C How To Program Fourth Edition

C大学教程

（第4版）

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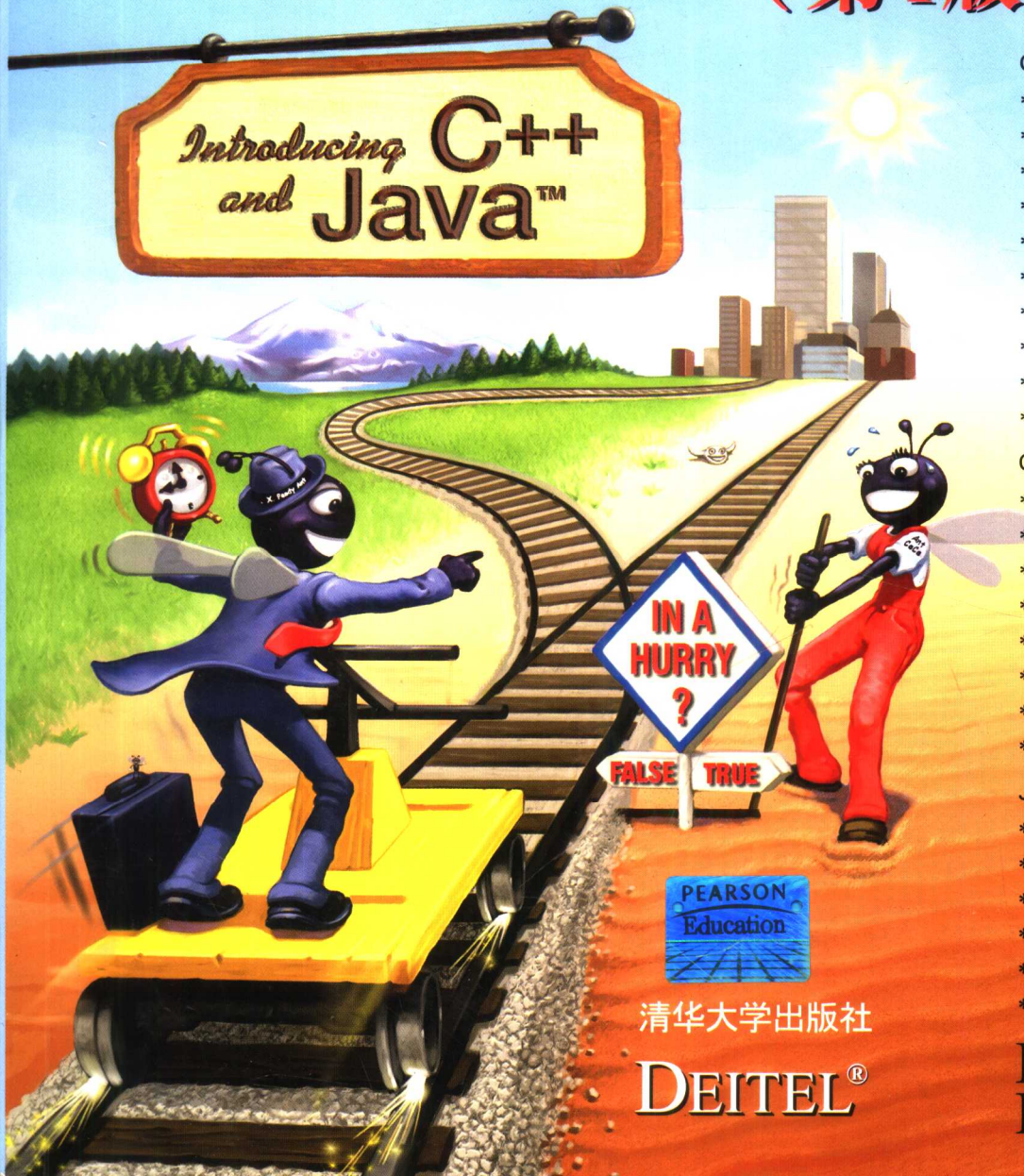

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C How To Program

Fourth Edition

C 大学教程

(第 4 版)

H. M. Deitel

清华大学出版社

北京

北京市版权局著作权合同登记号　图字 01-2007-2096 号

图书在版编目(CIP)数据

C 大学教程：第 4 版：英文/(美)戴特尔(Deitel, H.M.)著. —影印本. —北京：清华大学出版社, 2007.8
书名原文：C How To Program, 4e
ISBN 978-7-302-15582-9

Ⅰ. C… Ⅱ. 戴… Ⅲ. C 语言—程序设计—高等学校—教材—英文 Ⅳ. TP312

中国版本图书馆 CIP 数据核字（2007）第 098363 号

责任印制：何　芊
出版发行：清华大学出版社　　**地　　址**：北京清华大学学研大厦 A 座
http://www.tup.com.cn　**邮　　编**：100084
c-service@tup.tsinghua.edu.cn
社 总 机：010-62770175　**邮购热线**：010-62786544
投稿咨询：010-62772015　**客户服务**：010-62776969
印 刷 者：清华大学印刷厂
装 订 者：三河市新茂装订有限公司
经　　销：全国新华书店
开　　本：185×230　**印　张**：79
附光盘 1 张
版　　次：2007 年 8 月第 1 版　　**印　　次**：2007 年 8 月第1 次印刷
印　　数：1～3000
定　　价：129.00 元

