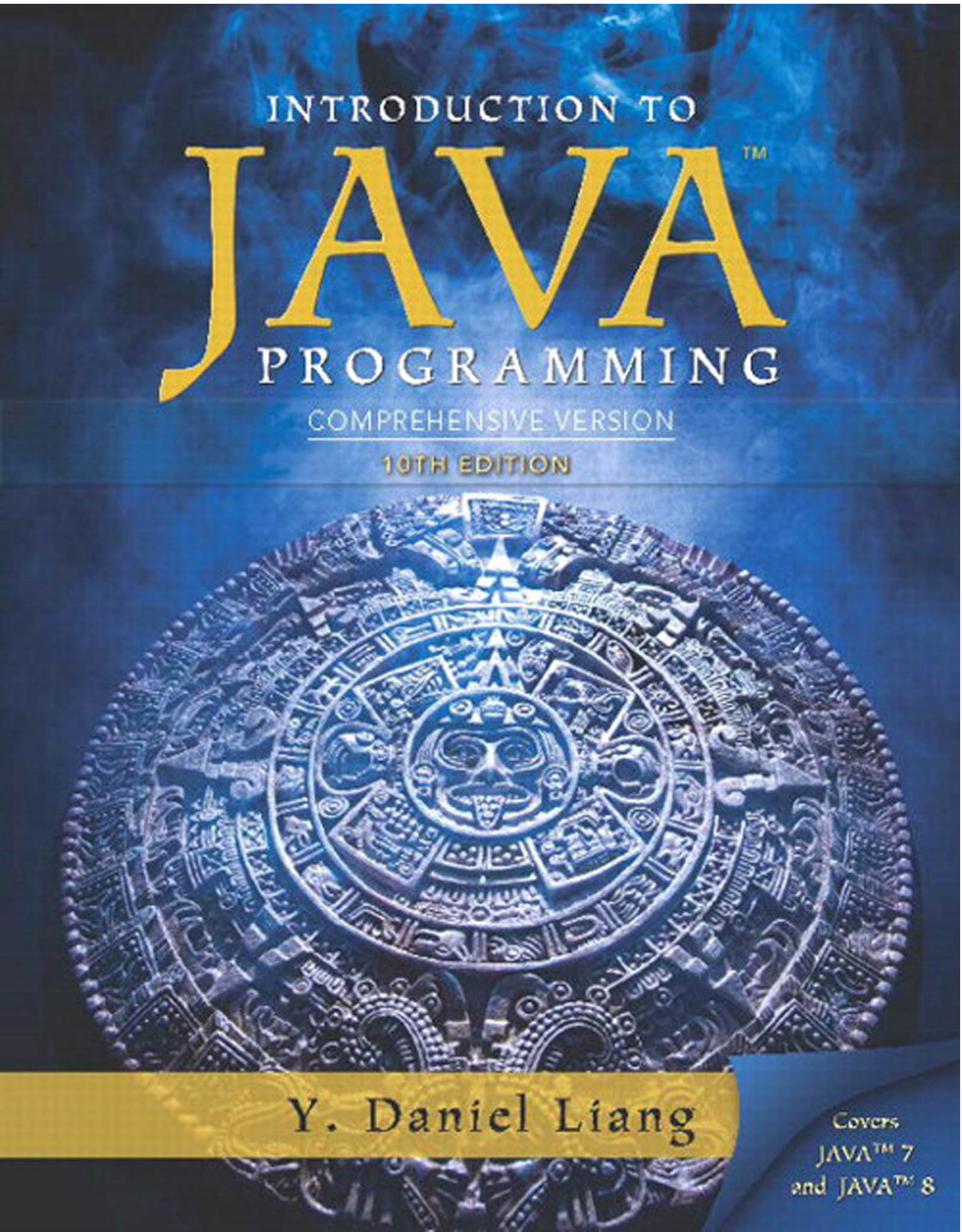
INTRODUCTION TO
JAVA™
PROGRAMMING
COMPREHENSIVE VERSION
10TH EDITION
Y. Daniel Liang
Covers
JAVA™ 7
and JAVA™ 8

INTRODUCTION TO JAVA®

PROGRAMMING

COMPREHENSIVE VERSION

Tenth Edition

Y. Daniel Liang

Armstrong Atlantic State University

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PREFACE

Dear Reader,

Many of you have provided feedback on earlier editions of this book, and your comments and suggestions have greatly improved the book. This edition has been substantially enhanced in presentation, organization, examples, exercises, and supplements. The new edition:

what is new?

