: ADDING A FLAG TO THE FLOWCHART



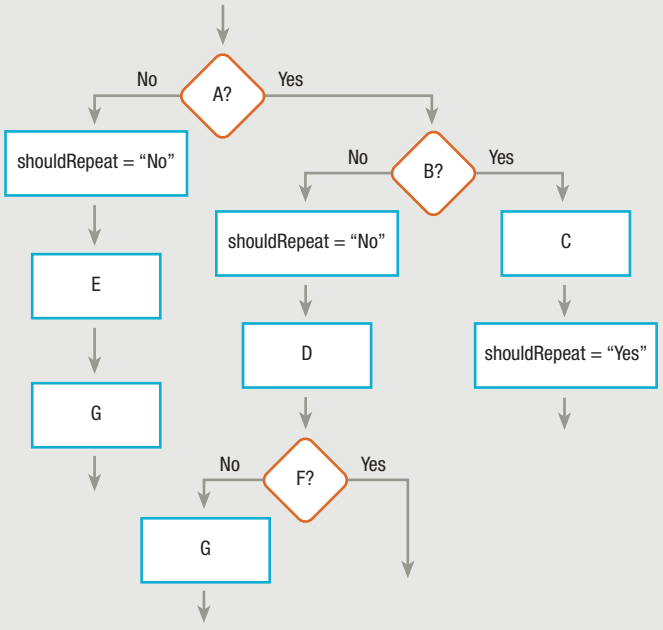
Similarly, after A is Yes, but when B is No, you never want to repeat Question A again, either. Figure A-10 shows that you set `shouldRepeat` to “No” when the answer to B is No. Then you continue with D and the F decision that executes G when F is No.

FIGURE A-10: ADDING A FLAG TO A SECOND PATH IN THE FLOWCHART



However, in the original flowchart segment in Figure A-1, when the B decision result is Yes, you *do* want to repeat A. So when B is Yes, perform the process for C and set the `shouldRepeat` flag equal to “Yes”, as shown in Figure A-11.

FIGURE A-11: ADDING A FLAG TO A THIRD PATH IN THE FLOWCHART



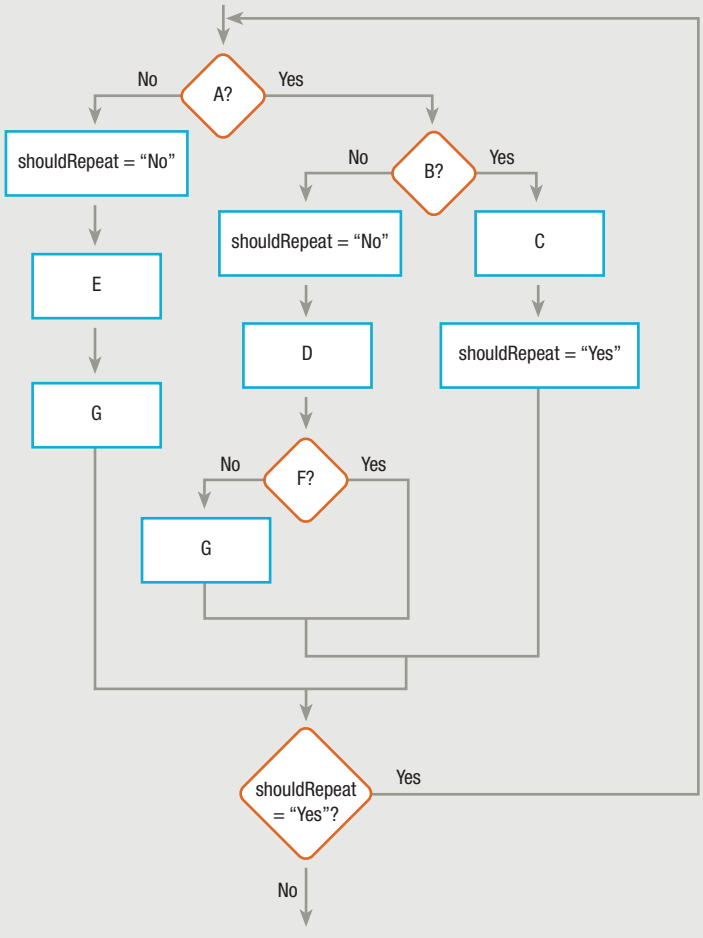
Now all paths of the flowchart can join together at the bottom with one final question: Is `shouldRepeat` equal to "Yes"? If it isn't, exit; but if it is, extend the flowline to go back to repeat Question A. See Figure A-12. Take a moment to verify that the steps that would execute following Figure A-12 are the same steps that would execute following Figure A-1.

- When A is No, E and G always execute.
- When A is Yes and B is No, D and decision F always execute.
- When A is Yes and B is Yes, C always executes and A repeats.

TIP

Figure A-12 contains three nested selection structures. In Figure A-12, notice how the F decision begins a complete selection structure whose Yes and No paths join together when the structure ends. This F selection structure is within one path of the B decision structure; the B decision begins a complete selection structure, the Yes and No paths of which join together at the bottom. Likewise, the B selection structure resides entirely within one path of the A selection structure.

FIGURE A-12: TYING UP THE LOOSE ENDS



The flowchart segment in Figure A-12 performs identically to the original spaghetti version in Figure A-1. However, is this new flowchart segment structured? There are so many steps in the diagram, it is hard to tell. You may be able to see the structure more clearly if you create a module named `aThroughG()`. If you create the module shown in Figure A-13, then the original flowchart segment can be drawn as in Figure A-14.

FIGURE A-13: THE `aThroughG()` MODULE

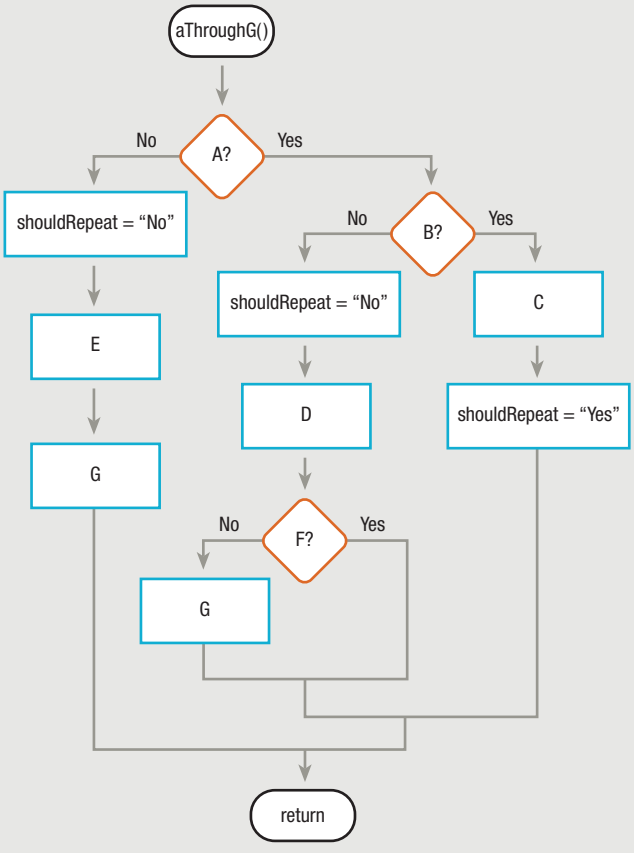
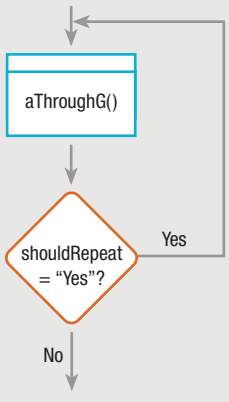
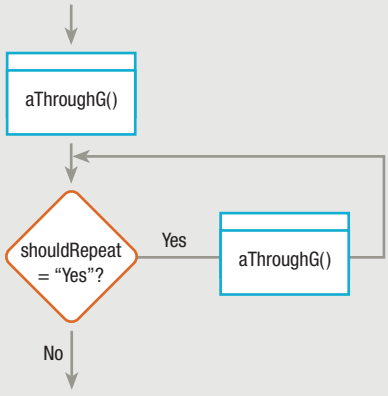


FIGURE A-14: LOGIC IN FIGURE A-12, SUBSTITUTING A MODULE FOR STEPS A THROUGH G



Now you can see that the completed flowchart segment in Figure A-14 is a `do until` loop. If you prefer to use a `while` loop, you can redraw Figure A-14 to perform a sequence followed by a `while` loop, as shown in Figure A-15.