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Preface

Welcome to ANSI/ISO Standard C, and to C++ and Java™, too! At Deitel & Associates, we write college-level programming-language textbooks and professional books and work hard to keep our published books up-to-date with a steady flow of new editions. Writing *C How to Program, Fourth Edition*, (*4/e* for short), was a joy. This book and its support materials have everything instructors and students need for an informative, interesting, challenging and entertaining educational experience. We have tuned the writing, the pedagogy, our coding style and the book's ancillary package. Also, we have included a Tour of the Book in this Preface. This will help instructors, students and professionals get a sense of the rich coverage this book provides of C, C++ and Java programming.

In this Preface, we overview the conventions we use in *C How to Program, 4/e*, such as syntax coloring the code examples, "code washing" and highlighting important code segments to help focus students' attention on key concepts introduced in each chapter. We also overview the new features of *C How to Program, 4/e*.

Prentice Hall has bundled Microsoft's Visual C++® 6 Introductory Edition software with the text. To further support novice programmers, we offer several of our new *Dive-Into™ Series* publications that are available free for download at `www.deitel.com`. These materials explain how to compile, execute and debug C, C++ and Java programs using various popular development environments.

We discuss *C How to Program, 4/e*'s comprehensive suite of educational materials that help instructors maximize their students' learning experience. These include an Instructor's Resource CD with solutions to the book's chapter exercises and a Test-Item File with hundreds of multiple-choice examination questions and answers. Additional instructor resources are available at the book's Companion Web Site (`www.prenhall.com/deitel`), which includes a Syllabus Manager and customizable PowerPoint® Lecture Notes. PowerPoint slides and additional support materials are available for students at the Companion Web Site, as well.

We also discuss the new *Student Solutions Manual* to accompany this textbook. This additional resource provides solutions to about half of the exercises in the textbook.

C How to Program, 4/e, was reviewed by a team of distinguished academics and industry professionals, including the head and former head of the C standards committee; we list their names and affiliations so you can get a sense of how carefully this book was scrutinized. The Preface concludes with information about the authors and about Deitel & Associates, Inc. As you read this book, if you have any questions, please send an e-mail to `deitel@deitel.com`; we will respond promptly. Please visit our Web site, `www.deitel.com`, regularly and be sure to sign up for the *Deitel® Buzz Online* e-mail newsletter at `www.deitel.com/newsletter/subscribe.html`. We use the Web site and the newsletter to keep our readers current on all Deitel publications and services.

Features of C How to Program, Fourth Edition

Syntax Highlighting

We syntax highlight all the C, C++ and Java code, as do many integrated-development environments and code editors. This greatly improves code readability—an especially important goal, given that this book contains over 13,280 lines of code. Our syntax-highlighting conventions are as follows:

```
comments appear like this
keywords appear like this
errors appear like this
constants and literal values appear like this
all other code appears in black
```

Code Highlighting and User-Input Highlighting

We have added extensive code highlighting to make it easier for readers to spot the featured segments of each program. This feature also helps students review the material rapidly when preparing for exams or labs. We have also highlighted in our screen dialogs all user inputs to distinguish them from program outputs.

"Code Washing"

"Code washing" is our term for applying comments, using meaningful identifiers, applying indentation and using vertical spacing to separate meaningful program units. This process results in programs that are much more readable and self-documenting. We have added extensive and descriptive comments to all of the code, including a comment before and after every major control statement, to help the student clearly understand the flow of the program. We have done extensive code washing of all the source code programs in the text, the ancillaries and the *Student Solutions Manual*.

To promote good programming practices, we updated all the source code programs in the C portion of this book with new coding standards. Variable definitions are now placed on separate lines to increase readability and every control statement has an opening and closing brace even when this is redundant. This will help the reader when he or she is beginning to develop large and complex programs. Every function prototype now matches the first line of the function definition, including the parameter names (which help document the program and reduce errors—especially for novice programmers).

Use of Terminology/Presentation
We have updated our use of terminology throughout the text to comply with the various language standards and specification.

Teaching Approach

Many educators believe that the complexity of C, and a number of other difficulties, make C unworthy for a first programming course—precisely the target course for this book. So why did we write this text?

Dr. Harvey M. Deitel (HMD) taught introductory programming courses in college environments for two decades with an emphasis on developing clearly written, well-structured programs. Much of what is taught in these courses is the basic principles of structured programming, with an emphasis on the effective use of control statements and functionalization. We have presented this material exactly the way HMD has done in his college courses. Students are motivated by the fact that they are learning a language that will be immediately useful to them as they enter industry.

Our goal was clear: Produce a C programming textbook for introductory university-level courses in computer programming for students with little or no programming experience, yet offer the deep and rigorous treatment of theory and practice demanded by traditional C courses. To meet these goals, we produced a book larger than other C texts—this because our text also patiently teaches structured programming principles. Hundreds of thousands of students worldwide have learned C from the earlier editions of this book.