- Replaces Swing with JavaFX. JavaFX is a new framework for developing Java GUI programs. JavaFX greatly simplifies GUI programming and is easier to learn than Swing.
- Introduces exception handling, abstract classes, and interfaces before GUI programming to enable the GUI chapters to be skipped completely if the instructor chooses not to cover GUI.
- Covers introductions to objects and strings earlier in Chapter 4 to enable students to use objects and strings to develop interesting programs early.
- Includes many new interesting examples and exercises to stimulate student interests. More than 100 additional programming exercises are provided to instructors only on the Companion Website.

Please visit www.pearsonhighered.com/liang for a complete list of new features as well as correlations to the previous edition.

fundamentals-first

The book is fundamentals first by introducing basic programming concepts and techniques before designing custom classes. The fundamental concepts and techniques of selection statements, loops, methods, and arrays are the foundation for programming. Building this strong foundation prepares students to learn object-oriented programming and advanced Java programming.

problem-driven

This book teaches programming in a problem-driven way that focuses on problem solving rather than syntax. We make introductory programming interesting by using thought-provoking problems in a broad context. The central thread of early chapters is on problem solving. Appropriate syntax and library are introduced to enable readers to write programs for solving the problems. To support the teaching of programming in a problem-driven way, the book provides a wide variety of problems at various levels of difficulty to motivate students. To appeal to students in all majors, the problems cover many application areas, including math, science, business, financial, gaming, animation, and multimedia.

data structures

The book seamlessly integrates programming, data structures, and algorithms into one text. It employs a practical approach to teach data structures. We first introduce how to use various data structures to develop efficient algorithms, and then show how to implement these data structures. Through implementation, students gain a deep understanding on the efficiency of data structures and on how and when to use certain data structures. Finally we design and implement custom data structures for trees and graphs.

comprehensive version

The book is widely used in the introductory programming, data structures, and algorithms courses in the universities around the world. This *comprehensive version* covers fundamentals of programming, object-oriented programming, GUI programming, data structures, algorithms, concurrency, networking, database, and Web programming. It is designed to prepare students to become proficient Java programmers. A *brief version* (*Introduction to Java Programming*, Brief Version, Tenth Edition) is available for a first course on programming, commonly known as CS1. The brief version contains the first 18 chapters of the comprehensive version. The first 13 chapters are appropriate for preparing the AP Computer Science exam.

brief version

AP Computer Science

examples and exercises

The best way to teach programming is *by example*, and the only way to learn programming is *by doing*. Basic concepts are explained by example and a large number of exercises

with various levels of difficulty are provided for students to practice. For our programming courses, we assign programming exercises after each lecture.

Our goal is to produce a text that teaches problem solving and programming in a broad context using a wide variety of interesting examples. If you have any comments on and suggestions for improving the book, please email me.

Sincerely,

Y. Daniel Liang
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ACM/IEEE Curricular 2013 and ABET Course Assessment

The new ACM/IEEE Computer Science Curricular 2013 defines the Body of Knowledge organized into 18 Knowledge Areas. To help instructors design the courses based on this book, we provide sample syllabi to identify the Knowledge Areas and Knowledge Units. The sample syllabi are for a three semester course sequence and serve as an example for institutional customization. The sample syllabi are available to instructors at www.pearsonhighered.com/liang.

Many of our users are from the ABET-accredited programs. A key component of the ABET accreditation is to identify the weakness through continuous course assessment against the course outcomes. We provide sample course outcomes for the courses and sample exams for measuring course outcomes on the instructor Website accessible from www.pearsonhighered.com/liang.

What's New in This Edition?

This edition is completely revised in every detail to enhance clarity, presentation, content, examples, and exercises. The major improvements are as follows:

- Updated to Java 8.
- Since Swing is replaced by JavaFX, all GUI examples and exercises are revised using JavaFX.
- Lambda expressions are used to simplify coding in JavaFX and threads.
- More than 100 additional programming exercises with solutions are provided to the instructor on the Companion Website. These exercises are not printed in the text.
- Math methods are introduced earlier in Chapter 4 to enable students to write code using math functions.
- Strings are introduced earlier in Chapter 4 to enable students to use objects and strings to develop interesting programs early.
- The GUI chapters are moved to after abstract classes and interfaces so that these chapters can be easily skipped if the instructor chooses not to cover GUI.
- Chapters 4, 14, 15, and 16 are brand new chapters.
- Chapters 28 and 29 have been substantially revised with simpler implementations for minimum spanning trees and shortest paths.

