



Preface

*Science and technology and the various forms of art,
all unite humanity in a single and interconnected system.*

—Zhores Aleksandrovich Medvede

Welcome to Internet and web programming with *Internet & World Wide Web How to Program, Fifth Edition*! This book presents leading-edge computing technologies for students, instructors and software developers.

The world of computing—and Internet and web programming in particular—has changed dramatically since the last edition. This new edition focuses on HTML5 and the related technologies in its ecosystem, diving into the exciting new features of HTML5, CSS3, the latest edition of JavaScript (ECMAScript 5) and HTML5 canvas. We focus on popular key technologies that will help you build Internet- and web-based applications that interact with other applications and with databases. These form the basis of the kinds of enterprise-level, networked applications that are popular in industry today.

Internet & World Wide Web How to Program, 5/e is appropriate for both introductory and intermediate-level client-side and server-side programming courses. The book is also suitable for professionals who want to update their skills with the latest Internet and web programming technologies.

At the heart of the book is the Deitel signature “live-code approach”—concepts are presented in the context of complete working HTML5 documents, CSS3 stylesheets, JavaScript scripts, XML documents, programs and database files, rather than in code snippets. Each complete code example is accompanied by live sample executions. The source code is available at www.deitel.com/books/iw3http5/ and at the book’s Companion Website www.pearsonhighered.com/deitel/.

As you read the book, if you have questions, send an e-mail to deitel@deitel.com; we’ll respond promptly. For updates on this book, visit www.deitel.com/books/iw3http5/, join our communities on Facebook (www.facebook.com/deitel1fan) and Twitter (@deitel), and subscribe to the *Deitel*[®] *Buzz Online* newsletter (www.deitel.com/newsletter/subscribe.html).

New and Updated Features

Here are the updates we’ve made for *Internet & World Wide Web How to Program, 5/e*:

- **New Chapter 1.** The new Chapter 1 engages students with intriguing facts and figures to get them excited about studying Internet and web applications development. The chapter includes a table of some of the research made possible by

computers and the Internet, current technology trends and hardware discussion, the data hierarchy, a new section on social networking, a table of popular web services, a table of business and technology publications and websites that will help you stay up to date with the latest technology news and trends, and updated excises.

- **New HTML5 features.** Chapter 3 introduces the latest features of HTML5 including the new HTML5 form input types and page structure elements (Fig. 1). *The new HTML5 features are not universally implemented in all of the web browsers.* This is changing as the browser vendors release new versions. We discuss many additional HTML5 features throughout the book.

New HTML5 features			
<i>Form Input Types</i>			
color	date	datetime	datetime-local
email	month	number	range
search	tel	time	url
week	input element	datalist element	autocomplete attribute
<i>Page Structure Elements</i>			
header	nav	figure	figcaption
article	summary	section	aside
meter	footer	text-level semantics (marking potential line breaks)	

Fig. 1 | New HTML5 form input types and page structure elements

- **New CSS3 features.** Chapter 5 introduces the latest features of CSS3 (Fig. 2). *The new CSS3 features are not universally implemented in all of the web browsers.* This is changing as the browser vendors release new versions.

New CSS3 features		
text shadows	rounded corners	color
box shadows	linear gradients	radial gradients
multiple background images	image borders	animations
transitions	transformations	@font-face rule
Flexible Box Layout Module	:nth-child selectors	multicolumn layouts
media queries		
<i>Non-standard features</i>		
text stroke	reflection	

Fig. 2 | New CSS3 features.

- **Updated treatment of JavaScript.** We've strengthened the JavaScript coverage in Chapters 6–16. JavaScript has become the *de facto* standard client-side scripting language for web-based applications due to its highly portable nature. Our treatment, which is appropriate for novices, serves two purposes—it introduces client-side scripting (Chapters 6–16), which makes web pages more dynamic and interactive, and it provides the programming foundation for the server-side scripting in PHP presented in Chapter 19. JavaScript looks similar to basic core language features in C, C++, C# and Java. Once you learn JavaScript, you've got a foothold on learning these other popular programming languages.
- **New HTML5 canvas.** Chapter 14 replaces the Flash and Silverlight chapters from the previous edition with the new HTML5 canvas element for 2D graphics (Fig. 3). canvas is built into the browser, eliminating the need for plug-ins like Flash and Silverlight, and helping you improve performance and convenience, and reduce costs. At the end of the chapter, you'll use canvas to build a fun, animated Cannon Game with audio effects, which we built in Flash in previous editions of this book.