C How to Program, 4/e, contains a rich collection of examples, exercises and projects drawn from many fields and designed to provide students with a chance to solve interesting, real-world problems. The code examples in the text have been tested on multiple compilers.

The book concentrates on the principles of good software engineering and stresses program clarity. We are educators who teach edge-of-the-practice topics in industry classrooms worldwide. This text emphasizes good pedagogy.

Live-Code Approach
C How to Program, 4/e, is loaded with numerous live-code examples— each new concept is presented in the context of a complete, working program that is immediately followed by one or more sample executions showing the program's input/output dialog. This style exemplifies the way we teach and write about programming. We call this method of teaching and writing the live-code approach. *We use programming languages to teach programming languages.* Reading the examples in the text is much like typing and running them on a computer.

World Wide Web Access
All of the source-code examples for *C How to Program, 4/e,* (and our other publications) are available on the Internet as downloads from the following Web sites:

```
www.deitel.com
www.prenhall.com/deitel
```

Registration is quick and easy and the downloads are free. We suggest downloading all the examples, then running each program as you read the corresponding text. Making changes to the examples and immediately seeing the effects of those changes is a great way to enhance your learning experience.

Objectives
Each chapter begins with a statement of objectives. This tells the student what to expect and gives the student an opportunity, after reading the chapter, to determine if he or she has met these objectives. It is a confidence builder and a source of positive reinforcement.

Quotations
The learning objectives are followed by a series of quotations. Some are humorous, some are philosophical and some offer interesting insights. Our students enjoy relating the quotations to the chapter material. You may appreciate some of the quotations more *after* reading the chapters.

Outline
The chapter outline helps the student approach the material in top-down fashion. This, too, helps students anticipate what is to come and set a comfortable and effective learning pace.

Sections
Each chapter is organized into small sections that address key C, C++ or Java topics.

13, 280 Lines of Syntax-Highlighted Code in 268 Example Programs (with Outputs)
We present C, C++ and Java features in the context of complete, working programs using our our live-code approach. Each program is immediately followed by a window containing the outputs produced when the program is run. This enables the student to confirm that the programs run as expected. Relating outputs to the program statements that produce those outputs is an excellent way to learn and to reinforce concepts. Our programs exercise many features of C, C++ and Java. Reading the book carefully is much like entering and running these programs on a computer. The code is "syntax highlighted" with keywords appearing in bold blue, comments appearing in italic blue, constants and literal values appearing in a lighter shade of bold blue and the rest of each program appearing in black. This makes it much easier to read the code—students will especially appreciate the syntax highlighting when they read the more substantial programs we present.

469 Illustrations/Figures
An abundance of colorized charts and line drawings is included. The discussions of control statements in Chapters 3 and 4 feature carefully drawn flowcharts. [*Note:* We do not teach the use of flowcharting as a program development tool, but we do use a brief flowchart-oriented presentation to specify the precise operation of C's control statements.] Chapter 12, Data Structures, uses colorized line drawings to illustrate creating and maintaining linked lists, queues, stacks and binary trees. The remainder of the book is abundantly illustrated.

768 Programming Tips
We have included seven programming tip elements to help students focus on important aspects of program development, testing and debugging, performance and portability. We highlight hundreds of these tips in the form of *Common Programming Errors*, *Error-Prevention Tips*, *Good Programming Practices*, *Look-and-Feel Observations*, *Performance Tips*, *Portability Tips* and *Software Engineering Observations*. These tips and practices represent the best we have been able to glean from six decades (combined) of programming and teaching experience. One of our students—a mathematics major—told us that she feels this approach is like the highlighting of axioms, theorems and corollaries in mathematics books; it provides a basis on which to build good software.

259 Common Programming Errors

Students learning a language—especially in their first programming course—tend to make certain kinds of errors frequently. Focusing on these Common Programming Errors *helps students avoid making the same errors. It also helps reduce long lines outside instructors' offices during office hours!*

132 Good Programming Practices

Good Programming Practices *are tips for writing clear programs. These techniques help students produce programs that are more readable, self-documenting and easier to maintain.*

49 Error-Prevention Tips

When we first designed this "tip type," we thought we would use it strictly to tell people how to test and debug programs and in previous editions have labelled this tip as "Testing and Debugging Tips." In fact, many of the tips describe aspects of C, C++ and Java that reduce the likelihood of "bugs" and thus simplify the testing and debugging processes. In addition, we also changed many of the Good Programming Practices *throughout the book to this tip type.*

32 Look-and-Feel Observations

In the Java portion of this book, we provide Look-and-Feel Observations *to highlight graphical user interface conventions. These observations help students design their own graphical user interfaces to conform with industry norms.*

68 Performance Tips

In our experience, teaching students to write clear and understandable programs is by far the most important goal for a first programming course. But students want to write the programs that run the fastest, use the least memory, require the smallest number of keystrokes, or dazzle in other nifty ways. Students really care about performance. They want to know what they can do to "turbo charge" their programs. So we highlight opportunities for improving program performance—making programs run faster or minimizing the amount of memory that they occupy.