Pedagogical Features

The book uses the following elements to help students get the most from the material:

- The **Objectives** at the beginning of each chapter list what students should learn from the chapter. This will help them determine whether they have met the objectives after completing the chapter.
- The **Introduction** opens the discussion with representative problems to give the reader an overview of what to expect from the chapter.
- **Key Points** highlight the important concepts covered in each section.
- **Check Points** provide review questions to help students track their progress as they read through the chapter and evaluate their learning.
- **Problems and Case Studies**, carefully chosen and presented in an easy-to-follow style, teach problem solving and programming concepts. The book uses many small, simple, and stimulating examples to demonstrate important ideas.
- The **Chapter Summary** reviews the important subjects that students should understand and remember. It helps them reinforce the key concepts they have learned in the chapter.
- **Quizzes** are accessible online, grouped by sections, for students to do self-test on programming concepts and techniques.
- **Programming Exercises** are grouped by sections to provide students with opportunities to apply the new skills they have learned on their own. The level of difficulty is rated as easy (no asterisk), moderate (*), hard (**), or challenging (***). The trick of learning programming is practice, practice, and practice. To that end, the book provides a great many exercises. Additionally, more than 100 programming exercises with solutions are provided to the instructors on the Companion Website. These exercises are not printed in the text.
- **Notes**, **Tips**, **Cautions**, and **Design Guides** are inserted throughout the text to offer valuable advice and insight on important aspects of program development.

Note
Provides additional information on the subject and reinforces important concepts.

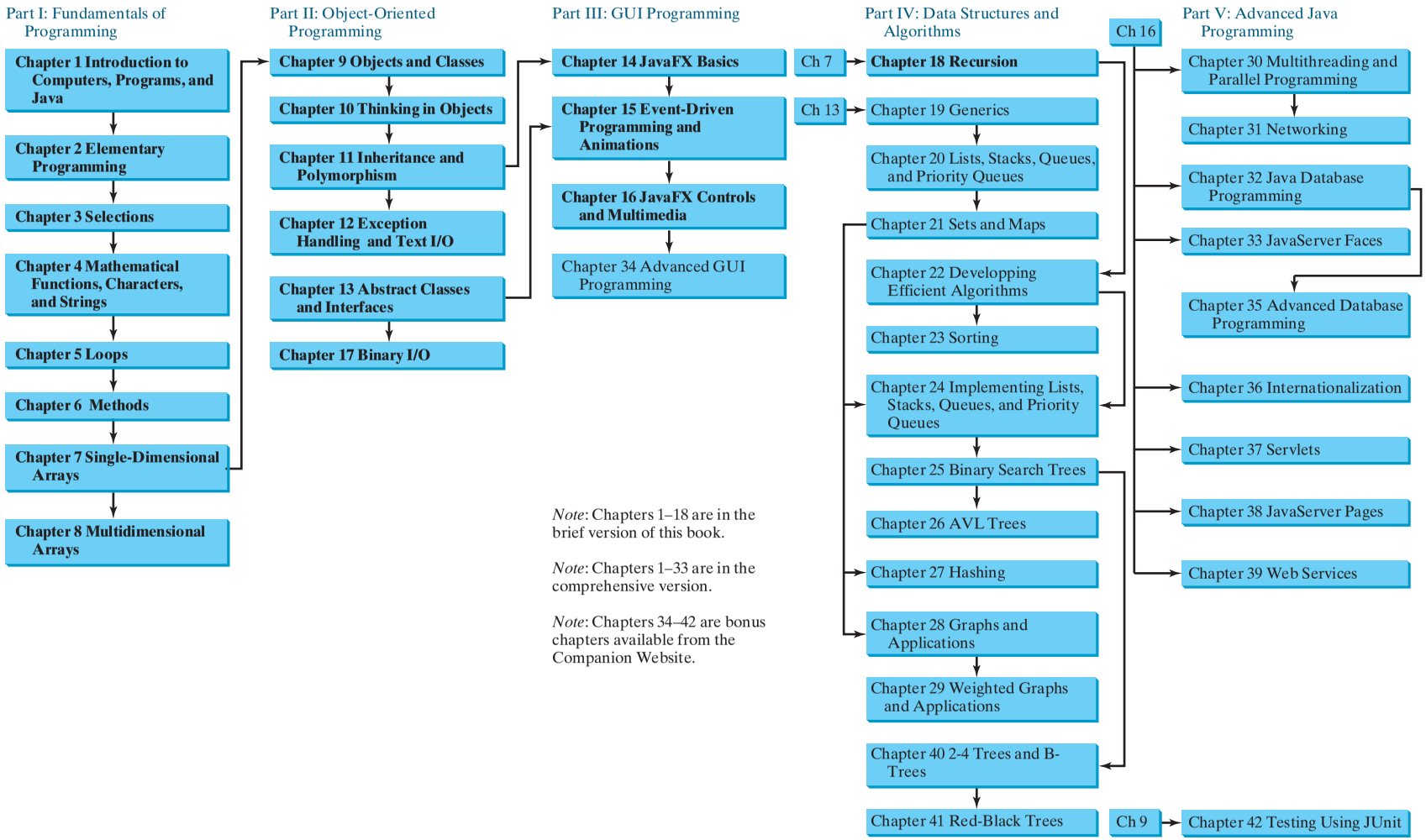
Tip
Teaches good programming style and practice.