FIGURE A-15: LOGIC IN FIGURE A-14, SUBSTITUTING A SEQUENCE AND `WHILE` LOOP FOR THE `DO UNTIL` LOOP



It has taken some effort, but any logical problem can be made to conform to structured rules. It may take extra steps, including repeating specific steps and using some flag variables, but every logical problem can be solved using the three structures: sequence, selection, and loop.

APPENDIX B

UNDERSTANDING NUMBERING SYSTEMS AND COMPUTER CODES

The numbering system with which you are most familiar is the decimal system—the system based on ten digits, 0 through 9. When you use the decimal system, there are no other symbols available; if you want to express a value larger than 9, you must resort to using multiple digits from the same pool of ten, placing them in columns.

When you use the decimal system, you analyze a multicolumn number by mentally assigning place values to each column. The value of the rightmost column is 1, the value of the next column to the left is 10, the next column is 100, and so on, multiplying the column value by 10 as you move to the left. There is no limit to the number of columns you can use; you simply keep adding columns to the left as you need to express higher values. For example, Figure B-1 shows how the value 305 is represented in the decimal system. You simply sum the value of the digit in each column after it has been multiplied by the value of its column.

FIGURE B-1: REPRESENTING 305 IN THE DECIMAL SYSTEM

Column value:	100	10	1
Number:	3	0	5
Evaluation:	3*100	+0*10	+5*1

The **binary numbering system** works in the same way as the decimal numbering system, except that it uses only two digits, 0 and 1. When you use the binary system, if you want to express a value greater than 1, you must resort to using multiple columns, because no single symbol is available that represents any value other than 0 or 1. However, instead of each new column to the left being 10 times greater than the previous column, when you use the binary system, each new column is only two times the value of the previous column. For example, Figure B-2 shows how the number 9 is represented in the binary system, and Figure B-3 shows how the value 305 is represented. Notice that in both figures that show binary numbers, as well as in the decimal system, it is perfectly acceptable—and often necessary—to write a number containing 0 as some of the digits. As with the decimal system, when you use the binary system, there is no limit to the number of columns you can use—you use as many as it takes to express a value.

FIGURE B-2: REPRESENTING 9 IN THE BINARY SYSTEM

Column value:	8	4	2	1
Number:	1	0	0	1
Conversion to decimal:	1*8 = 8 +0*4 = 0 +0*2 = 0 +1*1 = 1 ——— Total: 9			

FIGURE B-3: REPRESENTING 305 IN THE BINARY SYSTEM

Column value:	256	128	64	32	16	8	4	2	1
Number:	1	0	0	1	1	0	0	0	1

Conversion to decimal:

```
    1*256 = 256
+   0*128 =   0
+   0* 64 =   0
+   1* 32 =  32
+   1* 16 =  16
+   0*  8 =   0
+   0*  4 =   0
+   0*  2 =   0
+   1*  1 =   1
-------------
Total:      305
```

TIP Mathematicians call decimal numbers **base 10 numbers** and binary numbers **base 2 numbers**.

Every computer stores every piece of data it ever uses as a set of 0s and 1s. Each 0 or 1 is known as a **bit**, which is short for **b**inary dig**it**. Every computer uses 0s and 1s because all values in a computer are stored as electronic signals that are either on or off. This two-state system is most easily represented using just two digits.

Every computer uses a set of binary digits to represent every character it can store. If computers used only one binary digit to represent characters, then only two different characters could be represented, because the single bit could be only 0 or 1. If they used only two digits, then only four characters could be represented—one that used each of the four codes 00, 01, 10, and 11, which in decimal values are 0, 1, 2, and 3, respectively. Many computers use sets of eight binary digits to represent each character they store, because using eight binary digits provides 256 different combinations. One combination can represent an "A", another a "B", still others "a" and "b", and so on. Two hundred fifty-six combinations are enough so that each capital letter, small letter, digit, and punctuation mark used in English has its own code; even a space has a code. For example, in some computers 01000001 represents the character "A". The binary number 01000001 has a decimal value of 65, but this numeric value is not important to ordinary computer users; it is simply a code that stands for "A". The code that uses 01000001 to mean "A" is the **American Standard Code for Information Interchange**, or **ASCII**.

TIP A set of eight bits is called a **byte**. Half a byte, or four bits, is a **nibble**.

The ASCII code is not the only computer code; it is typical, and is the one used in most personal computers. The **Extended Binary Coded Decimal Interchange Code**, or **EBCDIC**, is an eight-bit code that is used in IBM mainframe computers. In these computers, the principle is the same—every character is stored as a series of binary digits. The only difference is that the actual values used are different. For example, in EBCDIC, an "A" is 11000001, or 193. Another code used by languages such as Java and C# is Unicode; with this code, 16 bits are used to represent each character. The character "A" in Unicode

has the same decimal value as the ASCII "A", 65, but it is stored as 0000000001000001. Using 16 bits provides many more possible combinations than using only eight—65,536 to be exact. With Unicode, not only are there enough available codes for all English letters and digits, but also for characters from many international alphabets.

Ordinary computer users seldom think about the numeric codes behind the letters, numbers, and punctuation marks they enter from their keyboards or see displayed on a monitor. However, they see the consequence of the values behind letters when they see data sorted in alphabetical order. When you sort a list of names, "Andrea" comes before "Brian," and "Caroline" comes after "Brian" because the numeric code for "A" is lower than the code for "B", and the numeric code for "C" is higher than the code for "B" no matter whether you are using ASCII, EBCDIC, or Unicode.

Table B-1 shows the decimal and binary values behind the most commonly used characters in the ASCII character set—the letters, numbers, and punctuation marks you can enter from your keyboard using a single key press.

TIP Most of the values not included in Table B-1 have a purpose. For example, the decimal value 7 represents a bell—a dinging sound your computer can make, often used to notify you of an error or some other unusual condition.

TIP Each binary number in Table B-1 is shown containing two sets of four digits; this convention makes the long eight-digit numbers easier to read.

TABLE B-1: DECIMAL AND BINARY VALUES FOR COMMON ASCII CHARACTERS

Decimal number	Binary number	ASCII character
32	0010 0000	Space
33	0010 0001	! Exclamation point
34	0010 0010	" Quotation mark, or double quote
35	0010 0011	# Number sign, also called an octothorpe or a pound sign
36	0010 0100	$ Dollar sign
37	0010 0101	% Percent
38	0010 0110	& Ampersand
39	0010 0111	' Apostrophe, single quote
40	0010 1000	(Left parenthesis
41	0010 1001	) Right parenthesis
42	0010 1010	* Asterisk
43	0010 1011	+ Plus sign
44	0010 1100	, Comma
45	0010 1101	- Hyphen or minus sign
46	0010 1110	. Period or decimal point
47	0010 1111	/ Slash or front slash

TABLE B-1: DECIMAL AND BINARY VALUES FOR COMMON ASCII CHARACTERS (CONTINUED)

Decimal number	Binary number	ASCII character
48	0011 0000	0
49	0011 0001	1
50	0011 0010	2
51	0011 0011	3
52	0011 0100	4
53	0011 0101	5
54	0011 0110	6
55	0011 0111	7
56	0011 1000	8
57	0011 1001	9
58	0011 1010	: Colon
59	0011 1011	; Semicolon
60	0011 1100	< Less-than sign
61	0011 1101	= Equal sign
62	0011 1110	> Greater-than sign
63	0011 1111	? Question mark
64	0100 0000	@ At sign
65	0100 0001	A
66	0100 0010	B
67	0100 0011	C
68	0100 0100	D
69	0100 0101	E
70	0100 0110	F
71	0100 0111	G
72	0100 1000	H
73	0100 1001	I
74	0100 1010	J
75	0100 1011	K
76	0100 1100	L
77	0100 1101	M
78	0100 1110	N
79	0100 1111	O

TABLE B-1: DECIMAL AND BINARY VALUES FOR COMMON ASCII CHARACTERS (CONTINUED)