38 Portability Tips

Software development is a complex and expensive activity. Organizations that develop software must often produce versions customized to a variety of computers and operating systems. So there is a strong emphasis today on portability, i.e., on producing software that will run on a variety of computer systems with few, if any, changes. Many people tout C, C++ and Java as appropriate languages for developing portable software. Some people assume that if they implement an application in one of the languages, the application will automatically be portable. This is simply not the case. Achieving portability requires careful and cautious design. There are many pitfalls. We include numerous Portability Tips *to help students write portable code. Java was designed from the start to maximize portability, but Java programs can also require modifications to "port" them.*

189 Software Engineering Observations

The Software Engineering Observations *highlight techniques, architectural issues and design issues, etc. that affect the architecture and construction of software systems, especially large-scale systems. Much of what the student learns here will be useful in upper-level courses and in industry as the student begins to work with large, complex real-world systems. C, C++ and Java are especially effective software engineering languages.*

Summary
Each chapter ends with additional pedagogical devices. We present an extensive, bullet-list-style *Summary* in every chapter. This helps the student review and reinforce key concepts. There is an average of 37 summary bullets per chapter.

Terminology
We include a *Terminology* section with an alphabetized list of the important terms defined in the chapter—again, further reinforcement. There is an average of 73 terms per chapter.

Summary of Tips, Practices and Errors
We collect and list from the chapter the *Good Programming Practices*, *Common Programming Errors*, *Look-and-Feel Observations*, *Performance Tips*, *Portability Tips*, *Software Engineering Observations* and *Error-Prevention Tips*.

728 Self-Review Exercises and Answers (Count Includes Separate Parts)
Extensive *Self-Review Exercises* and *Answers to Self-Review Exercises* are included for self study. This gives the student a chance to build confidence with the material and prepare to attempt the regular exercises.

993 Exercises (Count Includes Separate Parts; 1722 Total Exercises)
Each chapter concludes with a substantial set of exercises including simple recall of important terminology and concepts; writing individual program statements; writing small portions of functions and C++/Java classes; writing complete functions, C++/Java classes and programs;and writing major term projects. The large number of exercises enables instructors to tailor their courses to the unique needs of their audiences and to vary course assignments each semester. Instructors can use these exercises to form homework assignments, short quizzes and major examinations.

4800+ Index Entries (Total of 7500+ Entries Counting Multiple References)
We have included an extensive *Index* at the back of the book. This helps the student find any term or concept by keyword. The *Index* is useful to people reading the book for the first time and is especially useful to practicing programmers who use the book as a reference. Most of the terms in the *Terminology* sections appear in the *Index* (along with many more index entries from each chapter). Thus, the student can use the *Index* in conjunction with the *Terminology* sections to be sure he or she has covered the key material of each chapter.

Software Included with C How to Program, 4/e

In writing this book, we have used a variety of C compilers. For the most part, the programs in the text will work on all ANSI/ISO C and C++ compilers, including the Visual C++ 6.0 Introductory Edition compiler included with this book.

The C material (Chapters 2–14) follows the ANSI C standard published in 1990. See the reference manuals for your particular system for more details about the language, or obtain a copy of ANSI/ISO 9899: 1990, "American National Standard for Information Systems—Programming Language C," from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

In 1999, ISO approved a new version of C, C99, which is not as yet widely used. Appendix B contains a comprehensive list of C99 Web resources. For more information on C99—and to purchase a copy of the C99 standards document (ISO/IEC 9899:1999)—visit the Web site of the American National Standards Institute (ANSI) at `www.ansi.org`.

The C++ material is based on the C++ programming language as developed by the Accredited Standards Committee INCITS, Information Technology and its Technical Committee J11, Programming Language C++, respectively. The C and C++ languages were approved by the International Standards Organization (ISO).

The serious programmer should read these documents carefully and reference them regularly. These documents are not tutorials. Rather they define their respective languages with the extraordinary level of precision that compiler implementors and "heavy-duty" developers demand.

The Java chapters are based on Sun Microsystem's Java programming language. Sun provides an implementation of the Java 2 Platform called the Java 2 Software Development Kit (J2SDK) that includes the minimum set of tools you need to write software in Java. You can download the most recent version the J2SDK from

```
java.sun.com/j2se/downloads.html
```

Information on installing and configuring the J2SDK is located at

```
developer.java.sun.com/developer/onlineTraining/new2java/
gettingstartedjava.html
```

We have carefully audited our presentation against these documents and documentation. Our book is intended to be used at the introductory and intermediate levels. We have not attempted to cover every feature discussed in these comprehensive documents.

DIVE-INTO™ Series Tutorials for Popular C, C++ and Java Environments

We have launched our new *DIVE-INTO™ SERIES* of tutorials to help our readers get started with many popular program-development environments. These are available free for download at `www.deitel.com/books/downloads.html`.

