



# Preface

Welcome to the C programming language—and to C++, too! This book presents leading-edge computing technologies for students, instructors and software development professionals.

At the heart of the book is the Deitel signature “live-code approach.” Concepts are presented in the context of complete working programs, rather than in code snippets. Each code example is immediately followed by one or more sample executions. All the source code is available at [www.deitel.com/books/cht6/](http://www.deitel.com/books/cht6/).

We believe that this book and its support materials will give you an informative, interesting, challenging and entertaining introduction to C.

As you read the book, if you have questions, send an e-mail to [deitel@deitel.com](mailto:deitel@deitel.com); we’ll respond promptly. For updates on this book and its supporting C and C++ software, and for the latest news on all Deitel publications and services, visit [www.deitel.com](http://www.deitel.com).

## New and Updated Features

Here are the updates we’ve made for *C How to Program, 6/e*:

- **“Making a Difference” Exercises Set.** We encourage you to use computers and the Internet to research and solve problems that really matter. These new exercises are meant to increase awareness of important issues the world is facing. We hope you’ll approach them with your own values, politics and beliefs.
- **Tested All Code on Windows and Linux.** We’ve tested every program (the examples and the exercises) using both Visual C++ 2008 and GNU GCC 4.3. The code examples and exercise code solutions were also tested using Visual Studio 2010 Beta.
- **New Design.** The book has a new interior design that graphically serves to organize, clarify and highlight the information, and enhances the book’s pedagogy.
- **Improved Terminology Sections.** We’ve added page numbers for the defining occurrences of all terms in the terminology lists for easy reference.
- **Updated Coverage of C++ and Object-Oriented Programming.** We updated Chapters 15–24 on object-oriented programming in C++ with material from our just published *C++ How to Program, 7/e*.
- **Titled Programming Exercises.** We’ve titled all the programming exercises. This helps instructors tune assignments for their classes.
- **New Web Appendices.** Chapters 15–17 from the previous edition are now searchable PDF Appendices E–G, available on the Companion Website (see the access card at the front of the book).

- *New Debugger Appendices.* We also added new debugging appendices for Visual C++<sup>®</sup> 2008 and GNU gdb.
- *Order of Evaluation.* We added cautions about order of evaluation issues.
- We replaced all uses of `gets` (from `<stdio.h>`) with `fgets`, because `gets` is now deprecated.
- *Additional Exercises.* We added more function pointer exercises. We also added the Fibonacci exercise project that improves the Fibonacci recursion example (tail recursion).
- *Secure C Programming Resource Center.* We've posted a new Secure C Programming Resource Center at [www.deitel.com/SecureC/](http://www.deitel.com/SecureC/). We've also added notes about secure C programming to the introductions in Chapter 7, Pointers, and Chapter 8, Strings.
- *Game Programming with Allegro.* We updated the chapter on game programming with the Allegro C library. In particular, we added instructions on installing the Allegro libraries for use with Visual C++<sup>®</sup> 2008 and GNU GCC 4.3.
- *Coverage of the C99 Standard.* We updated and enhanced the detailed appendix on C99, which was reviewed by John Benito, Convener of ISO WG14—the Working Group responsible for the C Programming Language Standard. Each C99 concept is now keyed to the section where it can be taught earlier in the book. C99 is not incorporated throughout the book because Microsoft does not yet support it and a large percentage of C courses use Microsoft's Visual C++<sup>®</sup> compiler. For additional information, check out the C99 Standard section in our C Resource center at [www.deitel.com/C/](http://www.deitel.com/C/). You'll find features of C99, articles from experts, the differences between Standard C and C99, FAQs, downloads and more.
- *C++-Style // Comments.* We discuss C++-style `//` comments early for instructors and students who'd prefer to use them. Although Microsoft C does not yet support C99, it does support C99's comments, which are borrowed from C++.
- *C Standard Library.* Section 1.8 now references P.J. Plauger's Dinkumware website ([www.dinkumware.com/manuals/default.aspx](http://www.dinkumware.com/manuals/default.aspx)) where students can find thorough searchable documentation for the C Standard Library functions.