HTML5 canvas features		
rectangles	lines	arcs and circles
shadows	quadratic curves	Bezier curves
linear gradients	radial gradients	image manipulation
images	patterns	transformations
alpha transparency	compositing	

Fig. 3 | HTML5 canvas features.

- **New and updated multimedia exercises.** Chapter 14 includes several new and updated multimedia exercises (Fig. 4).

New and updated multimedia exercises		
Cannon Game Enhancements	Random Interimage Transition	Digital Clock Background Audio
Animation	Scrolling Image Marquee	Analog Clock
Scrolling Marquee Sign	Automatic Jigsaw Puzzle	Maze Generator and Walker
Dynamic Audio and Graphical Kaleidoscope	Generator	Shuffleboard
One-Armed Bandit	Horse Race	Floor Planner
Game of Pool	Fireworks Designer	Reaction Time Tester
Crossword Puzzle	15 Puzzle	Vacuuming Robot
Rotating Images	Coloring Black-and-White Photographs and Images	Eyesight Tester

Fig. 4 | New and updated multimedia exercises.

- *Tested on seven browsers.* For the last edition of this book, we tested all the code on two desktop browsers—Internet Explorer and Firefox. For this new edition, we tested all of the code in the most current versions of *seven* popular browsers—five for the **desktop** (**Chrome**, **Internet Explorer**, **Firefox**, **Opera** and **Safari**) and two for **mobile** devices (**iPhone/iPad** and **Android**). *HTML5 and CSS3 are evolving and the final standards have not been approved yet.* The browser vendors are selectively implementing features that are likely to be standardized. Some vendors have higher levels of feature compliance than others. With each new version of the browsers, the trend has been to significantly increase the amount of functionality that's been implemented. The HTML5 test site (html5test.com) measures how well each browser supports the pending standards and specifications. You can view test scores and see which features are supported by each browser. You can also check sites such as <http://caniuse.com/> for a list of features covered by each browser. *Not every document in this book will render properly in each browser.* Instead of choosing only capabilities that exist universally, we demonstrate exciting new features in whatever browser handles the new functionality best. As you read this book, run each example in multiple web browsers so you can view and interact with it as it was originally intended. And remember, things are changing quickly, so a browser that did not support a feature when we wrote the book could support it when you read the book.
- *Validated HTML5, CSS3 and JavaScript code.* All of the HTML5, CSS3 and JavaScript code in the book was validated using validator.w3.org/ for HTML5, jigsaw.w3.org/css-validator for CSS3 and jshint.com for JavaScript. *Not every script fully validates but most do.* Although all of the code works properly, you may receive warnings (or possibly errors) when validating code with some of the new features.
- *Smartphone and tablet apps.* You're probably familiar with the explosion of apps available for the **iPhone/iPad** and **Android** platforms. There's almost a million apps between the two. Previously, writing apps for these platforms required detailed knowledge of each, and in the case of iPhone/iPad, was strictly controlled by Apple; Android is more open. With the techniques you'll learn in this book, you'll be able to write apps that are portable between a great variety of desktop and mobile platforms, including iPhone/iPad and Android. You'll even be able to sell those apps on your own terms (or through certain app stores as well). This is an exciting possibility! It's one of the true virtues of developing with HTML5, CSS3 and JavaScript in general, and HTML5 canvas in particular. Running an HTML5 app on your smartphone or tablet is as simple as opening it in your compliant web browser. *You may still encounter some portability issues.*
- *New HTML5 web storage capabilities.* In Chapter 11, we use HTML5's new web storage capabilities to create a web application that stores a user's favorite Twitter searches on the computer for easy access at a later time. Web storage replaces the controversial cookie technology, offering lots more storage space. Chapter 11 also briefly introduces JSON, a means for creating JavaScript objects—typically for transferring data over the Internet between client-side and server-side programs.