Currently, we have the following *DIVE-INTO™ SERIES* publications:

- *DIVE-INTO Microsoft® Visual C++® 6*
- *DIVE-INTO Microsoft® Visual C++® .NET*
- *DIVE-INTO Borland™ C++Builder™ Compiler* (command-line version)
- *DIVE-INTO Borland™ C++Builder™ Personal* (IDE version)
- *DIVE-INTO GNU C++ on Linux*
- *DIVE-INTO GNU C++ via Cygwin on Windows* (Cygwin is a UNIX emulator for Windows that includes the GNU C++ compiler.)
- *DIVE-INTO Forte for Java Community Edition 3.0*
- *DIVE-INTO SunOne Studio Community Edition 4.0*

Each of these tutorials shows how to compile, execute and debug C, C++ and Java applications in that particular compiler product. Many of these documents also provide step-by-step instructions with screen shots to help readers install the software. Each document overviews the compiler and its online documentation.

Ancillary Package for C How to Program, 4/e

C How to Program, 4/e, has extensive ancillary materials for instructors. The *Instructor's Resource CD (IRCD)* contains solutions to most of the end-of-chapter exercises. This CD is available only to instructors through their Prentice Hall representatives. [***NOTE:* Please do not write to us requesting the instructor's CD. Distribution of this CD is limited strictly to college professors teaching from the book. Instructors may obtain the solutions manual only from their Prentice Hall representatives.**] The ancillaries for this book also include a *Test Item File* of multiple-choice questions. In addition, we provide PowerPoint® slides containing all the code and figures in the text and bulleted items that summarize the key points in the text. Instructors can customize the slides. The PowerPoint® slides are downloadable from `www.deitel.com` and are available as part of Prentice Hall's Companion Web Site (`www.prenhall.com/deitel`) for *C How to Program, 4/e*, which offers resources for both instructors and students. For instructors, the Companion Web Site offers a Syllabus Manager, which helps instructors plan courses interactively and create online syllabi.

Students also benefit from the functionality of the *Companion Web Site*. Book-specific resources for students include:

- Customizable PowerPoint® slides
- Source code for all example programs
- Reference materials from the book appendices (such as operator-precedence chart, character set and Web resources)

Chapter-specific resources available for students include:

- Chapter objectives
- Highlights (e.g., chapter summary)
- Outline
- Tips (e.g., *Common Programming Errors*, *Good Programming Practices*, *Portability Tips*, *Performance Tips*, *Look-and-Feel Observations*, *Software Engineering Observations* and *Error-Prevention Tips*)
- Online Study Guide—contains additional short-answer self-review exercises (e.g., true/false and matching questions) with answers and provides immediate feedback to the student

Students can track their results and course performance on quizzes using the *Student Profile* feature, which records and manages all feedback and results from tests taken on the *Companion Web Site*. To access DEITEL® *Companion Web Site*, visit `www.prenhall.com/deitel`.

Student Solutions Manual

The *C Student Solutions Manual* (ISBN 0-13-145245-2) to accompany *C How to Program, 4/e* provides solutions to approximately half of the exercises in the text. Many of the solved exercises are similar to the unsolved exercises, which will help students when completing homework assignments.

DEITEL® e-Learning Initiatives

e-Books and Support for Wireless Devices

Wireless devices will have an enormous role in the future of the Internet. Given recent bandwidth enhancements and the emergence of 2.5 and 3G technologies, it is projected that, within a few years, more people will access the Internet through wireless devices than through desktop computers. Deitel & Associates is committed to wireless accessibility and has published *Wireless Internet & Mobile Business How to Program*. We are investigating new electronic formats, such as wireless e-books so that students and professors can access content virtually anytime, anywhere. For periodic updates on these initiatives subscribe to the *DEITEL® Buzz Online* e-mail newsletter, `www.deitel.com/newsletter/subscribe.html` or visit `www.deitel.com`.

DEITEL® Buzz Online E-mail Newsletter

Our free e-mail newsletter, the *DEITEL® Buzz Online*, includes commentary on industry trends and developments, links to free articles and resources from our published books and upcoming publications, product-release schedules, errata, challenges, anecdotes, information on our corporate instructor-led training courses and more. To subscribe, visit

```
www.deitel.com/newsletter/subscribe.html
```

The New DEITEL® Developer Series

Deitel & Associates, Inc., is making a major commitment to covering leading-edge technologies for industry software professionals through the launch of our *DEITEL® Developer Series*. The first books in the series are *Web Services A Technical Introduction* and *Java Web Services for Experienced Programmers*. We are working on *ASP .NET with Visual Basic .NET for Experienced Programmers*, *ASP .NET with C# for Experienced Programmers* and many more. Please visit `www.deitel.com` or subscribe to our e-mail newsletter at `www.deitel.com/newsletter/subscribe.html` for continuous updates on all published and forthcoming *DEITEL Developer Series* titles.