## Other Features

Other features of *C How to Program, 6/e*, include:

### *Game Programming with the Allegro C Game Programming Library*

Appendix E introduces the Allegro game programming C library. This library—originally developed by Climax game programmer Shawn Hargreaves—was created to be a powerful tool for programming games in C while still remaining relatively simple compared to other, more complicated graphics libraries such as DirectX and OpenGL. In Appendix E, we use Allegro's capabilities to create the simple game of Pong. Along the way, we demonstrate how to display graphics, play sounds, receive input from the keyboard and create timed events—features you can use to create games of your own. Students and instructors

alike will find Allegro challenging and entertaining. We include extensive web resources in our Allegro Resource Center ([www.deitel.com/allegro](http://www.deitel.com/allegro)), one of which offers more than 1000 open-source Allegro games.

### *Sorting: A Deeper Look*

Sorting places data in order, based on one or more sort keys. We begin our presentation of sorting with a simple algorithm in Chapter 6. In Appendix F, we present a deeper look at sorting. We consider several algorithms and compare them with regard to their memory consumption and processor demands. For this purpose, we introduce Big O notation, which indicates how hard an algorithm may have to work to solve a problem. Through examples and exercises, Appendix F discusses the selection sort, insertion sort, recursive merge sort, recursive selection sort, bucket sort and recursive Quicksort.

## Web-Based Materials

This book is supported by substantial online materials. The book's Companion Website ([www.pearsonhighered.com/deitel](http://www.pearsonhighered.com/deitel); see the access card at the front of the book) contains the following appendices in *searchable* PDF format:

- Appendix E, Game Programming with the Allegro C Library
- Appendix F, Sorting: A Deeper Look
- Appendix G, Introduction to C99
- Appendix H, Using the Visual Studio Debugger
- Appendix I, Using the GNU Debugger

## Dependency Charts

The dependency charts in Figs. 1–2 show the dependencies among the chapters to help instructors plan their syllabi. *C How to Program, 6/e* is appropriate for CS1 and CS2 courses, and intermediate-level C and C++ programming courses. The C++ part of the book assumes that you have studied the C part.

## Teaching Approach

*C How to Program, 6/e*, contains a rich collection of examples. We concentrate on demonstrating the principles of good software engineering and stressing program clarity.

*Live-Code Approach.* *C How to Program, 6/e*, is loaded with “live-code” examples. Most new concepts are presented in the context of complete working C applications, followed by one or more executions showing program inputs and outputs.

### *Syntax Shading*

For readability, we syntax shade the code, similar to the way most integrated-development environments and code editors syntax color code. Our syntax-shading conventions are:

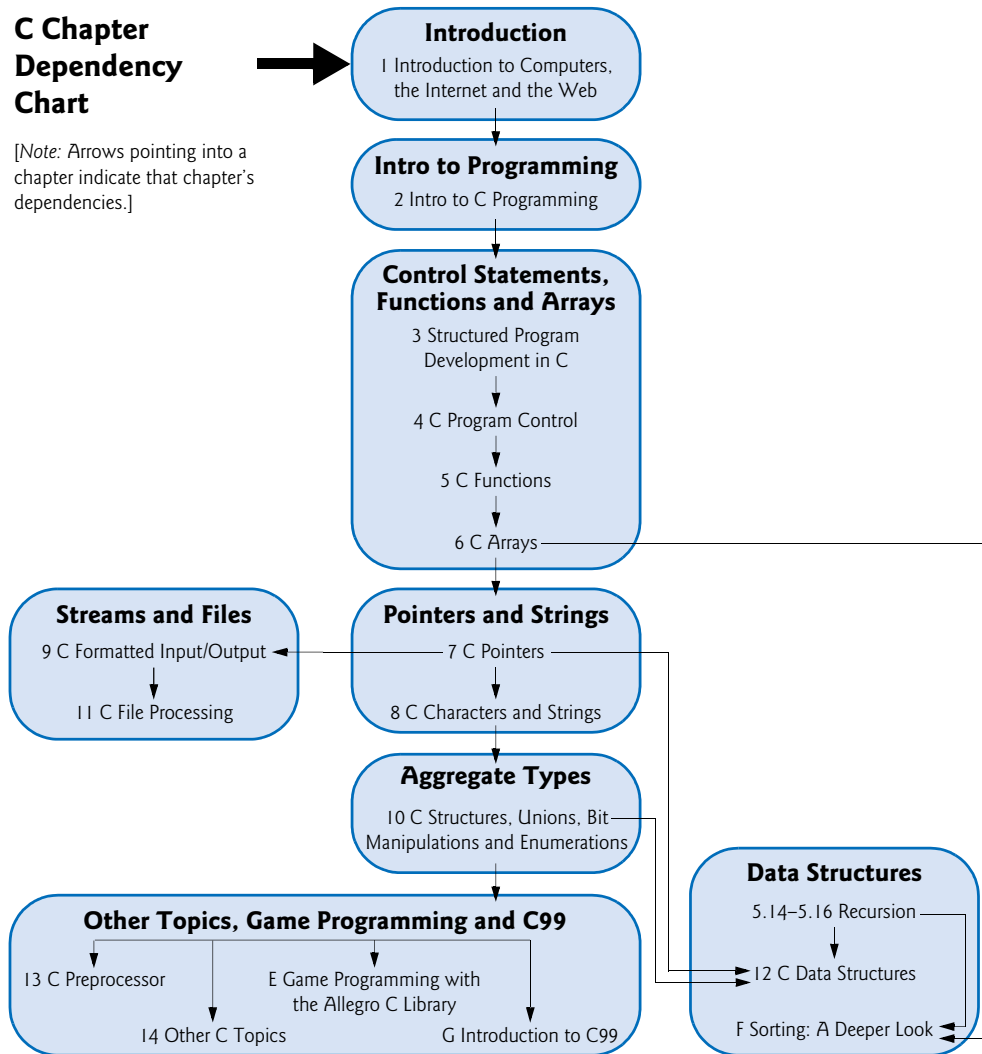
```

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