Caution
Helps students steer away from the pitfalls of programming errors.

Design Guide
Provides guidelines for designing programs.

Flexible Chapter Orderings

The book is designed to provide flexible chapter orderings to enable GUI, exception handling, recursion, generics, and the Java Collections Framework to be covered earlier or later. The diagram on the next page shows the chapter dependencies.


Part I: Fundamentals of Programming
Chapter 1 Introduction to Computers, Programs, and Java
Chapter 2 Elementary Programming
Chapter 3 Selections
Chapter 4 Mathematical Functions, Characters, and Strings
Chapter 5 Loops
Chapter 6 Methods
Chapter 7 Single-Dimensional Arrays
Chapter 8 Multidimensional Arrays
Part II: Object-Oriented Programming
Chapter 9 Objects and Classes
Chapter 10 Thinking in Objects
Chapter 11 Inheritance and Polymorphism
Chapter 12 Exception Handling and Text I/O
Chapter 13 Abstract Classes and Interfaces
Chapter 17 Binary I/O
Part III: GUI Programming
Chapter 14 JavaFX Basics
Chapter 15 Event-Driven Programming and Animations
Chapter 16 JavaFX Controls and Multimedia
Chapter 34 Advanced GUI Programming
Ch 7
Ch 13
Part IV: Data Structures and Algorithms
Chapter 18 Recursion
Chapter 19 Generics
Chapter 20 Lists, Stacks, Queues, and Priority Queues
Chapter 21 Sets and Maps
Chapter 22 Developping Efficient Algorithms
Chapter 23 Sorting
Chapter 24 Implementing Lists, Stacks, Queues, and Priority Queues
Chapter 25 Binary Search Trees
Chapter 26 AVL Trees
Chapter 27 Hashing
Chapter 28 Graphs and Applications
Chapter 29 Weighted Graphs and Applications
Chapter 40 2-4 Trees and B-Trees
Chapter 41 Red-Black Trees
Ch 16
Ch 9
Part V: Advanced Java Programming
Chapter 30 Multithreading and Parallel Programming
Chapter 31 Networking
Chapter 32 Java Database Programming
Chapter 33 JavaServer Faces
Chapter 35 Advanced Database Programming
Chapter 36 Internationalization
Chapter 37 Servlets
Chapter 38 JavaServer Pages
Chapter 39 Web Services
Chapter 42 Testing Using JUnit
Note: Chapters 1–18 are in the brief version of this book.
Note: Chapters 1–33 are in the comprehensive version.
Note: Chapters 34–42 are bonus chapters available from the Companion Website.

Organization of the Book

The chapters can be grouped into five parts that, taken together, form a comprehensive introduction to Java programming, data structures and algorithms, and database and Web programming. Because knowledge is cumulative, the early chapters provide the conceptual basis for understanding programming and guide students through simple examples and exercises; subsequent chapters progressively present Java programming in detail, culminating with the development of comprehensive Java applications. The appendixes contain a mixed bag of topics, including an introduction to number systems, bitwise operations, regular expressions, and enumerated types.