Decimal number	Binary number	ASCII character	
80	0101 0000	P	
81	0101 0001	Q	
82	0101 0010	R	
83	0101 0011	S	
84	0101 0100	T	
85	0101 0101	U	
86	0101 0110	V	
87	0101 0111	W	
88	0101 1000	X	
89	0101 1001	Y	
90	0101 1010	Z	
91	0101 1011	[	Opening or left bracket
92	0101 1100	\	Backslash
93	0101 1101	]	Closing or right bracket
94	0101 1110	^	Caret
95	0101 1111	_	Underline or underscore
96	0110 0000	`	Grave accent
97	0110 0001	a	
98	0110 0010	b	
99	0110 0011	c	
100	0110 0100	d	
101	0110 0101	e	
102	0110 0110	f	
103	0110 0111	g	
104	0110 1000	h	
105	0110 1001	i	
106	0110 1010	j	
107	0110 1011	k	
108	0110 1100	l	
109	0110 1101	m	
110	0110 1110	n	
111	0110 1111	o	

TABLE B-1: DECIMAL AND BINARY VALUES FOR COMMON ASCII CHARACTERS (CONTINUED)

Decimal number	Binary number	ASCII character	
112	0111 0000	p	
113	0111 0001	q	
114	0111 0010	r	
115	0111 0011	s	
116	0111 0100	t	
117	0111 0101	u	
118	0111 0110	v	
119	0111 0111	w	
120	0111 1000	x	
121	0111 1001	y	
122	0111 1010	z	
123	0111 1011	{	Opening or left brace
124	0111 1100	|	Vertical line or pipe
125	0111 1101	}	Closing or right brace
126	0111 1110	~	Tilde

APPENDIX C

USING A LARGE DECISION TABLE

In Chapter 5, you learned to use a simple decision table, but real-life problems often require many decisions. A complicated decision process is represented in the following situation. Suppose your employer sends you a memo outlining a year-end bonus plan with complicated rules. Appendix C walks you through the process of solving this problem by using a large decision table.

```
To: Programming staff
From: The boss
I need a report listing every employee and the
bonus I plan to give him or her. Everybody gets
at least $100. All the employees in Department 2
get $200, unless they have more than 5 dependents.
Anybody with more than 5 dependents gets $1000
unless they're in Department 2. Nobody with an ID
number greater than 800 gets more than $100 even
if they're in Department 2 or have more than 5
dependents.
P.S. I need this by 5 o'clock.
```

Drawing the flowchart or writing the pseudocode for this task may seem daunting. You can use a decision table to help you manage all the decisions, and you can begin to create one by listing all the possible decisions you need to make to determine an employee's bonus. They are:

- `empDept = 2?`
- `empDepend > 5?`
- `empIdNum > 800?`

Next, determine how many possible Boolean value combinations exist for the conditions. In this case, there are eight possible combinations, shown in Figure C-1. An employee can be in Department 2, have over five dependents, and have an ID number greater than 800. Another employee can be in Department 2, have over five dependents, but have an ID number that is 800 or less. Because each condition has two outcomes and there are three conditions, there are 2 * 2 * 2 , or eight possibilities. Four conditions would produce 16 possible outcome combinations, five would produce 32, and so on.

FIGURE C-1: POSSIBLE OUTCOMES OF BONUS CONDITIONS

Condition	Outcome							
empDept = 2	T	T	T	T	F	F	F	F
empDepend > 5	T	T	F	F	T	T	F	F
empIdNum > 800	T	F	T	F	T	F	T	F

TIP

In Figure C-1, notice how the pattern of Ts and Fs varies in each row. The bottom row contains one T and F, repeating four times, the second row contains two of each, repeating twice, and the top row contains four of each without repeating. If a fourth decision was required, you would place an identical grid of Ts and Fs to the right of this one, then add a new top row containing eight Ts (covering all eight columns you see currently) followed by eight Fs (covering the new copy of the grid to the right).

Next, list the possible outcome values for the bonus amounts. If you declare a numeric variable named `bonus` by placing the statement `num bonus` in your list of variables at the beginning of the program, then the possible outcomes can be expressed as:

- `bonus = 100`
- `bonus = 200`
- `bonus = 1000`

Finally, choose one required outcome for each possible combination of conditions. For example, the first possible outcome is a $100 bonus. As Figure C-2 shows, you place Xs in the `bonus = 100` row each time `empIdNum > 800` is true, no matter what other conditions exist, because the memo from the boss said, "Nobody with an ID number greater than 800 gets more than $100, even if they're in Department 2 or have more than 5 dependents."

FIGURE C-2: DECISION TABLE FOR BONUSES, PART 1

Condition	Outcome							
empDept = 2	T	T	T	T	F	F	F	F
empDepend > 5	T	T	F	F	T	T	F	F
empIdNum > 800	T	F	T	F	T	F	T	F
bonus = 100	X		X		X		X	
bonus = 200								
bonus = 1000								

Next, place an X in the `bonus = 1000` row under all remaining columns (that is, those without a selected outcome) in which `empDepend > 5` is true *unless* the `empDept = 2` condition is true, because the memo stated, "Anybody with more than 5 dependents gets $1000 unless they're in Department 2." The first four columns of the decision table do not qualify, because the `empDept` value is 2; only the sixth column in Figure C-3 meets the criteria for the $1000 bonus.

FIGURE C-3: DECISION TABLE FOR BONUSES, PART 2

Condition	Outcome							
empDept = 2	T	T	T	T	F	F	F	F
empDepend > 5	T	T	F	F	T	T	F	F
empIdNum > 800	T	F	T	F	T	F	T	F
bonus = 100	X		X		X		X	
bonus = 200								
bonus = 1000						X		

Place Xs in the `bonus = 200` row for any remaining columns in which `empDept = 2` is true and `empDepend > 5` is false, because "All the employees in Department 2 get $200, unless they have more than 5 dependents." Column 4 in Figure C-4 satisfies these criteria.

FIGURE C-4: DECISION TABLE FOR BONUSES, PART 3

Condition	Outcome							
empDept = 2	T	T	T	T	F	F	F	F
empDepend > 5	T	T	F	F	T	T	F	F
empIdNum > 800	T	F	T	F	T	F	T	F
bonus = 100	X		X		X		X	
bonus = 200				X				
bonus = 1000						X		

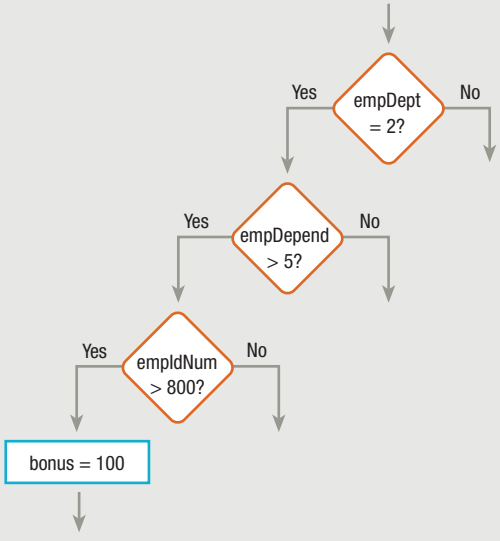
Finally, fill any unmarked columns with an X in the `bonus = 100` row because, according to the memo, "Everybody gets at least $100." The only columns remaining are the second column and the last column on the right. See Figure C-5.

FIGURE C-5: DECISION TABLE FOR BONUSES, PART 4

Condition	Outcome							
empDept = 2	T	T	T	T	F	F	F	F
empDepend > 5	T	T	F	F	T	T	F	F
empIdNum > 800	T	F	T	F	T	F	T	F
bonus = 100	X	X	X		X		X	X
bonus = 200				X				
bonus = 1000						X		

The decision table is complete. When you count the Xs, you'll find there are eight possible outcomes. Take a moment and confirm that each bonus is the appropriate value based on the specifications in the original memo from the boss. Now you can start to plan the logic. If you choose to use a flowchart, you start by drawing the path to the first outcome, which occurs when `empDept = 2`, `empDepend > 5`, and `empIdNum > 800` are all true, and which corresponds to the first column in the decision table. See Figure C-6.

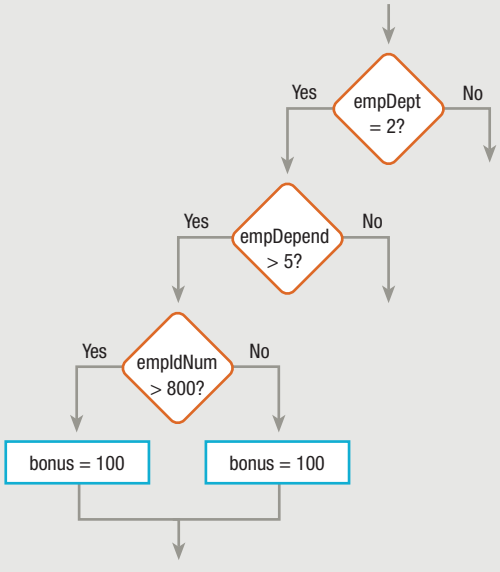
FIGURE C-6: FLOWCHART AND PSEUDOCODE FOR BONUS DECISION, PART 1




```
if empDept = 2 then
     if empDepend > 5 then
          if empIdNum > 800 then
               bonus = 100
```

To continue creating the diagram started in Figure C-6, add the "false" outcome to the `empIdNum > 800` decision; this corresponds to the second column in the decision table. When an employee's department is 2, dependents greater than 5, and ID number not greater than 800, the employee's bonus should be $100. See Figure C-7.