```

## C Chapter Dependency Chart

[Note: Arrows pointing into a chapter indicate that chapter's dependencies.]



**Fig. 1** | C chapter dependency chart.

### Code Highlighting

We place gray rectangles around the key code.

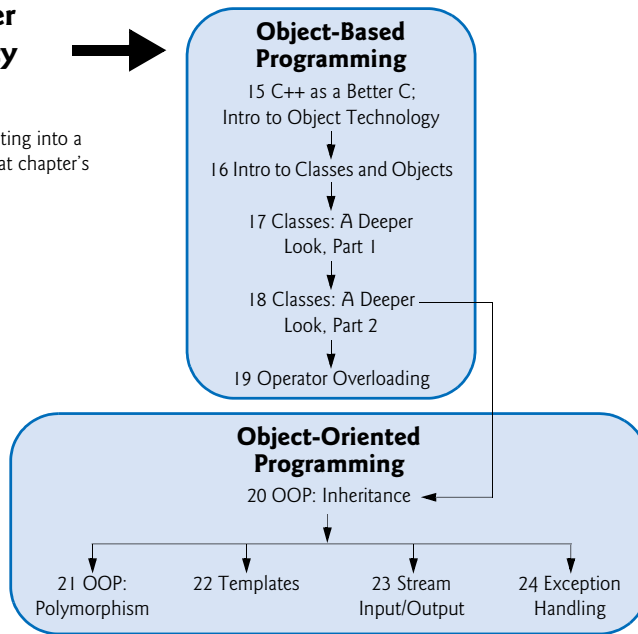
**Using Fonts for Emphasis.** We place the key terms and the index's page reference for each defining occurrence in **bold blue** text for easy reference. We emphasize on-screen components in the **bold Helvetica** font (e.g., the **File** menu) and C program text in the **Lucida** font (for example, `int x = 5;`).

**Web Access.** All of the source-code examples are available for download from:

[www.deitel.com/books/cht6/](http://www.deitel.com/books/cht6/)

## C++ Chapter Dependency Chart

[Note: Arrows pointing into a chapter indicate that chapter's dependencies.]



**Fig. 2** | C++ chapter dependency chart.

**Quotations.** Each chapter begins with quotations. We hope that you enjoy relating these to the chapter material.

**Objectives.** The quotes are followed by a list of chapter objectives.

**Illustrations/Figures.** Abundant charts, tables, line drawings, UML diagrams, programs and program output are included.

### Programming Tips

We include programming tips to help you focus on important aspects of program development. These tips and practices represent the best we've gleaned from a combined seven decades of programming and teaching experience.