The *DEITEL Developer Series* is divided into three subseries. The *A Technical Introduction* subseries provides IT managers and developers with detailed overviews of emerging technologies. The *A Programmer's Introduction* subseries is designed to teach the fundamentals of new languages and software technologies to programmers and novices from the ground up; these books discuss programming fundamentals, followed by brief introductions to more sophisticated topics. The *For Experienced Programmers* subseries is designed for seasoned developers seeking a deeper treatment of new programming languages and technologies, without the encumbrance of introductory material; the books in this subseries move quickly to in-depth coverage of the features of the programming languages and software technologies being covered.

A Tour of the Book

The book is divided into four major parts. The first part, Chapters 1 through 14, presents a thorough treatment of the C programming language including a formal introduction to structured programming. The second part (Chapters 15 through 23)—unique among C textbooks—presents a substantial treatment of C++ and object-oriented programming sufficient for an upper-level undergraduate college course. The third part—Chapters 24 through

30 (and also unique among C books)—presents a thorough introduction to Java, including graphics programming, graphical user interface (GUI) programming using Java Swing, multimedia programming and event-driven programming. The fourth part, Appendices A through F, presents a variety of reference materials that support the main text.

Part 1: Procedural Programming in C

Chapter 1—Introduction to Computers, the Internet and the World Wide Web—discusses what computers are, how they work and how they are programmed. It introduces the notion of structured programming and explains why this set of techniques has fostered a revolution in the way programs are written. The chapter gives a brief history of the development of programming languages from machine languages, to assembly languages, to high-level languages. The origins of the C, C++ and Java programming languages are discussed. The chapter includes an introduction to a typical C programming environment. We discuss the explosion in interest in the Internet that has occurred with the advent of the World Wide Web and the Java programming language.

Chapter 2—Introduction to C Programming—gives a concise introduction to writing C programs. A detailed treatment of decision making and arithmetic operations in C is presented. After studying this chapter, the student will understand how to write simple, but complete, C programs.

Chapter 3—Structured Program Development—is probably the most important chapter in the text, especially for the serious student of computer science. It introduces the notion of algorithms (procedures) for solving problems. It explains the importance of structured programming in producing programs that are understandable, debuggable, maintainable and likely to work properly on the first try. It introduces the fundamental control statements of structured programming, namely the sequence, selection (`if` and `if...else`) and repetition (`while`) statements. It explains the technique of top-down, stepwise refinement that is critical to the production of properly structured programs. It presents the popular program design aid, structured pseudocode. The methods and approaches used in Chapter 3 are applicable to structured programming in any programming language, not just C. This chapter helps the student develop good programming habits in preparation for dealing with the more substantial programming tasks in the remainder of the text.

Chapter 4—C Program Control—refines the notions of structured programming and introduces additional control statements. It examines repetition in detail and compares the alternatives of counter-controlled loops and sentinel-controlled loops. The `for` statement is introduced as a convenient means for implementing counter-controlled loops. The `switch` selection statement and the `do...while` repetition statement are presented. The chapter concludes with a discussion of logical operators.

Chapter 5—C Functions—discusses the design and construction of program modules. C's function-related capabilities include standard library functions, programmer-defined functions, recursion and call-by-value capabilities. The techniques presented in Chapter 5 are essential to the production and appreciation of properly structured programs, especially the kinds of larger programs and software that system programmers and application programmers are likely to develop in real-world applications. The "divide and conquer" strategy is presented as an effective means for solving complex problems by dividing them into simpler interacting components. Students enjoy the treatment of random numbers and simulation, and they appreciate the discussion of the dice game of craps which makes elegant use of control statements. We introduce enumerations in this chapter and provide a

more detailed discussion in Chapter 10. Chapter 5 offers a solid introduction to recursion and includes a table summarizing the dozens of recursion examples and exercises distributed throughout the remainder of the book. Some books leave recursion for a chapter late in the book; we feel this topic is best covered gradually throughout the text. The extensive exercises include several classical recursion problems such as the Towers of Hanoi.

Chapter 6—C Arrays—discusses the structuring of data into arrays, or groups, of related data items of the same type. The chapter presents numerous examples of both single-subscripted arrays and double-subscripted arrays. It is widely recognized that structuring data properly is just as important as using control statements effectively in developing properly structured programs. The examples investigate various common array manipulations, printing histograms, sorting data, passing arrays to functions and an introduction to the field of survey data analysis (with simple statistics). A feature of this chapter is the careful discussion of elementary sorting and searching techniques and the presentation of binary searching as a dramatic improvement over linear searching. The end-of-chapter exercises include a variety of interesting and challenging problems, such as improved sorting techniques, the design of an airline reservations system, an introduction to the concept of turtle graphics (made famous in the LOGO language) and the Knight's Tour and Eight Queens problems that introduce the notions of heuristic programming so widely employed in the field of artificial intelligence.