Part I: Fundamentals of Programming (Chapters 1–8)

The first part of the book is a stepping stone, preparing you to embark on the journey of learning Java. You will begin to learn about Java (Chapter 1) and fundamental programming techniques with primitive data types, variables, constants, assignments, expressions, and operators (Chapter 2), selection statements (Chapter 3), mathematical functions, characters, and strings (Chapter 4), loops (Chapter 5), methods (Chapter 6), and arrays (Chapters 7–8). After Chapter 7, you can jump to Chapter 18 to learn how to write recursive methods for solving inherently recursive problems.

Part II: Object-Oriented Programming (Chapters 9–13, and 17)

This part introduces object-oriented programming. Java is an object-oriented programming language that uses abstraction, encapsulation, inheritance, and polymorphism to provide great flexibility, modularity, and reusability in developing software. You will learn programming with objects and classes (Chapters 9–10), class inheritance (Chapter 11), polymorphism (Chapter 11), exception handling (Chapter 12), abstract classes (Chapter 13), and interfaces (Chapter 13). Text I/O is introduced in Chapter 12 and binary I/O is discussed in Chapter 17.

Part III: GUI Programming (Chapters 14–16 and Bonus Chapter 34)

JavaFX is a new framework for developing Java GUI programs. It is not only useful for developing GUI programs, but also an excellent pedagogical tool for learning object-oriented programming. This part introduces Java GUI programming using JavaFX in Chapters 14–16. Major topics include GUI basics (Chapter 14), container panes (Chapter 14), drawing shapes (Chapter 14), event-driven programming (Chapter 15), animations (Chapter 15), and GUI controls (Chapter 16), and playing audio and video (Chapter 16). You will learn the architecture of JavaFX GUI programming and use the controls, shapes, panes, image, and video to develop useful applications. Chapter 34 covers advanced features in JavaFX.

Part IV: Data Structures and Algorithms (Chapters 18–29 and Bonus Chapters 40–41)

This part covers the main subjects in a typical data structures and algorithms course. Chapter 18 introduces recursion to write methods for solving inherently recursive problems. Chapter 19 presents how generics can improve software reliability. Chapters 20 and 21 introduce the Java Collection Framework, which defines a set of useful API for data structures. Chapter 22 discusses measuring algorithm efficiency in order to choose an appropriate algorithm for applications. Chapter 23 describes classic sorting algorithms. You will learn how to implement several classic data structures lists, queues, and priority queues in Chapter 24. Chapters 25 and 26 introduce binary search trees and AVL trees. Chapter 27 presents hashing and implementing maps and sets using hashing. Chapters 28 and 29 introduce graph applications. The 2-4 trees, B-trees, and red-black trees are covered in Bonus Chapters 40–41.

Part V: Advanced Java Programming (Chapters 30–33 and Bonus Chapters 35–39, 42)

This part of the book is devoted to advanced Java programming. Chapter 30 treats the use of multithreading to make programs more responsive and interactive and introduces parallel programming. Chapter 31 discusses how to write programs that talk with each other from different hosts over the Internet. Chapter 32 introduces the use of Java to develop database

projects. Chapter 33 introduces modern Web application development using JavaServer Faces. Chapter 35 delves into advanced Java database programming. Chapter 36 covers the use of internationalization support to develop projects for international audiences. Chapters 37 and 38 introduce how to use Java servlets and JavaServer Pages to generate dynamic content from Web servers. Chapter 39 discusses Web services. Chapter 42 introduces testing Java programs using JUnit.

Appendixes

This part of the book covers a mixed bag of topics. Appendix A lists Java keywords. Appendix B gives tables of ASCII characters and their associated codes in decimal and in hex. Appendix C shows the operator precedence. Appendix D summarizes Java modifiers and their usage. Appendix E discusses special floating-point values. Appendix F introduces number systems and conversions among binary, decimal, and hex numbers. Finally, Appendix G introduces bitwise operations. Appendix H introduces regular expressions. Appendix I covers enumerated types.