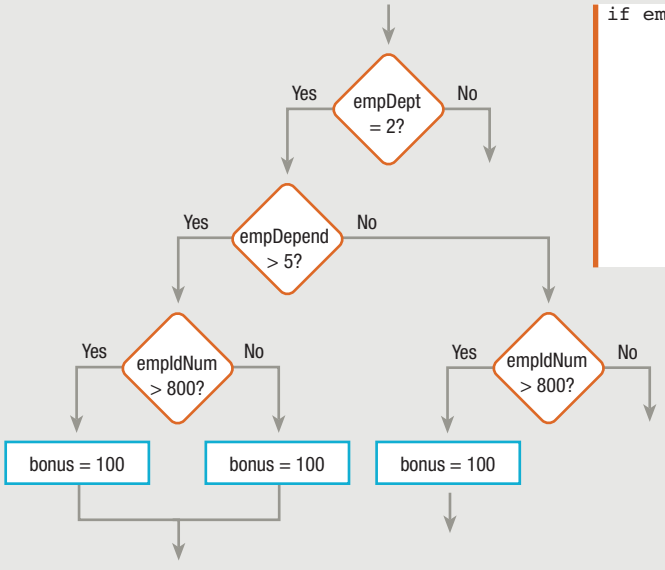
FIGURE C-7: FLOWCHART AND PSEUDOCODE FOR BONUS DECISION, PART 2




```
if empDept = 2 then
     if empDepend > 5 then
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 100
```

Continue the diagram in Figure C-7 by adding the "false" outcome when the `empDepend > 5` decision is No and the `empIdNum > 800` decision is Yes, which is represented by the third column in the decision table. In this case, the bonus is again $100. See Figure C-8.

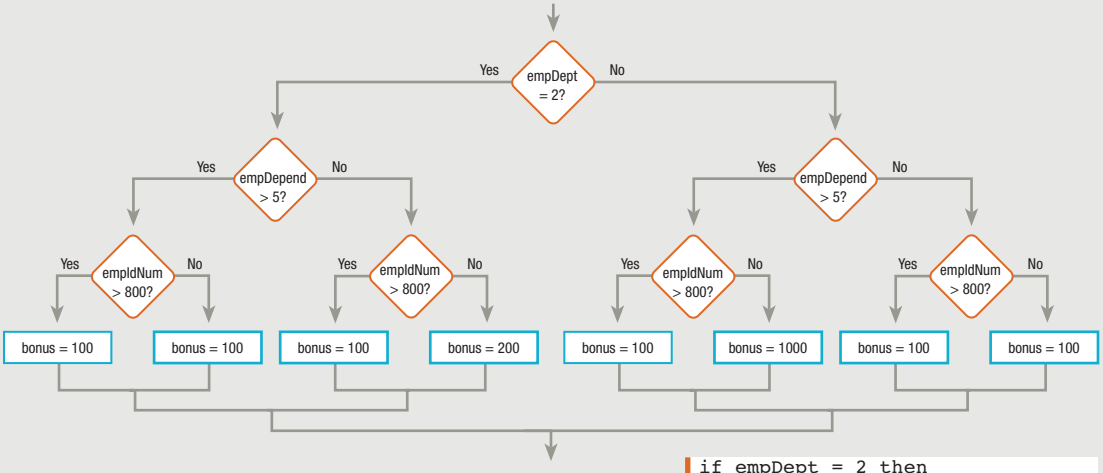
FIGURE C-8: FLOWCHART AND PSEUDOCODE FOR BONUS DECISION, PART 3




```
if empDept = 2 then
     if empDepend > 5 then
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 100
          endif
     else
          if empIdNum > 800 then
               bonus = 100
```

Continue adding decisions until you have drawn all eight possible outcomes, as shown in Figure C-9.

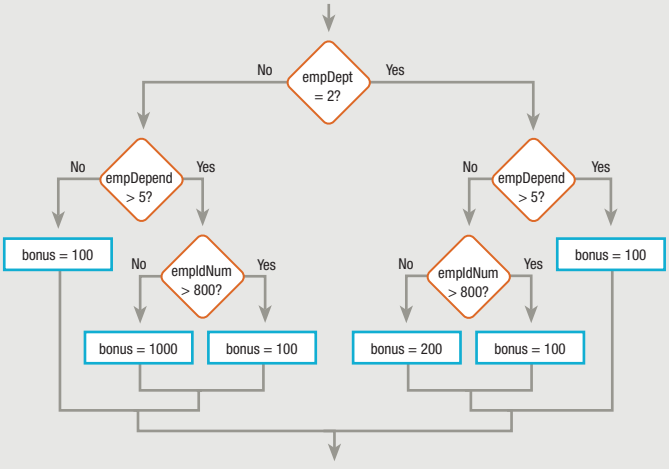
FIGURE C-9: FLOWCHART AND PSEUDOCODE FOR BONUS DECISION, PART 4




```
if empDept = 2 then
     if empDepend > 5 then
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 100
          endif
     else
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 200
          endif
else
     if empDepend > 5 then
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 1000
          endif
     else
          if empIdNum > 800 then
               bonus = 100
          else
               bonus = 100
          endif
endif
```

The logic shown in Figure C-9 correctly assigns a bonus to any employee, no matter what combination of characteristics the employee's record holds. However, you can eliminate many of the decisions shown in Figure C-9; you can eliminate any decision that doesn't make a difference. For example, if you look at the far left side of Figure C-9, you see that when `empDept` is 2 and `empDepend` is greater than 5, the outcome of `empIdNum > 800` does not matter; the `bonus` value is 100 either way. You might as well eliminate the selection. Similarly, on the far right, the `empIdNum` question makes no difference. Finally, many programmers prefer the True, or Yes, side of a flowchart decision always to appear on the right side. The result is Figure C-10.

FIGURE C-10: COMPLETE FLOWCHART AND PSEUDOCODE FOR BONUS DECISION




```
if empDept = 2 then
      if empDepend > 5 then
            bonus = 100
      else
            if empIdNum > 800 then
                  bonus = 100
            else
                  bonus = 200
            endif
      endif
else
      if empDepend > 5 then
            if empIdNum > 800 then
                  bonus = 100
            else
                  bonus = 1000
            endif
      else
            bonus = 100
      endif
endif
```

GLOSSARY

absolute value—The positive value of a number.

abstract class—A class that is created only to be a parent class and not to have objects of its own.

abstract data type—A type whose internal form is hidden behind a set of methods you use to access the data.

abstraction—The process of paying attention to important properties while ignoring nonessential details.

access specifier or **access modifier**—The adjective that defines the type of access that outside classes will have to an attribute or method.

accessibility—A quality of screen design that makes programs easier to use for people with physical limitations.

accumulator—A variable that you use to gather or accumulate values.

activity diagram—A UML diagram that shows the flow of actions of a system, including branches that occur when decisions affect the outcome.

addition record—A record in a transaction file that represents a new master record.

address—A location of computer memory where data or instructions are stored.

aggregation—An association in which one or more classes make up the parts of a larger whole class.

algorithm—The sequence of steps necessary to solve any problem.

alternate keys—In a database, the keys that remain after you choose a primary key from among candidate keys.