- *Enhanced Craps game featuring HTML5 audio and video elements.* The Craps game in Chapter 9 now includes an HTML5 audio element that plays a dice-rolling sound each time the user rolls the dice. Also, we link to a page with an embedded HTML5 video element that plays a video explaining the rules of the game.
- *jQuery Ajax case study.* The previous edition of this book included a calendar application that used the Dojo libraries—which were popular at the time—to create the user interface, communicate with the server asynchronously, handle events and manipulate the DOM. Since then, jQuery has become the most popular JavaScript library. For this edition, we’ve updated the calendar application (Chapter 16) using jQuery and placed it online as a jQuery Ajax case study.
- *New HTML5 WebSockets and Web Workers capabilities.* We’ve added an online treatment of two new technologies—WebSockets, which provides a simple model for networking, and Web Workers which provides multithreading on a web page.
- *Ajax-enabled web applications.* We’ve updated the chapter on building Ajax-enabled web applications, with applications that demonstrate *partial-page updates* and type-ahead capabilities—each of these are key capabilities of Rich Internet Applications.
- *HTML DOM and XML DOM.* We’ve enhanced the treatments of HTML DOM manipulation, JavaScript events and XML DOM manipulation with JavaScript.
- *LINQ.* Since the last edition of the book, Microsoft introduced LINQ (Language-Integrated Query) to replace SQL for database access. Chapter 18 provides an introduction to LINQ basics and an introduction to LINQ to SQL (the technology that replaces SQL).
- *Updated PHP coverage.* Chapter 19 has been updated to the latest version of PHP. If you start this book as a novice and study the JavaScript in Chapters 6–13, you’ll have the programming experience needed to understand server-side programming in PHP. [Our treatment of server-side programming in ASP.NET requires knowledge of C# or Visual Basic, and in JSF requires knowledge of Java.]
- *ASP.NET, ASP.NET Ajax and web services.* This updated three-chapter sequence is now provided for each of Microsoft’s two key applications development languages—C# and Visual Basic. The C# chapters and the first VB chapter are in the print book and the remaining Visual Basic chapters are available online at the book’s Companion Website (see the inside front cover).
- *JavaServer Faces (JSF), JSF Ajax and web services.* This updated three-chapter sequence, available online, emphasizes building Ajax-enabled JSF applications.
- *Web services.* We now provide chapters on building both SOAP-based web services and REST-based web services with ASP.NET in Visual Basic, ASP.NET in C# and JSF in Java.
- *Client/Server applications.* Several client-side case studies now enable students to interact with preimplemented web services that we host at test.deitel.com.

- *New and updated case studies.* The book includes rich case studies using various technologies—Deitel Cover Viewer (JavaScript/DOM), Address Book (Ajax), Cannon Game (HTML5 Canvas), Mailing List (PHP/MySQL), Guest Book and Password-Protected Books Database (ASP.NET), Address Book (JavaServer Faces) and Blackjack (JAX-WS web services).

New Pedagogic Features

- *Making a Difference exercises in Chapter 1.* We encourage you to use computers and the Internet to research and solve significant social problems. These exercises are meant to increase awareness and discussion of important issues the world is facing. We hope you'll approach them with your own values, politics and beliefs. Check out the many Making a Difference resources we provide, including our new Making a Difference Resource Center at www.deitel.com/MakingADifference for additional ideas you may want to investigate further.
- *Page numbers for key terms in chapter summaries.* For key terms that appear in the Chapters 1–19 summaries, we include the page number of the key term's defining occurrence in the text.