#### Good Programming Practice

*The Good Programming Practices call attention to techniques that will help you produce programs that are clearer, more understandable and more maintainable.*



#### Common Programming Error

*Pointing out these Common Programming Errors reduces the likelihood that you'll make them.*



#### Error-Prevention Tip

*These tips contain suggestions for exposing and removing bugs from your programs; many describe aspects of C that prevent bugs from getting into programs in the first place.*



### Performance Tip

*These tips highlight opportunities for making your programs run faster or minimizing the amount of memory that they occupy.*



### Portability Tip

*The Portability Tips help you write code that will run on a variety of platforms.*



### Software Engineering Observation

*The Software Engineering Observations highlight architectural and design issues that affect the construction of software systems, especially large-scale systems.*

*Summary Bullets.* We present a section-by-section, bullet-list summary of the chapter.

*Terminology.* We include an alphabetized list of the important terms defined in each chapter with the page number of each term's defining occurrence for easy reference.

*Self-Review Exercises and Answers.* Extensive self-review exercises *and* answers are included for self-study.

*Exercises.* Each chapter concludes with a substantial set of exercises including:

- simple recall of important terminology and concepts,
- identifying the errors in code samples,
- writing individual C statements,
- writing small portions of functions and classes,
- writing complete C functions, classes and programs, and
- major projects.

Instructors can use these exercises to form homework assignments, short quizzes, major examinations and term projects. [NOTE: Please do not write to us requesting access to the Pearson Instructor's Resource Center which contains the book's instructor supplements, including the exercise solutions. Access is limited strictly to college instructors teaching from the book. Instructors may obtain access only through their Pearson representatives. Solutions are *not* provided for "project" exercises.] Check out our Programming Projects Resource Center ([www.deitel.com/ProgrammingProjects/](http://www.deitel.com/ProgrammingProjects/)) for lots of additional exercise and project possibilities.

*Index.* We've included an extensive index, which is especially useful when you use the book as a reference. Defining occurrences of key terms are highlighted with a **bold blue** page number.

## Student Resources

Many C and C++ development tools are available. We wrote *C How to Program, 6/e* primarily using Microsoft's free Visual C++<sup>®</sup> Express Edition (which is available free for download at [www.microsoft.com/express/vc/](http://www.microsoft.com/express/vc/)) and the free GNU C++ ([gcc.gnu.org/install/binaries.html](http://gcc.gnu.org/install/binaries.html)), which is already installed on most Linux systems and can be installed on

Mac OS X and Windows systems as well. You can learn more about Visual C++<sup>®</sup> Express at [msdn.microsoft.com/vstudio/express/visualc](http://msdn.microsoft.com/vstudio/express/visualc). You can learn more about GNU C++ at [gcc.gnu.org](http://gcc.gnu.org). Apple includes GNU C++ in their Xcode development tools, which Mac OS X users can download from [developer.apple.com/tools/xcode](http://developer.apple.com/tools/xcode).

You can download the book's examples and additional resources from:

[www.deitel.com/books/chtp6/](http://www.deitel.com/books/chtp6/)

For additional resources and software downloads see our C Resource Center:

[www.deitel.com/c/](http://www.deitel.com/c/)

For other C and C++ compilers that are available free for download:

[www.thefreecountry.com/developercity/ccompilers.shtml](http://www.thefreecountry.com/developercity/ccompilers.shtml)  
[www.compilers.net/Dir/Compilers/CCpp.htm](http://www.compilers.net/Dir/Compilers/CCpp.htm)

## CourseSmart Web Books

Today's students and instructors have increasing demands on their time and money. Pearson has responded to that need by offering digital texts and course materials online through CourseSmart. CourseSmart allows faculty to review course materials online saving time and costs. It is also environmentally sound and offers students a high-quality digital version of the text for as much as 50% off the cost of a print copy of the text. Students receive the same content offered in the print textbook enhanced by search, note-taking, and printing tools. For more information, visit [www.coursesmart.com](http://www.coursesmart.com).

## Software for the Book

This book includes the Microsoft<sup>®</sup> Visual Studio<sup>®</sup> 2008 Express Editions All-in-One DVD, which contains the Visual C++<sup>®</sup> 2008 Express Edition (and other Microsoft development tools). You can also download the latest version of Visual C++ Express Edition from:

[www.microsoft.com/express/vc](http://www.microsoft.com/express/vc)

Per Microsoft's website, Express Editions are "lightweight, easy-to-use and easy-to-learn tools for the hobbyist, novice and student developer." They are appropriate for academic courses and for professionals who do not have access to a complete version of Visual Studio 2008.