AND decision—A decision in which two conditions must both be true for an action to take place.

annotation symbol or **annotation box**—A flowchart symbol that represents an attached box containing notes.

anomaly—An irregularity in a database's design that causes problems and inconvenience.

argument—The passed variable named within a module header; also called a parameter. An argument is also the expression in the comma-separated list in a function call.

arithmetic expression—A statement, or part of a statement, that performs arithmetic and has a value.

array—A series or list of variables in computer memory, all of which have the same name but are differentiated with special numbers called subscripts.

ascending order—The arrangement of records from lowest to highest, based on a value within a field.

assignment operator—The equal sign; it always requires the name of a memory location on its left side.

assignment statement—A programming statement that stores the result of any calculation performed on its right side to the named location on its left side.

association relationship—The connection or link between objects in a UML diagram.

atomic attributes—Attributes or columns that are as small as possible so as to contain an undividable piece of data.

atomic transactions—Transactions that appear to execute completely or not at all.

attribute—A characteristic that defines an object as part of a class; one field or column in a database table.

authentication techniques—Storing and verifying passwords or even using physical characteristics, such as fingerprints or voice recognition, before users can view data.

base class—A parent class from which other classes are derived. *See also* original class and superclass.

base table—The "one" table in a one-to-many relationship.

batch—A group of transactions applied all at once.

batch processing—A process in which all data items are gathered prior to running a program.

binary selection or **binary decision**—A selection or decision structure that has an action associated with each of two possible outcomes. It is also called an if-then-else structure.

black box—A device you can use without understanding its internal processes; its module statements are "invisible" to the rest of the program.

block—A group of statements that execute as a single unit.

Boolean expression—An expression that represents only one of two states, usually expressed as true or false.

bubble sort—A sort in which you arrange records in either ascending or descending order by comparing items in a list in pairs; when an item is out of order, it swaps values with the item below it.

built-in methods or **built-in functions**—Prewritten modules that perform frequently needed tasks.

byte—A unit of computer storage that can contain any of 256 combinations of 0s and 1s that often represent a character.

calling module or **calling program**—A module or program that calls a module.

camel casing—The format for naming variables in which multiple-word variable names are run together, and each new word within the variable name begins with an uppercase letter.

candidate keys—Columns or attributes that could serve as a primary key in a table.

cardinality and **multiplicity**—The arithmetic relationships between objects.

cascading if statement—A decision "inside of" another decision.

case structure—A structure that provides a convenient alternative to using a series of decisions when you must make choices based on the value stored in a single variable.

catch—To receive an exception and handle a problem.

`catch` block—The group of statements that execute when a value is caught.

central processing unit (CPU)—The piece of hardware that processes data.

change record—A record in a transaction file that indicates an alteration that should be made to a master file record.

character—A letter, number, or special symbol such as "A", "7", and "$". *See also* data hierarchy.

character constant—In most programming languages, a character constant holds a single character. In this book, "character constant" is used synonymously with "string constant" to mean one or more characters enclosed within quotation marks. If a working program contains the statement `lastName = "Lincoln"`, then "Lincoln" is a character or string constant.

character variable—In most programming languages, a variable that holds a single character value. If a working program contains the statement `lastName = "Lincoln"`, then `lastName` is a character or string variable. In this book, "character variable" is used synonymously with "string variable" and "text variable".

child class—A class that inherits the attributes of another class. *See also* derived class, descendent class, and subclass.

child file—The updated version of a master file; the saved version is the parent file.

class—A term that describes a group or collection of objects with common properties.

class definition—A set of program statements that tell you the characteristics of the class's objects and the methods that can be applied to its objects.

class diagram—A tool used to describe a class; it contains a rectangle divided into three sections.

client—A person who requests a program and who will actually use the output of a program. Also called a user.

client of a class—A program or method that uses a class object.

coding—To write statements in a programming language.

cohesion—A measure of how the internal statements of a module or subroutine serve to accomplish the module's purposes.

coincidental cohesion—A type of cohesion based on coincidence—that is, the operations in a module just happen to have been placed together.

command line or **command prompt**—The location on your computer screen at which you type entries to communicate with the computer's operating system.

common coupling—A type of coupling that occurs when two or more modules access the same record.

communication diagram—A UML diagram that emphasizes the organization of objects that participate in a system.

communicational cohesion—A type of cohesion that occurs in modules that perform tasks that share data. The tasks are not related, just the data items.

compiler—Software that translates a high-level language into machine language and tells you if you have used a programming language incorrectly. Similar to an interpreter. However, a compiler translates all the statements in a program prior to executing any statements.

component diagram—A UML diagram that emphasizes the files, database tables, documents, and other components that a system's software uses.

compound key—A key constructed from multiple columns. Also known as a composite key.

concatenate columns—To combine columns to produce a compound key.

concurrent update problem—A problem that occurs when two database users need to make changes to the same record at the same time.

connector—A flowchart symbol used when limited page size forces you to continue the flowchart on the following page.

console application—A program that requires the user to enter choices using the keyboard.

constructor—A method that establishes an object.

control break—A temporary detour in the logic of a program.

control break field—A variable that holds the value that signals a break in a program.

control break program—A program in which a change in the value of a variable initiates special actions or causes special or unusual processing to occur.

control break report—A report that lists items in groups. Frequently, each group is followed by a subtotal.

control coupling—A type of coupling that occurs when a main program (or other module) passes an argument to a module, controlling the module's actions or telling it what to do.

conversion—The entire set of actions an organization must take to switch over to using a new program or set of programs.

counter—Any numeric variable you use to count the number of times an event has occurred.

coupling—A measure of the strength of the connection between two program modules.

data—All the text, numbers, and other information that are processed by a computer.

data coupling—The loosest type of coupling; therefore, it is the most desirable. Data coupling occurs when modules share a data item by passing parameters. Data coupling is also known as simple data coupling or normal coupling.

data dictionary—A list of every variable name used in a program, along with its type, size, and description.

data file—A file that contains only data for another computer program to read, not headings or other formatting.

data hiding—To completely contain and access the data or variables you use within the module in which they are declared.

data hierarchy—The representation of the relationship of databases, files, records, fields, and characters.

data integrity—The quality of a database table that follows a set of rules to make the data accurate and consistent.

data redundancy—The unnecessary repetition of data.

data type—Describes the kind of values the variable can hold and the types of operations that can be performed with it.

database—A logical container that holds a group of files, often called tables, that together serve the information needs of an organization.

database management software—A set of programs that allows users to create table descriptions; identify key fields; add records to, delete records from, and update records within a table; arrange records so they are sorted by different fields; write questions that select specific records from a table for viewing; write questions that combine information from multiple tables; create reports and forms; and keep data secure by employing sophisticated security measures.

data-structured coupling—A type of coupling similar to data coupling, in which an entire record is passed from one module to another.

dead code—Any set of program statements that will never execute—for example, those statements within a module that follow the `return` statement. Also called unreachable code.

dead path—A logical path that can never be traveled. Also called an unreachable path.

decision—Testing a value.

decision structure—A programming structure in which you ask a question, and depending on the answer, you take one of two courses of action. Then, no matter which path you follow, you continue with the next task. Also called a selection structure.

decision symbol—A diamond shape that represents a decision in a flowchart.

decision table—A problem-analysis tool that consists of four parts: conditions, possible combinations of Boolean values for the conditions, possible actions based on the conditions, and the specific actions that correspond to each Boolean value of each condition.

declaration—A statement that names a variable and tells the computer which type of data to expect.

declaring a variable—To provide a name for the memory location where the computer will store the variable value and notifying the computer what type of data to expect. In contrast, when defining a variable, an initial value for the variable is also supplied.

decrementing—To decrease a variable, often by one.

default constructor—A constructor that requires no arguments.

default value—A value assigned after all test conditions are found to be false.

defensive programming—Trying to prepare for all possible errors in programs before they occur.

defining a variable—To provide a variable with a value, as well as a name and a type, when you create it. In contrast, when you are simply declaring a variable, the variable is not initialized.

definite loop—A loop for which you definitely know the repetition factor.

delete anomaly—A problem that occurs in a database when a row in a table is deleted and related data is lost.

deletion record—A record in a transaction file that flags a record that should be removed from a master file.

delimiter—A character that separates data items, such as a comma or space.

denormalize—To place a table in a lower normal form by placing some repeated information back into it.

deployment diagram—A UML diagram that focuses on a system's hardware.

derived class—A class that inherits the attributes of another class. *See also* child class, descendent class, and subclass.

descendent class—A class that inherits the attributes of another class. *See also* child class, derived class, and subclass.

descending order—The arrangement of records highest to lowest, based on a value within a field.

desk-checking—The process of walking through a program's logic on paper.

destructor—A method that destroys an object.

detail line—On a report, a line that contains data details. Most reports contain many detail lines.

dimming—Identifying a disabled component by making its appearance muted or softer.

dispatcher module—A module that dispatches messages to a sequence of more cohesive modules.

`do until` or `do while` loop—A structure in which you ensure that a procedure executes at least once; then, depending on the answer to the controlling question, the loop may or may not execute additional times.

documentation—All of the supporting material that goes with a program.