Dependency Chart

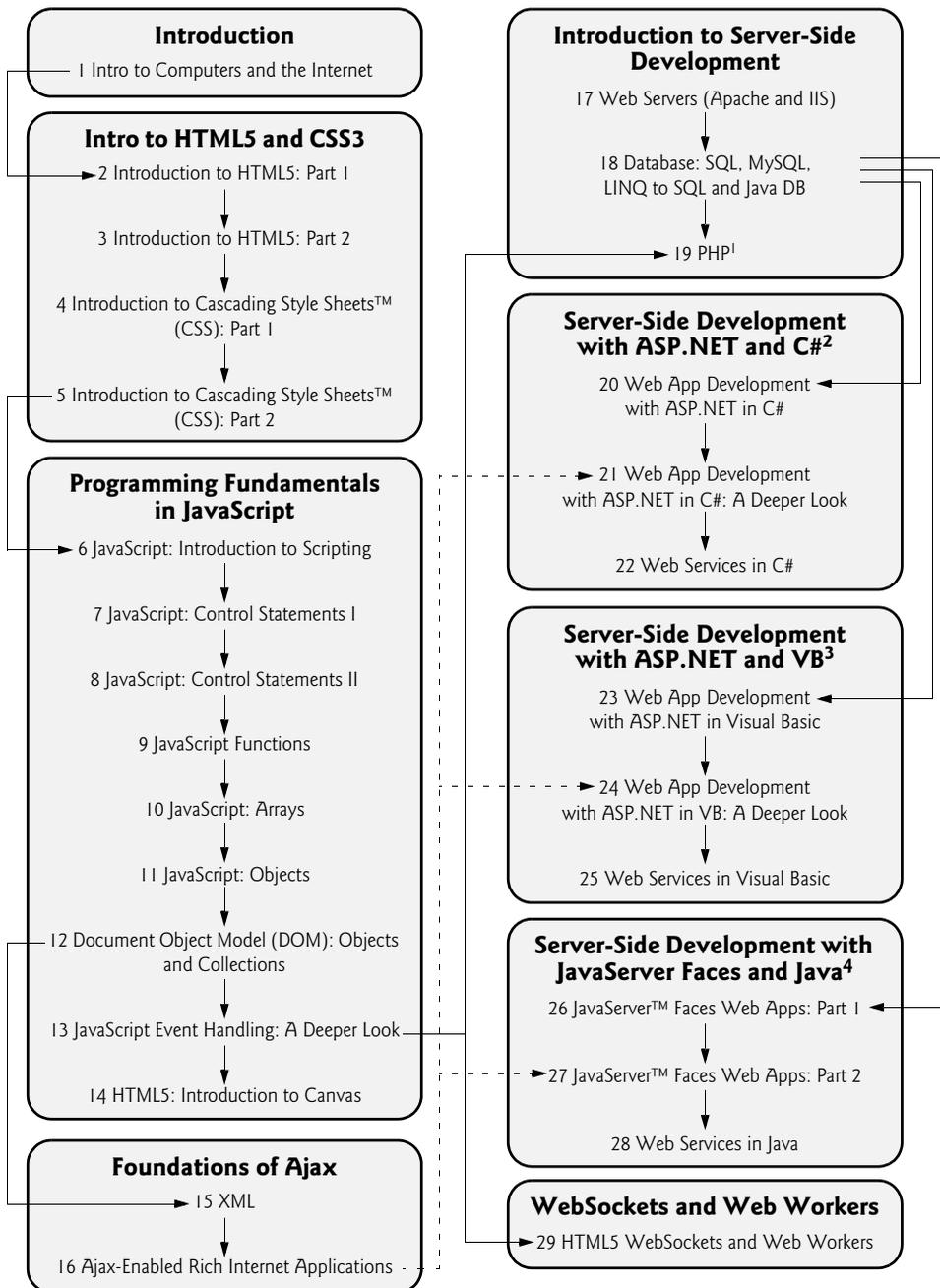
The chart in Fig. 5 shows the book's modular organization and the dependencies among the chapters to help instructors plan their syllabi. *Internet & World Wide Web How to Program, 5/e*, is appropriate for a variety of introductory and intermediate -level programming courses, most notably client-side programming and server-side programming. Chapters 1–23 are in the printed book; Chapters 24–29 and some appendices are online.

We recommend that you study all of a given chapter's dependencies before studying that chapter, though other orders are certainly possible. Some of the dependencies apply only to sections of chapters, so we advise instructors to browse the material before designing a course of study. This book is intended for courses that teach pure client-side web programming, courses that teach pure server-side web programming, and courses that mix and match some of each. Readers interested in studying server-side technologies should understand how to build web pages using HTML5 and CSS3, and object-based programming in JavaScript. Chapters 15 and 16 can be taught as part of a client-side unit, at the beginning of a server-side unit or split between the two.

HTML5 Accessibility Online Appendix

According to the W3C Web Accessibility Initiative, your web pages and applications should be accessible so that “people with disabilities can perceive, understand, navigate, and interact with the web, and that they can contribute to the web.”¹ In an online appendix, we enumerate accessibility issues you should consider when designing web pages and web-based applications. We also provide resources that show you how to use HTML5, CSS3, JavaScript and various design techniques to create accessible web pages and applications. As appropriate, we tie the information in this appendix back to the appropriate chapters and sections so that you can see how the applications may be enhanced to improve web accessibility.

1. <http://www.w3.org/WAI/intro/accessibility.php>.



1. Chapter 19 assumes only that you're familiar with the programming fundamentals presented in Chapters 6–13.
2. The C# chapters require knowledge of C# and the Microsoft .NET class libraries.
3. The Visual Basic chapters require knowledge of Visual Basic and the Microsoft .NET class libraries.
4. The Java chapters require knowledge of Java and the Java class libraries.

Fig. 5 | *Internet & World Wide Web How to Program, 5/e* chapter dependency chart.

HTML5 Geolocation Online Appendix

The HTML5 Geolocation API allows you to build web applications that gather location information (i.e., latitude and longitude coordinates) using technologies like GPS, IP addresses, WiFi connections or cellular tower connections. It's supported by the seven desktop and mobile browsers we used to test the code throughout the book.