With the exception of one example in Chapter 9, C Formatted Input/Output, and the examples in Appendix G, Introduction to C99, all of the examples in this book compile and run in Visual C++<sup>®</sup> 2008 and the beta version of Visual C++<sup>®</sup> 2010. All of the examples compile and run in GNU GCC 4.3. GCC is available for most platforms, including Linux, Mac OS X (via Xcode) and Windows—via tools like Cygwin ([www.cygwin.com](http://www.cygwin.com)) and MinGW ([www.mingw.org](http://www.mingw.org)).

## Instructor Supplements

The following supplements are available to qualified instructors only through Pearson Education's Instructor Resource Center ([www.pearsonhighered.com/irc](http://www.pearsonhighered.com/irc)):

- *Solutions Manual* with solutions to most of the end-of-chapter exercises.

- *Test Item File* of multiple-choice questions (approximately two per book section)
- Customizable PowerPoint® slides containing all the code and figures in the text, plus bulleted items that summarize key points in the text

If you are not already a registered faculty member, contact your Pearson representative or visit [www.pearsonhighered.com/educator/replocator/](http://www.pearsonhighered.com/educator/replocator/).

## Deitel® Buzz Online Free E-mail Newsletter

The *Deitel® Buzz Online* e-mail newsletter will keep you posted about issues related to *C How to Program, 6/e*. It also 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](http://www.deitel.com/newsletter/subscribe.html)

## The Deitel Online Resource Centers

Our website [www.deitel.com](http://www.deitel.com) provides more than 100 Resource Centers on various topics including programming languages, software development, Web 2.0, Internet business and open-source projects—see the list of Resource Centers in the first few pages of this book and visit [www.deitel.com/ResourceCenters.html](http://www.deitel.com/ResourceCenters.html). We've found many exceptional resources online, including tutorials, documentation, software downloads, articles, blogs, podcasts, videos, code samples, books, e-books and more—most of them are free. Each week we announce our latest Resource Centers in our newsletter, the *Deitel® Buzz Online*. Some of the Resource Centers you might find helpful while studying this book are C, C++, C++ Boost Libraries, C++ Game Programming, Visual C++, UML, Code Search Engines and Code Sites, Game Programming and Programming Projects.

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## Acknowledgments

It's a pleasure to acknowledge the efforts of people whose names do not appear on the cover, but whose hard work, cooperation, friendship and understanding were crucial to the book's production. Many people at Deitel & Associates, Inc., devoted long hours to this project—thanks especially to Abbey Deitel and Barbara Deitel.

We would also like to thank the participants of our Honors Internship program who contributed to this publication—Christine Chen, an Operations Research and Information Engineering major at Cornell University; and Matthew Pearson, a Computer Science graduate of Cornell University.

We are fortunate to have worked on this project with the dedicated team of publishing professionals at Pearson. We appreciate the efforts of Marcia Horton, Editorial Director of Pearson's Engineering and Computer Science Division, and Michael Hirsch, Editor-in-Chief of Computer Science. Carole Snyder recruited the book's review team and managed the review process. Francesco Santalucia (an independent artist) and Kristine Carney of Pearson designed the book's cover—we provided the concept, and they made it happen. Scott Disanno and Bob Engelhardt managed the book's production. Erin Davis and Margaret Waples marketed the book through academic and professional channels.

### **C How to Program, 6/e Reviewers**

We wish to acknowledge the efforts of our reviewers. Adhering to a tight time schedule, they scrutinized the text and the programs and provided countless suggestions for improving the accuracy and completeness of the presentation:

- John Benito, Blue Pilot Consulting, Inc. and Convener of ISO WG14—the Working Group responsible for the C Programming Language Standard.
- Xiaolong Li, Indiana State University
- Tom Rethard, The University of Texas at Arlington

### **C How to Program, 5/e Reviewers**

- Alireza Fazelpour (Palm Beach Community College)
- Don Kostuch (Independent Consultant)
- Ed James Beckham (Altera)
- Gary Sibbitts (St. Louis Community College at Meramec)
- Ian Barland (Radford University)
- Kevin Mark Jones (Hewlett Packard)
- Mahesh Hariharan (Microsoft)
- William Mike Miller (Edison Design Group, Inc.)
- Benjamin Seyfarth (University of Southern Mississippi)
- William Albrecht (University of South Florida)
- William Smith (Tulsa Community College)