Chapter 7—C Pointers—presents one of the most powerful and difficult to master features of the C language: pointers. The chapter provides detailed explanations of pointer operators, call by reference, pointer expressions, pointer arithmetic, the relationship between pointers and arrays, arrays of pointers and pointers to functions. The chapter exercises include a delightful simulation of the classic race between the tortoise and the hare, card shuffling and dealing algorithms and recursive maze traversals. A special section entitled "Building Your Own Computer" is also included. This section explains machine language programming and proceeds with a project involving the design and implementation of a computer simulator that allows the reader to write and run machine language programs. This unique feature of the text will be especially useful to the reader who wants to understand how computers really work. Our students enjoy this project and often implement substantial enhancements, many of which are suggested in the exercises. In Chapter 12, another special section guides the reader through building a compiler; the machine language produced by the compiler is then executed on the machine language simulator produced in Chapter 7.

Chapter 8—C Characters and Strings—deals with the fundamentals of processing nonnumeric data. The chapter includes a thorough walkthrough of the character and string processing functions available in C's libraries. The techniques discussed here are widely used in building word processors, page layout and typesetting software and text-processing applications. The chapter includes a variety of exercises that explore text-processing applications. The student will enjoy the exercises on writing limericks, writing random poetry, converting English to pig Latin, generating seven-letter words that are equivalent to a given telephone number, text justification, check protection, writing a check amount in words, generating Morse Code, metric conversions and dunning letters. The last exercise challenges the student to use a computerized dictionary to create a crossword puzzle generator.

Chapter 9—C Formatted Input/Output—presents all the powerful formatting capabilities of `printf` and `scanf`. We discuss `printf`'s output formatting capabilities such as rounding floating point values to a given number of decimal places, aligning columns of

numbers, right-justification and left-justification, insertion of literal information, forcing a plus sign, printing leading zeros, using exponential notation, using octal and hexadecimal numbers and controlling field widths and precisions. We discuss all of `printf`'s escape sequences for cursor movement, printing special characters and causing an audible alert. We examine all of `scanf`'s input formatting capabilities, including inputting specific types of data and skipping specific characters in an input stream. We discuss all of `scanf`'s conversion specifiers for reading decimal, octal, hexadecimal, floating point, character and string values. We discuss scanning inputs to match (or not match) the characters in a scan set. The chapter exercises test virtually all of C's formatted input/output capabilities.

Chapter 10—C Structures, Unions, Bit Manipulations and Enumerations—presents a variety of important features. Structures are like records in other programming languages—they group data items of various types. Structures are used in Chapter 11 to form files consisting of records of information. Structures are used in conjunction with pointers and dynamic memory allocation in Chapter 12 to form dynamic data structures such as linked lists, queues, stacks and trees. Unions enable an area of memory to be used for different types of data at different times; such sharing can reduce a program's memory requirements or secondary-storage requirements. Enumerations provide a convenient means of defining useful symbolic constants; this helps make programs more self-documenting. C's powerful bit manipulation capabilities enable programmers to write programs that exercise lower-level hardware capabilities. This helps programs process bit strings, set individual bits on or off and store information more compactly. Such capabilities, often found only in low-level assembly languages, are valued by programmers writing system software such as operating systems and networking software. A feature of the chapter is its revised, high-performance card shuffling and dealing simulation. This is an excellent opportunity for the instructor to emphasize the quality of algorithms.

Chapter 11—C File Processing—discusses the techniques used to process text files with sequential access and random access. The chapter begins with an introduction to the data hierarchy from bits, to bytes, to fields, to records, to files. Next, C's simple view of files and streams is presented. Sequential-access files are discussed using programs that show how to open and close files, how to store data sequentially in a file and how to read data sequentially from a file. Random-access files are discussed using programs that show how to create a file sequentially for random access, how to read and write data to a file with random access and how to read data sequentially from a randomly accessed file. The fourth random-access program combines many of the techniques of accessing files both sequentially and randomly into a complete transaction-processing program.

Chapter 12—C Data Structures—discusses the techniques used to create and manipulate dynamic data structures. The chapter begins with discussions of self-referential structures and dynamic memory allocation and proceeds with a discussion of how to create and maintain various dynamic data structures including linked lists, queues (or waiting lines), stacks and trees. For each type of data structure, we present complete, working programs and show sample outputs. The chapter helps the student master pointers. It includes abundant examples using indirection and double indirection—a particularly difficult concept. One problem when working with pointers is that students have trouble visualizing the data structures and how their nodes are linked together. So we have included illustrations that show the links, and the sequence in which they are created. The binary tree example is a nice capstone for the study of pointers and dynamic data structures. This example creates a

binary tree; enforces duplicate elimination; and introduces recursive preorder, inorder and postorder tree traversals. Students have a genuine sense of accomplishment when they study and implement this example. They particularly appreciate seeing that the inorder traversal prints the node values in sorted order. The chapter includes a substantial collection of exercises. A highlight of the exercises is the special section "Building Your Own Compiler." The exercises walk the student through the development of an infix-to-postfix-conversion program and a postfix-expression-evaluation program. We then modify the postfix evaluation algorithm to generate machine-language code. The compiler places this code in a file (using the techniques of Chapter 11). Students can run the machine language produced by their compilers on the software simulators they built in the exercises of Chapter 7!