Java Development Tools

You can use a text editor, such as the Windows Notepad or WordPad, to create Java programs and to compile and run the programs from the command window. You can also use a Java development tool, such as NetBeans or Eclipse. These tools support an integrated development environment (IDE) for developing Java programs quickly. Editing, compiling, building, executing, and debugging programs are integrated in one graphical user interface. Using these tools effectively can greatly increase your programming productivity. NetBeans and Eclipse are easy to use if you follow the tutorials. Tutorials on NetBeans and Eclipse can be found under Tutorials on the Student Companion Website at www.pearsonhighered.com/liang.

IDE tutorials

Student Resource Website

The Student Resource Website www.pearsonhighered.com/liang provides access to some of the following resources. Other resources are available using the student access code printed on the inside front cover of this book. (For students with a used copy of this book, you can purchase access to the premium student resources through www.pearsonhighered.com/liang.)

- Answers to review questions
- Solutions to even-numbered programming exercises
- Source code for the examples in the book
- Interactive quiz (organized by sections for each chapter)
- Supplements
- Debugging tips
- Algorithm animations
- Errata

Instructor Resource Website

The Instructor Resource Website, accessible from www.pearsonhighered.com/liang, provides access to the following resources:

- Microsoft PowerPoint slides with interactive buttons to view full-color, syntax-highlighted source code and to run programs without leaving the slides.
- Solutions to all programming exercises. Students will have access to the solutions of even-numbered programming exercises.

- More than 100 additional programming exercises organized by chapters. These exercises are available only to the instructors. Solutions to these exercises are provided.
- Web-based quiz generator. (Instructors can choose chapters to generate quizzes from a large database of more than two thousand questions.)
- Sample exams. Most exams have four parts:
  - Multiple-choice questions or short-answer questions
  - Correct programming errors
  - Trace programs
  - Write programs
- ACM/IEEE Curricula 2013. The new ACM/IEEE Computer Science Curricula 2013 defines the Body of Knowledge organized into 18 Knowledge Areas. To help instructors design the courses based on this book, we provide sample syllabi to identify the Knowledge Areas and Knowledge Units. The sample syllabi are for a three semester course sequence and serve as an example for institutional customization. Instructors can access the syllabi at www.pearsonhighered.com/liang.
- Sample exams with ABET course assessment.
- Projects. In general, each project gives a description and asks students to analyze, design, and implement the project.

Some readers have requested the materials from the Instructor Resource Website. Please understand that these are for instructors only. Such requests will not be answered.

Online Practice and Assessment with MyProgrammingLab

MyProgrammingLab

MyProgrammingLab helps students fully grasp the logic, semantics, and syntax of programming. Through practice exercises and immediate, personalized feedback, MyProgrammingLab improves the programming competence of beginning students who often struggle with the basic concepts and paradigms of popular high-level programming languages.

A self-study and homework tool, a MyProgrammingLab course consists of hundreds of small practice problems organized around the structure of this textbook. For students, the system automatically detects errors in the logic and syntax of their code submissions and offers targeted hints that enable students to figure out what went wrong—and why. For instructors, a comprehensive gradebook tracks correct and incorrect answers and stores the code inputted by students for review.

MyProgrammingLab is offered to users of this book in partnership with Turing's Craft, the makers of the CodeLab interactive programming exercise system. For a full demonstration, to see feedback from instructors and students, or to get started using MyProgrammingLab in your course, visit www.myprogramminglab.com.

VideoNotes

VideoNote

We are excited about the new VideoNotes feature that is found in this new edition. These videos provide additional help by presenting examples of key topics and showing how to solve problems completely, from design through coding. VideoNotes are available from www.pearsonhighered.com/liang.


Animation

Algorithm Animations

We have provided numerous animations for algorithms. These are valuable pedagogical tools to demonstrate how algorithms work. Algorithm animations can be accessed from the Companion Website.

Acknowledgments

I would like to thank Armstrong Atlantic State University for enabling me to teach what I write and for supporting me in writing what I teach. Teaching is the source of inspiration for continuing to improve the book. I am grateful to the instructors and students who have offered comments, suggestions, bug reports, and praise.

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It is a great pleasure, honor, and privilege to work with Pearson. I would like to thank Tracy Johnson and her colleagues Marcia Horton, Yez Alayan, Carole Snyder, Scott Disanno, Bob Engelhardt, Haseen Khan, and their colleagues for organizing, producing, and promoting this project.

As always, I am indebted to my wife, Samantha, for her love, support, and encouragement.

BRIEF CONTENTS