### ***Allegro Reviewers for C How to Program, 5/e***

- Shawn Hargreaves (Software Design Engineer, Microsoft Xbox)
- Matthew Leverton (Founder and Webmaster of Allegro.cc)
- Ryan Patterson (Independent Consultant)
- Douglas Walls (Senior Staff Engineer, C compiler, Sun Microsystems)

### ***C99 Reviewers for C How to Program, 5/e***

- Lawrence Jones, (UGS Corp.)
- Douglas Walls (Senior Staff Engineer, C compiler, Sun Microsystems)

Well, there you have it! C is a powerful programming language that will help you write programs quickly and effectively. C scales nicely into the realm of enterprise systems development to help organizations build their business-critical and mission-critical information systems. As you read the book, we would sincerely appreciate your comments, criticisms, corrections and suggestions for improving the text. Please address all correspondence to:

`deitel@deitel.com`

We'll respond promptly, and post corrections and clarifications on:

`www.deitel.com/books/cht6/`

We hope you enjoy working with *C How to Program, Sixth Edition* as much as we enjoyed writing it!

*Paul Deitel*

*Harvey Deitel*

Maynard, Massachusetts

August 2009

## About the Authors

**Paul J. Deitel**, CEO and Chief Technical Officer of Deitel & Associates, Inc., is a graduate of MIT's Sloan School of Management, where he studied Information Technology. Through Deitel & Associates, Inc., he has delivered C, C++, Java, C#, Visual Basic and Internet programming courses to industry clients, including Cisco, IBM, Sun Microsystems, Dell, Lucent Technologies, Fidelity, NASA at the Kennedy Space Center, the National Severe Storm Laboratory, White Sands Missile Range, Rogue Wave Software, Boeing, SunGard Higher Education, Stratus, Cambridge Technology Partners, Open Environment Corporation, One Wave, Hyperion Software, Adra Systems, Entergy, Cable-Data Systems, Nortel Networks, Puma, iRobot, Invensys and many more. He holds the Java Certified Programmer and Java Certified Developer certifications and has been designated by Sun Microsystems as a Java Champion. He has also lectured on Java and C++ for the Boston Chapter of the Association for Computing Machinery. He and his co-author, Dr. Harvey M. Deitel, are the world's best-selling programming-language textbook authors.

**Dr. Harvey M. Deitel**, Chairman and Chief Strategy Officer of Deitel & Associates, Inc., has 48 years of academic and industry experience in the computer field. Dr. Deitel earned B.S. and M.S. degrees from MIT and a Ph.D. from Boston University. He has extensive college teaching experience, including earning tenure and serving as the Chairman of the Computer Science Department at Boston College before founding Deitel & Associates, Inc., with his son, Paul J. Deitel. He and Paul are the co-authors of dozens of books and multimedia packages and they are writing many more. With translations published in Japanese, German, Russian, Traditional Chinese, Simplified Chinese, Spanish, Korean, French, Polish, Italian, Portuguese, Greek, Urdu and Turkish, the Deitels' texts have earned international recognition. Dr. Deitel has delivered hundreds of professional seminars to major corporations, academic institutions, government organizations and the military.

## About Deitel & Associates, Inc.

Deitel & Associates, Inc., is an internationally recognized authoring and corporate training organization specializing in computer programming languages, Internet and web software technology, object-technology education and iPhone applications development. The company provides instructor-led courses delivered at client sites worldwide on major programming languages and platforms, such as C, C++, Visual C++<sup>®</sup>, Java<sup>™</sup>, Visual C#<sup>®</sup>, Visual Basic<sup>®</sup>, XML<sup>®</sup>, Python<sup>®</sup>, object technology, Internet and web programming, iPhone programming and a growing list of additional programming and software-development-related courses. The founders of Deitel & Associates, Inc., are Paul J. Deitel and Dr. Harvey M. Deitel. The company's clients include many of the world's largest companies, government agencies, branches of the military, and academic institutions. Through its 33-year publishing partnership with Prentice Hall/Pearson, Deitel & Associates, Inc., publishes leading-edge programming textbooks, professional books, interactive multimedia *Cyber Classrooms*, *LiveLessons* video courses (online at [www.safaribooksonline.com](http://www.safaribooksonline.com) and on DVD at [www.deitel.com/books/livelessons/](http://www.deitel.com/books/livelessons/)), and e-content for popular course-management systems.

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