The Geolocation API specification lists several use cases,² including:

- finding points of interest in the user's area
- annotating content with location information
- showing the user's position on a map
- providing route navigation
- alerting the user when points of interest are nearby
- providing up-to-date local information
- tagging locations in status updates on social networking sites

For example, you could create a location-based mobile web app that uses GPS location information from a smartphone to track a runner's route on a map, calculate the distance traveled and the average speed. Similarly, you could create an app that returns a list of nearby businesses. In this online appendix, we build a mobile location-based app.

Teaching Approach

Internet & World Wide Web How to Program, 5/e, contains hundreds of complete working examples across a wide variety of markup, styling, scripting and programming languages. We stress clarity and concentrate on building well-engineered software.

Syntax Shading. For readability, we syntax shade the code, similar to the way most integrated-development environments and code editors syntax color the 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

```

Code Highlighting. We place gray rectangles around key code segments.

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

Web Access. All of the source-code examples can be downloaded from:

```

www.deitel.com/books/iw3http5
www.pearsonhighered.com/deitel

```

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

2. http://www.w3.org/TR/geolocation-API/#usecases_section.

Illustrations/Figures. Abundant tables, line drawings, documents, scripts, programs and program outputs are included.

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



Good Programming Practices

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



Common Programming Errors

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



Error-Prevention Tips

These tips contain suggestions for exposing and removing bugs from your programs; many of the tips describe aspects of programming that prevent bugs from getting into programs.



Performance Tips

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



Portability Tips

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



Software Engineering Observations

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 for rapid review of key points. For ease of reference, we include the page number of each key term's defining occurrence in the text.

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

Exercises. The chapter exercises include:

- simple recall of important terminology and concepts
- What's wrong with this code?
- writing individual statements
- writing complete functions and scripts
- major projects

Index. We've included an extensive index. Defining occurrences of key terms are highlighted with a **bold** page number.

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 offers students a high-quality digital version of the text for less than 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.

Instructor Resources

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

- *PowerPoint® slides* containing all the code and figures in the text, plus bulleted items that summarize key points.
- *Solutions Manual* with solutions to many of the end-of-chapter exercises. Please check the Instructor Resource Center to determine which exercises have solutions.

Please do not write to us requesting access to the Pearson Instructor's Resource Center. Access is restricted to college instructors teaching from the book. Instructors may obtain access only through their Pearson representatives. If you're not a registered faculty member, contact your Pearson representative or visit www.pearsonhighered.com/educator/relocator/.

Solutions are *not* provided for "project" exercises. Check out our Programming Projects Resource Center for lots of additional exercise and project possibilities (www.deitel.com/ProgrammingProjects/).

Acknowledgments

We'd like to thank Barbara Deitel for long hours devoted to this project. We're fortunate to have worked with the dedicated team of publishing professionals at Pearson. We appreciate the guidance, savvy and energy of Michael Hirsch, Editor-in-Chief of Computer Science. Carole Snyder recruited the book's reviewers and managed the review process. Bob Engelhardt managed the book's production.

Reviewers

We wish to acknowledge the efforts of our fourth and fifth edition reviewers. They scrutinized the text and the programs and provided countless suggestions for improving the presentation: Timothy Boronczyk (Consultant), Roland Bouman (MySQL AB), Chris Bowen (Microsoft), Peter Brandano (KoolConnect Technologies, Inc.), Matt Chotin (Adobe), Chris Cornutt (PHPDeveloper.org), Phil Costa (Adobe), Umachitra Damodaran (Sun Microsystems), Vadiraj Deshpande (Sun Microsystems), Justin Erenkrantz (The Apache Software Foundation), Christopher Finke (Netscape), Jesse James Garrett (Adaptive Path), Mike Harsh (Microsoft), Chris Heilmann (Mozilla), Kevin Henrikson (Zimbra.com), Tim Heuer (Microsoft), Molly E. Holtzschlag (W3C), Ralph Hooper (University of Alabama, Tuscaloosa), Chris Horton (University of Alabama), John Hrvatina (Microsoft), Johnvey Hwang (Splunk, Inc.), Joe Kromer (New Perspective and the