DOS prompt—The command line in the DOS operating system.

dual-alternative if—A structure that defines one action to be taken when the tested condition is true and another action to be taken when it is false. Also called a dual-alternative selection or an if-then-else structure.

dual-alternative selection—A selection structure that has an action associated with each of two possible outcomes. Also called a dual-alternative if or an if-then-else structure.

dummy value—A preselected value that stops the execution of a program. *See also* sentinel value.

early exit—Leaving a loop before all scheduled repetitions—for example, as soon as a match is found.

element—Each separate variable in an array.

elide—To omit part of a UML diagram for clarity.

else clause—Part of a decision that holds the action or actions that execute only when the Boolean expression in the decision is false.

encapsulation—To completely contain and access the data or variables you use within the module in which they are declared. Encapsulation means that program components are bundled together.

encryption—The process of coding data into a format that human beings cannot read.

end user—A person who uses computer programs. Also called a user.

end-of-job routine—The steps you take at the end of the program to finish the application.

entity—One record or row in a database table.

`eof`—An end-of-data file marker, short for "end of file."

event—An occurrence that generates a message sent to an object.

event-based or **event-driven**—A quality of GUI programs in which actions occur in response to user-initiated events such as clicking a mouse button.

exception—The generic name used for an error in object-oriented languages; presumably, errors are not usual occurrences, but are "exceptions" to the rule.

exception-handling methods—A group of error-handling methods that object-oriented, event-driven programs employ.

executing—To have a computer use a written and compiled program. *See also* running.

extend variation—A use case variation that shows functions beyond those found in a base case.

extensible—Able, in the context of a programming language, to have new data types created in it.

external coupling—A type of coupling that occurs when two or more modules access the same global variable.

external program documentation—The supporting paperwork that programmers develop along with a program.

external storage—Persistent, relatively permanent storage outside the main memory of a computer, on a device such as a floppy disk, hard disk, or magnetic tape.

field—A single data item such as `lastName`, `streetAddress`, or `annualSalary`. *See also* data hierarchy.

file—A group of records that go together for some logical reason. *See also* data hierarchy.

file description—A document that describes the data contained in a file.

first normal form (1NF)—The normalization form in which you eliminate repeating groups.

flag—A variable that you set to indicate whether some event has occurred.

floating-point—A value that is a fractional numeric variable and contains a decimal point.

flowchart—A pictorial representation of the logical steps it takes to solve a problem.

flowline—A line or arrow that connects the steps in a flowchart.

footer—A message that prints at the end of a page or other section of a report.

footer line—The end-of-job message line. Also called a footer.

forcing—Assigning a specific value to a variable, particularly when the assignment causes a sudden change in value. You can also force a field to a value to override incorrect data.

foreign key—A column that is not a key in a table, but contains an attribute that is a key in a related table.

`for` **statement**—A statement that is frequently used to code definite loops. Most often, it contains a loop control variable that it initializes, evaluates, and increments.

function—A small program unit. Functions are also called modules, subroutines, procedures, or methods. A function is also a module that automatically provides a mathematical value such as a square root, absolute value, or random number.

functional cohesion—A quality of a module that determines the degree to which all the module statements contribute to the same task. Functional cohesion is the highest level of cohesion; you should strive for it in all methods you write.

functional decomposition—The act of reducing a large program into more manageable modules.

functionally dependent—The quality of an attribute that allows it to be determined by another attribute.

garbage—The unknown value of an undefined variable.

generalization variation—A use case variation that you use in a UML diagram when a use case is less specific than others, and you want to be able to substitute the more specific case for a general one.

global variable—A variable given a type and name once, and then used in all modules of the program.

graphical user interface (GUI)—A program interface that uses screens to display program output and allows users to interact with an operating system by clicking icons to select options.

graying—Identifying a disabled component by making its appearance muted or softer.

group name—A name for a collection of associated variables.

handler body node—The UML diagram name for an exception-handling `catch` block.

hard copy—A printed copy.

hard-coded value—A value that is explicitly assigned or used in a program.

hardware—The equipment of a computer system.

has-a relationship—An association in which one or more classes make up the parts of a larger whole class.

heading line—On a report, a line that contains the title and any column headings; usually appears only once per page.

hierarchy chart—A diagram that illustrates modules' relationships.

high-level programming language—A programming language that is English-like, as opposed to a low-level programming language.

high value—A value that is greater than any possible value in a field.

housekeeping—A module that includes steps you must perform at the beginning of a program to get ready for the rest of the program.

Hungarian notation—A variable-naming convention in which a variable's data type or other information is stored as part of the name.

icon—A small picture on a computer screen that a user can select with a mouse.

identifier—A variable name.

if clause—Part of a decision that holds the action that results when a Boolean expression in a decision is true.

if-then—Another name for a single-alternative selection structure.

if-then-else—Another name for a dual-alternative selection structure or dual-alternative `if` structure.

immutable—Not changing during normal operation.

implementation hiding—Hiding the details of the way a program or module works.

in scope—To be existing and usable. A local variable is in scope from the moment it is declared until it ceases to exist.

include variation—A use case variation that you use when a case can be part of multiple use cases in a UML diagram.

incrementing—To add to a variable (often, to add 1).

indefinite loop or **indeterminate loop**—A loop for which you cannot predetermine the number of executions.

index—To store a list of key fields paired with the storage address for the corresponding data record. An index is also a subscript.

infinite loop—A loop that never stops executing; a repeating flow of logic without an ending.

information hiding—To completely contain and access the data or variables you use within the module in which they are declared. In object-oriented programming, information hiding is the concept that other classes should not alter an object's attributes—outside classes should only be allowed to make a request that an attribute be altered; then it is up to the class methods to determine whether the request is appropriate.

inheritance—The process of acquiring the traits of one's predecessors.

initialization loop—A loop structure that provides initial values for every element in any array.

initializing—To provide a variable with a value when you create it, which is part of defining a variable.

inner loop—A loop that is contained within another loop. *See also* outer loop.

input device—A hardware device such as a keyboard or mouse; through these devices, data items enter the computer system.

input symbol—Represented as a parallelogram in flowcharts.

insert anomaly—A problem that occurs in a database when new, incomplete rows are added to a table.

insertion sort—A sort that involves looking at each pair of elements in an array. For an ascending sort, when you find an element that is smaller than the one before it, you search the array backward from that point to see where an element smaller than the out-of-order element is located. At that point, you open a new position for the out-of-order element by moving each subsequent element down one position. Then, you insert the out-of-order element into the newly opened position.

instance—An existing object of a class.

instantiate—To create a class object.

integer—A value that is a whole-number, numeric variable.

interactive applications—Applications in which the program interacts with a user who types data at a keyboard.

interactive processing—A process in which programs depend on user input while the programs are running.

interactivity diagram—A drawing that shows the relationship between screens in an interactive GUI program.

interface—The user-friendly boundary between the user and the internal mechanisms of the device.

internal program documentation—The documentation within a program.

internal storage—Temporary storage within the computer; also called memory, main memory, primary memory, or random access memory.

interpreter—Software that translates a high-level language into machine language and tells you if you have used a programming language incorrectly. Similar to a compiler. However, an interpreter translates one statement at a time, executing each statement as soon as it is translated.