Chapter 13—The C Preprocessor—provides detailed discussions of the preprocessor directives. The chapter includes detailed information on the `#include` directive (that causes a copy of a specified file to be included in place of the directive in the source code file before the file is compiled) and the `#define` directive that creates symbolic constants and macros. The chapter explains conditional compilation for enabling the programmer to control the execution of preprocessor directives and the compilation of program code. The # operator that converts its operand to a string and the ## operator that concatenates two tokens are discussed. Predefined symbolic constants `__LINE__`, `__FILE__`, `__DATE__` and `__TIME__` are presented. Finally, macro `assert` of the `assert.h` header is discussed. Macro `assert` is valuable in program testing, debugging, verification and validation.

Chapter 14—Other C Topics—presents additional topics including several advanced topics not ordinarily covered in introductory courses. We show how to redirect program input to come from a file, redirect program output to be placed in a file, redirect the output of one program to be the input of another (called "piping"), append the output of a program to an existing file, develop functions that use variable-length argument lists, pass command-line arguments to function `main` and use them in a program, compile programs whose components are spread across multiple files, register functions with `atexit` to be executed at program termination, terminate program execution with function `exit`, use the `const` and `volatile` type qualifiers, specify the type of a numeric constant using the integer and floating-point suffixes, use the signal-handling library to trap unexpected events, create and use dynamic arrays with `calloc` and `realloc`, and use `unions` as a space-saving technique.

Part 2: Object-Based, Object-Oriented and Generic Programming in C++

Chapter 15—C++ as a "Better C"—introduces the non-object-oriented features of C++. These features improve the process of writing procedural programs. The chapter discusses single-line comments, stream input/output, declarations, creating new data types, function prototypes and type checking, `inline` functions (as a replacement for macros), reference parameters, the `const` qualifier, dynamic memory allocation, default arguments, the unary scope resolution operator, function overloading, linkage specifications and function templates.

Chapter 16—C++ Classes and Data Abstraction—begins our discussion of object-based programming. The chapter represents a wonderful opportunity for teaching data abstraction the "right way"—through a language (C++) expressly devoted to implementing abstract data types (ADTs). In recent years, data abstraction has become a major topic in introductory computing courses. Chapters 16 through 18 include a solid treatment of data

abstraction. Chapter 16 discusses implementing ADTs as C++-style `classes` and why this approach is superior to using `structs`, accessing `class` members, separating interface from implementation, using access functions and utility functions, initializing objects with constructors, destroying objects with destructors, assignment by default memberwise copy and software reusability. One of the chapter exercises challenges the reader to develop a class for complex numbers.

Chapter 17—C++ Classes Part II—continues the study of classes and data abstraction. The chapter discusses declaring and using constant objects, constant member functions, composition—the process of building classes that have objects of other classes as members, `friend` functions and `friend` classes that have special access rights to the `private` and `protected` members of classes, the `this` pointer that enables an object to know its own address, dynamic memory allocation, `static` class members for containing and manipulating class-wide data, examples of popular abstract data types (arrays, strings and queues), container classes and iterators. The chapter exercises ask the student to develop a savings account class and a class for holding sets of integers. We discuss dynamic memory allocation with `new` and `delete`. When `new` fails, it returns a 0 pointer in pre-standard C++. We use this pre-standard style in Chapters 17 through 22. We defer to Chapter 23 the discussion of the new style of `new` failure in which `new` now "throws an exception." We motivate the discussion of `static` class members with a video-game-based example. We emphasize throughout the book and in our professional seminars how important it is to hide implementation details from clients of a class.

Chapter 18—C++ Operator Overloading—is one of the most popular topics in our C++ courses. Students really enjoy this material. They find it a perfect match with the discussion of abstract data types in Chapters 16 and 17. Operator overloading enables the programmer to tell the compiler how to use existing operators with objects of new class types. C++ already knows how to use these operators with objects of built-in types such as integers, floating point numbers and characters. But suppose we create a new string class—what would the plus sign mean when used between string objects? Many programmers use plus with strings to mean concatenation. The chapter discusses the fundamentals of operator overloading, restrictions in operator overloading, overloading with class member functions vs. with nonmember functions, overloading unary and binary operators and converting between types. A feature of the chapter is the substantial case study of an array class, a huge-integer class and a complex numbers class (the last two appear with full source code in the exercises). This material is different from what you do in most programming languages and courses. Operator overloading is a complex topic, but an enriching one. Using operator overloading wisely helps you add that extra "polish" to your classes. With the techniques of Chapters 16, 17 and 18, it is possible to craft a `Date` class that, if we had been using it for the last two decades, could easily have eliminated a major portion of the so-called "Year 2000 (or Y2K) Problem." One of the exercises encourages the reader to add operator overloading to class `Complex` to enable convenient manipulation of objects of this class with operator symbols—as in mathematics—rather than with function calls as the student did in the Chapter 17 exercises.

Chapter 19—C++ Inheritance—deals with one of the most fundamental capabilities of object-oriented programming languages. Inheritance is a form of software reusability in which new classes are developed quickly and easily by absorbing the capabilities of existing classes and adding appropriate new capabilities. The chapter discusses the notions