Pittsburgh Adobe Flash Users Group), Jennifer Kyrnin (Web Design Guide at About.com), Eric Lawrence (Microsoft), Pete LePage (Microsoft), Dr. Roy Levow (Florida Atlantic University), Billy B. L. Lim (Illinois State University), Shobana Mahadevan (Sun Microsystems), Patrick Mineault (Freelance Flash Programmer), Anand Narayanaswamy (Microsoft), John Peterson (Insync and V.I.O., Inc.), Jennifer Powers (University of Albany), Ignacio Ricci (Ignacioricci.com), Jake Rutter (onerutter.com), Robin Schumacher (MySQL AB), José Antonio González Seco (Parlamento de Andalucía), Dr. George Semeczko (Royal & SunAlliance Insurance Canada), Steven Shaffer (Penn State University), Michael Smith (W3C), Karen Tegtmeyer (Model Technologies, Inc.), Paul Vencill (MITRE), Raymond Wen (Microsoft), Eric M. Wendelin (Auto-trol Technology Corporation), Raymond F. Wisman (Indiana University), Keith Wood (Hyro, Ltd.) and Daniel Zappala (Brigham Young University).

As you read the book, we'd appreciate your comments, criticisms, corrections and suggestions for improvement. Please address all correspondence to:

`deitel@deitel.com`

We'll respond promptly. We hope you enjoy working with *Internet & World Wide Web How to Program, 5/e*.

Paul, Harvey and Abbey Deitel

About the Authors

Paul J. Deitel, CEO and Chief Technical Officer of Deitel & Associates, Inc., is a graduate of MIT, where he studied Information Technology. Through Deitel & Associates, Inc., he has delivered hundreds of Java, C++, C, C#, Visual Basic and Internet programming courses to industry clients, including Cisco, IBM, Siemens, 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, One Wave, Hyperion Software, Adra Systems, Entergy, CableData Systems, Nortel Networks, Puma, iRobot, Invensys and many more. 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 50 years of 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 LiveLessons video packages and they are writing many more. The Deitels' texts have earned international recognition, with translations published in Japanese, German, Russian, Chinese, Spanish, Korean, French, Polish, Italian, Portuguese, Greek, Urdu and Turkish. Dr. Deitel has delivered hundreds of professional programming seminars to major corporations, academic institutions, government organizations and the military.

Abbey Deitel, President of Deitel & Associates, Inc., is a graduate of Carnegie Mellon University's Tepper School of Management where she received a B.S. in Industrial Management. Abbey has been managing the business operations of Deitel & Associates, Inc.

for 14 years. She has contributed to numerous Deitel & Associates publications and is the co-author of *iPhone for Programmers: An App-Driven Approach* and *Android for Programmers: An App-Driven Approach*.

Corporate Training from Deitel & Associates, Inc.

Deitel & Associates, Inc., is an internationally recognized corporate training and authoring organization. The company provides instructor-led courses delivered at client sites worldwide on major programming languages and platforms, such as Java™, C++, Visual C++®, C, Visual C#®, Visual Basic®, XML®, Python®, object technology, Internet and web programming, Android™ and iPhone® app development, and a growing list of additional programming and software-development 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 35-year publishing partnership with Prentice Hall/Pearson, Deitel & Associates, Inc., publishes leading-edge programming textbooks, professional books and *LiveLessons* video courses. Deitel & Associates, Inc., and the authors can be reached via e-mail at:

deitel@deitel.com

To learn more about the company, its publications and its *Dive Into*® *Series* Corporate Training curriculum delivered at client locations worldwide, visit:

www.deitel.com/training/

subscribe to the *Deitel*® *Buzz Online* e-mail newsletter at:

www.deitel.com/newsletter/subscribe.html

and join the authors' communities on Facebook (www.facebook.com/DeitelFan) and Twitter (@deitel).

Individuals wishing to purchase Deitel books, and *LiveLessons* video training courses can do so through www.deitel.com. Bulk orders by corporations, the government, the military and academic institutions should be placed directly with Pearson. For more information, visit

www.pearsonhighered.com

About the Front Cover: Fractal Art

The cover of this book features a *fractal*—a geometric figure that can be generated from a pattern repeated recursively. The figure is modified by applying the pattern to each segment of the original figure. Although these figures were studied before the 20th century, it was the mathematician Benoit Mandelbrot, who in the 1970s introduced the term “fractal,” along with the specifics of how a fractal is created and the practical applications of fractals. Fractal geometry provides mathematical models for many complex forms found in nature, such as mountains, clouds and coastlines. Fractals can also be used to understand systems or patterns that appear in nature (e.g., ecosystems), in the human body (e.g., in the folds of the brain), or in the universe (e.g., galaxy clusters). Not all fractals resemble objects in nature. Drawing fractals has become a popular art form. We discuss recursion in Section 9.9.