IPO chart—A tool that identifies and categorizes each item needed within a module as pertaining to input, processing, or output.

is-a relationship—A relationship in which one item is an object that is an instance of a class. In object-oriented programming, the "is a" phrase can test whether an object is an instance of a class.

iteration—Repetition; another name for a loop structure. *See also* loop structure.

join column—The column on which two tables are connected.

join operation or a **join**—A connection between two tables based on the values in a common column.

key—A field or column that uniquely identifies a record.

key field—The field whose contents make the record unique among all records in a file.

library—A collection of classes that serve related purposes.

line counter—A variable that keeps track of the number of printed lines on a page.

linked list—A list that contains one extra field in every record of stored data. This extra field holds the physical address of the next logical record.

listener—An object that is "interested in" an event to which you want it to respond.

local variable—A variable declared within the module that uses it.

lock—A mechanism that prevents changes to a database for a period of time.

logic—Instructions given to the computer in a specific sequence, without leaving any instructions out or adding extraneous instructions.

logical AND operator—A symbol that you use to combine decisions so that two (or more) conditions must be true for an action to occur.

logical cohesion—A type of cohesion that takes place when a member module performs one or more tasks depending on a decision. The actions performed might go together logically (that is, perform the same type of action), but they don't work on the same data.

logical error—An error that occurs when incorrect instructions are performed, or when instructions are performed in the wrong order.

logical operator—As the term is most often used, an operator that compares single bits. However, some programmers use the term synonymously with "relational comparison operator."

logical order—The order in which you use a list, even though it is not necessarily physically stored in that order.

logical OR operator—A symbol that you use to combine decisions when any one can be true for an action to occur.

loop—A structure that repeats actions while some condition continues.

loop body—The set of statements that execute within a loop.

loop control variable—A variable that determines whether a loop will continue.

loop structure—A structure in which you continue to repeat actions based on the answer to a question.

loose coupling—A characteristic of a program that occurs when modules do not depend on others.

low-level detail—A small, nonabstract step.

low-level programming language—A programming language not far removed from machine language, as opposed to a high-level programming language.

lozenge—A four-sided shape where the top and bottom sides are parallel straight lines and the left and right sides are convex curves; terminal symbols, or start/stop symbols, in flowcharts are lozenges.

machine language—A computer's on-off circuitry language; the low-level language made up of 1s and 0s that the computer understands.

main loop—The part of a program that contains the steps that are repeated for every record.

main menu—The menu that determines whether execution of the program will continue.

main program—The program that runs from start to stop and calls other modules.

mainline logic—The overall logic of the main program from beginning to end.

major-level break—A break caused by a change in the value of a higher-level field.

many-to-many relationship—A relationship in which multiple rows in each of two tables can correspond to multiple rows in the other.

master file—A file that holds relatively permanent data.

matching record—A transaction file record that contains data about the same entity in a master file record.

mean—The arithmetic average of a list.

median—The value in the middle position of a list when the values are sorted.

menu program—A common type of interactive program in which the user sees a number of options on the screen and can select any one of them.

merging files—Combining two or more files while maintaining the sequential order.

method—A small program unit. Methods are also called modules, subroutines, functions, or procedures.

method type or **method return type**—The data type of the value that a method returns.

minor-level break—A break caused by a change in the value of a lower-level field.

mnemonic—A memory device; variable identifiers act as mnemonics for hard-to-remember memory addresses.

modularization—The process of breaking down programs into reasonable units called modules, subroutines, functions, or methods.

module—A small program unit. Programmers also refer to modules as subroutines, procedures, functions, or methods.

module header—The introductory title statement of a module.

multidimensional array or **two-dimensional array**—An array that represents a table or grid containing rows and columns.

multilevel menu—A list in which the selection of a menu option leads to another menu from which the user can make further, more refined selections.

multiple inheritance—A type of inheritance in which a class can inherit from more than one parent.

multiple-level control break—A break in which the normal flow of control breaks away for special processing in response to more than just one change in condition.

named constant—A constant that holds a value that never changes during the execution of a program.

nested decision or **nested if**—A decision "inside of" another decision.

nesting—To place a structure within another structure.

nesting loop—A loop within a loop.

nondefault constructor—A constructor that requires arguments.

non-key attribute—Any column in a table that is not a key.

normal coupling—*See also* data coupling.

normal forms—Rules for constructing a well-designed database.

normalization—The process of designing and creating a set of database tables that satisfies the users' needs and avoids redundancies and anomalies.

null—An empty column in a database table.

null case—The branch of a decision in which no action is taken.

numeric constant—A specific numeric value.

numeric variable—A variable that holds numeric values.

object diagram—A UML diagram that is similar to a class diagram, but that models specific instances of classes.

object dictionary—A list of the objects used in a program, including which screens they are used on and whether any code, or script, is associated with them.

object-oriented programming—A programming technique that focuses on objects, or "things," and describes their features, or attributes, and their behaviors. It also focuses on an application's data and the methods you need to manipulate it.

off-by-one errors—Errors that usually occur when you assume an array's first subscript is 1 but it actually is 0.

offline processing—A process in which you collect data well ahead of the actual computer processing of paychecks or bills, for example.

one-to-many relationship—A relationship in which one row in a table can be related to many rows in another table. It is the most common type of relationship among tables.

one-to-one relationship—A relationship in which a row in one table corresponds to exactly one row in another table.

online processing—A process in which the user's data or requests are gathered during the execution of the program, while the computer is operating.

opening a file—To tell the computer where the input is coming from, the name of the file (and possibly the folder), and preparing the file for reading.

operating system—The software that you use to run a computer and manage its resources.

OR decision—A decision that contains two (or more) decisions; if at least one condition is met, the resulting action takes place.

original class—A class that has descendents. *See also* base class and superclass.

out of bounds—A subscript that is not within the range of acceptable subscripts.

out of scope—A variable that has ceased to exist, or less frequently, does not yet exist.

outer loop—A loop that contains another loop. *See also* inner loop.

output device—A computer device such as a printer or monitor that lets people view, interpret, and work with information produced by a computer.

output symbol—Represented as a parallelogram in flowcharts.

overloading a method—In object-oriented programs, the act of creating multiple methods with the same name but different argument lists.

overriding a method—In object-oriented programs, a child class method taking precedence over a parent class method because both have the same signature.

package—A collection of classes that serve related purposes.

parallel arrays—Two or more arrays in which each element in one array is associated with the element in the same relative position in the other array or arrays.

parameter list—The series of parameters, or passed values, that appears in a module header.

parent file—The saved version of a master file; the updated version is the child file.

partial key dependency—A dependency that occurs when a column in a table depends on only part of the table's key.

pass a value—To send a copy of data in one module of a program to another module for use.

pathological coupling—A type of coupling that occurs when two or more modules change one another's data.

permission—A property assigned to a user that indicates which parts of the database the user can view, and which parts he or she can change or delete.

persistent lock—A long-term database lock required when users want to maintain a consistent view of their data while making modifications over a long transaction.

physical order—The order in which a list is actually stored.

pointer variable—A variable that holds a memory address.

polymorphism—A feature that allows the same operation to be carried out differently depending on the context.

posttest loop—`Do while` and `do until` loops in which a condition is tested after the loop body has executed.

precedence—The quality of an operation that means it is evaluated before others.

prefix—A set of characters used at the beginning of related variable names.

pretest loop—A `while` loop in which a condition is tested before entering the loop even once.

primary key—A field or column that uniquely identifies a record.

priming input or **priming read**—The statement that reads the first input data record prior to starting a structured loop.

primitive data type—A simple data type as opposed to a class type.

print chart or **print layout** or **printer spacing chart**—A tool for planning program output.

private access—In object-oriented programming, data that cannot be accessed by any method that is not part of the class.

procedural cohesion—A type of cohesion that takes place when, as with sequential cohesion, the tasks of a module are performed in sequence. However, unlike operations in sequential cohesion, the tasks in procedural cohesion do not share data.

procedural program—A program in which one procedure follows another from the beginning until the end.

procedural programming—A programming technique that focuses on the procedures that programmers create.

procedure—A small program unit. Procedures are also called modules, subroutines, functions, or methods.

processing—To organize data items, check them for accuracy, or perform mathematical operations on them.

processing symbol—Represented as a rectangle in flowcharts.

program comment—A nonexecuting statement that programmers place within their code to explain program statements in English.

program documentation—The set of instructions that programmers use when they begin to plan the logic of a program.

programmer-defined type—A class.

programming language—A language such as Visual Basic, C#, C++, Java, or COBOL, used to write programs.

prompt—A message that appears on a monitor, asking the user for a response.

property—An attribute of prewritten GUI classes. Also, a value of an object's attributes.

protected access—In object-oriented programming, a modifier used when you want no outside classes to be able to use a data field directly, except classes that are children of the original class.

protected node—The UML diagram name for an exception-throwing `try` block.

prototype—A signature, in some programming languages.

pseudocode—An English-like representation of the logical steps it takes to solve a problem.

public access—In object-oriented programming, the ability of other programs and methods to use the methods that control access to private data.

pure polymorphism—A form of polymorphism that occurs when one function body can be used with a variety of arguments.

query—A question that pulls related data items together from a database in a format that enhances efficient management decision making. Its purpose is often to display a subset of data.

query by example—The process of creating a query by filling in blanks.

random-access storage device—A device such as a disk from which records can be accessed in any order.

range—A series of values that encompasses every value between a high and low limit.

range check—A test that compares a variable to a series of values between limits.

range of values—A set of contiguous values.

real-time applications—Interactive computer programs that run while a transaction is taking place, not at some later time.

record—A group of fields that go together for some logical reason. *See also* data hierarchy.

recovery—The process of returning a database to a correct form that existed before an error occurred.

reference—A memory address.

reference variable—A variable that holds a memory address.

register—To sign up components that will react to events initiated by other components.

related table—The "many" table in a one-to-many relationship.

relational comparison operator—The symbol that expresses Boolean comparisons. Examples include =, >, <, >=, <=, and <>.

relational database—A database that contains a group of tables from which you can make connections to produce virtual tables.

relationship—A connection between two tables.

reliability—The feature of modular programs that assures you that a module has been tested and proven to function correctly.

repeating group—A subset of rows in a database table that all depend on the same key.

repetition—Another name for a loop structure. *See also* loop structure.

return a value—To pass a copy of a value back to the module that calls the value.

reusability—The feature of modular programs that allows individual modules to be used in a variety of applications.

reverse engineering—The process of creating a model of an existing system.

rolling up the totals—The process of adding a total to a higher-level total.

running—To have a computer use a written and compiled program. *See also* executing.

saving—To store a program on some nonvolatile medium.

scenario—Each variation in the sequence of actions required in a use case.

second normal form (2NF)—The normalization form in which you eliminate partial key dependencies.

SELECT-FROM-WHERE—An SQL statement that selects the fields you want to view from a specific table where one or more conditions are met.

selection sort—In an ascending selection sort, you search for the smallest list value, and then swap it with the value in the first position. You then repeat the process with each subsequent list position.

selection structure—A programming structure in which you ask a question, and depending on the answer, you take one of two courses of action. Then, no matter which path you follow, you continue with the next task. Also called a decision structure.

self-documenting program—A program that describes itself to the reader through the use of comments and clear variable names.

semantic error—An error that occurs when a correct word is used in an incorrect context.

sentinel value—A limit, or ending value.

sequence diagram—A UML diagram that shows the timing of events in a single use case.

sequence structure—A programming structure in which you perform an action or task, and then you perform the next action in order. A sequence can contain any number of tasks, but there is no chance to branch off and skip any of the tasks.

sequential cohesion—A state in which a module performs operations that must be carried out in a specific order on the same data.

sequential file—A file in which records are stored one after another in some order.

sequential order—Records arranged one after another on the basis of the value in some field.

short-circuiting—The compiler technique of not evaluating an expression when the outcome makes no difference.

signature—The part of a method that includes its return type, name, and parameter list. In some languages, a signature is also called a prototype.

simple data coupling— *See also* data coupling.

single-alternative if or **single-alternative selection**—A selection structure where action is required for only one outcome of the question. You call this form of the selection structure an if-then, because no "else" action is necessary. *See also* unary selection.

single-dimensional array or **one-dimensional array**—An array that represents a single list of values.

single-level control break—A break in the logic of a program based on the value of a single variable.

single-level menu—A list from which a user makes a selection that results in the program's ultimate purpose, as opposed to displaying additional menus.

sinking sort—Another name for a bubble sort.

size (of an array)—The number of elements it can hold.

soft copy—A screen copy.

software—Programs written by programmers that tell the computer what to do.

sort—To take records that are not in order and rearrange them to be in order based on the contents of one or more fields.

source—A component from which an event is generated.

source code—The readable statements of a program, written in a programming language.

spaghetti code—Snarled, unstructured program logic.

stacking—To attach structures end-to-end.

standard input device—The default device from which input comes, most often the keyboard.

standard output device—The default device to which output is sent, usually the monitor.

state machine diagram—A UML diagram that shows the different statuses of a class or object at different points in time.

state of an object—The collective value of all an object's attributes at any point in time.

static method—A class method that does not receive a `this` reference and does not require an object to execute.

stereotype—A feature that adds to the UML vocabulary of shapes to make them more meaningful for the reader.

storyboard—A picture or sketch of a screen the user will see when running a program.

string constant—One or more characters enclosed within quotation marks. If a working program contains the statement `lastName = "Lincoln"`, then "Lincoln" is a character or string constant. In this book, "string constant" is used synonymously with "character constant."

string variable—A variable that holds character values. If a working program contains the statement `lastName = "Lincoln"`, then `lastName` is a character or string variable. In this book, "string variable" is used synonymously with "character variable" and "text variable."

structure—A basic unit of programming logic; each structure is a sequence, selection, or loop.

Structured Query Language (SQL)—A commonly used language for accessing data in database tables.

stub—An empty procedure, intended to be coded later.

subclass—A class that inherits the attributes of another class. *See also* child class, derived class, and descendent class.

submenu—A second-level, or later-level, menu.

submodule—A module that is called by another module.

subroutine—A small program unit. Subroutines are also called modules, procedures, functions, or methods.

subscript—A number that indicates the position of a particular item within an array.

summary line—On a report, a line that contains end-of-report information. *See also* total line.

summary report—A report that does not include any information about individual records, but instead includes group totals and other statistics.

sunny day case—A case in which no errors occur.

superclass—A parent class from which other classes are derived. *See also* base class and original class.

swap—To set the first variable in a set of two values equal to the value of the second, and the second variable equal to the value of the first.

syntax—The rules of a language.

syntax error—An error in language or grammar.

system design—The detailed specification of how all the parts of a system will be implemented and coordinated.

table—In a database, a collection of data in rows and columns.

temporal cohesion—A type of cohesion that takes place when the tasks in a module are related by time.

temporal order—An order in which records are stored based on their creation time.

terminal symbol—Represents the end of the flowchart; its shape is a lozenge. Also called a start/stop symbol.

text variable—A variable that holds character values. If a working program contains the statement `lastName = "Lincoln"`, then `lastName` is a text variable. *See also* string variable.

third normal form (3NF)—The normalization form in which you eliminate transitive dependencies.

`this` reference or **`this` pointer**—A reference that holds an object's memory address within a method of the object's class.

three-dimensional array—An array in which you access values using three subscripts.

throw—To pass an exception from the module where a problem occurs to another module.

tight coupling—A characteristic of a program that occurs when modules excessively depend on each other; it makes programs more prone to errors.

time signal—A UML diagram symbol that indicates that a specific amount of time has passed before an action is started.

total line—On a report, a line that contains end-of-report information. *See also* summary line.

transaction file—A file that holds temporary data generated by the entities represented in the master file.

transitive dependency—A dependency that occurs when the value of a non-key attribute determines, or predicts, the value of another non-key attribute.

trivial Boolean expression—A Boolean expression that always evaluates to the same result.

try—To employ a module that might throw an exception.

`try` block—A segment of code in which an attempt is made to execute a module that might throw an exception.

UML—A standard way to specify, construct, and document systems that use object-oriented methods. UML is an acronym for Unified Modeling Language.

unary selection—A selection structure where action is required for only one outcome of the question. You call this form of the selection structure an if-then, because no "else" action is necessary. *See also* single-alternative if or single-alternative selection.

unnormalized table—A database table that contains repeating groups.

unreachable code—Any set of program statements that will never execute—for example, those statements within a module that follow the `return` statement. Also called dead code.

update anomaly—A problem that occurs in a database when a table is altered, resulting in repeated data.

updating a master file—To make changes to the values in a master file's fields based on transaction records.

use case diagram—A UML diagram that shows how a business works from the perspective of those who approach it from the outside, or those who actually use the business.

user—A person who uses computer programs. Also called an end user.

user-defined type—A class.

user documentation—All the manuals or other instructional materials that nontechnical people use, as well as the operating instructions that computer operators and data-entry personnel need.

user-friendly—The quality of a program that makes it easy for the user to make desired choices.

validating input—Checking the user's responses to ensure they fall within acceptable bounds.

variable—A memory location whose contents can vary or differ over time.

view—A particular way of looking at a database.

visual development environment—An environment in which you can create programs by dragging components such as buttons and labels onto a screen and arranging them visually.

void—A data type indicating no value. The word "void" means "empty" or "nothing"; it is often used as the return type for a method that returns no value.

volatile—The characteristic of internal memory, which loses its contents every time the computer loses power.

`while do` **loop**—A loop in which a process continues while some condition continues to be true. Also called a `while` loop.

`while` **statement**—A statement that can be used to code any loop.

whole-part relationship—An association in which one or more classes make up the parts of a larger whole class. This type of relationship is also called an aggregation. You also can call a whole-part relationship a has-a relationship because the phrase describes the association between the whole and one of its parts.

work field or **work variable**—A variable you use to temporarily hold a value or calculation result.

zero-based array—An array in which the first element is accessed using a subscript of 0.

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