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Foundations of Program Design

NINTH EDITION

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java™ SOFTWARE SOLUTIONS

Ninth Edition
Global Edition

FOUNDATIONS OF PROGRAM DESIGN

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This book is dedicated to our families.
Sharon, Justin, Kayla, Nathan, and Samantha Lewis
and
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Preface

Welcome to the Ninth Edition of *Java Software Solutions: Foundations of Program Design*. We are pleased that this book has served the needs of so many students and faculty over the years. This edition has been tailored further to improve the coverage of topics key to introductory computing.

New to This Edition

The biggest change to this edition of Java Software Solutions is a sweeping overhaul of the Graphics Track sections of the book to fully embrace the JavaFX API. Swing is no longer actively supported by Oracle. JavaFX is now the preferred approach for developing graphics and graphical user interfaces (GUIs) in Java, and we make use of it throughout this text.

The changes include the following:

- Coverage of JavaFX graphical shapes.
- Coverage of JavaFX controls, including buttons, text fields, check boxes, radio buttons, choice boxes, color pickers, date pickers, dialog boxes, sliders, and spinners.
- Use of Java 8 method references and lambda expressions to define event handlers.
- An exploration of the JavaFX class hierarchy.
- An explanation of JavaFX properties and property binding.
- Revised end-of-chapter exercises and programming projects.
- A new appendix (Appendix G) that presents an overview of JavaFX layout panes.
- A new appendix (Appendix H) that introduces the JavaFX Scene Builder software.

There are two exciting aspects to embracing JavaFX. First, it provides a much cleaner approach to GUI development than Swing did. Equivalent programs using JavaFX are shorter and more easily understood.

Second, the JavaFX approach embraces core object-oriented principles better than Swing did. For example, all graphic shapes are represented by classes with fundamental data elements, such as a `Circle` class with a radius. Early on (Chapter 3), the shape classes provide a wealth of basic, well-designed classes, just when students need to understand what classes and objects are all about.

The use of Java 8 method references provides an easy-to-understand approach to defining event handlers. The use of the (underlying) lambda expressions is also explored as an alternative approach.

JavaFX layout panes are used and explained as needed in examples, with a full overview of layout panes provided in a new appendix. We think this works better than the way we treated Swing layout managers, as a separate topic in a chapter.

All GUI development in the book is done "by hand" in straight Java code, which is important for beginning students. The JavaFX drag-and-drop Scene Builder is discussed in a new appendix, but it is not used in the book itself.

In addition to the changes related to JavaFX, we also updated examples and discussions in various places throughout the book as needed to bring them up-to-date and improve their pedagogy.

We're excited about the opportunities this new edition of Java Software Solutions provides for both students and instructors. As always, questions and comments are welcome.

Cornerstones of the Text

This text is based on the following basic ideas that we believe make for a sound introductory text:

- *True object-orientation.* A text that really teaches a solid object-oriented approach must use what we call object-speak. That is, all processing should be discussed in object-oriented terms. That does not mean, however, that the first program a student sees must discuss the writing of multiple classes and methods. A student should learn to use objects before learning to write them. This text uses a natural progression that culminates in the ability to design real object-oriented solutions.
- *Sound programming practices.* Students should not be taught how to program; they should be taught how to write good software. There's a difference. Writing software is not a set of cookbook actions, and a good program is more than a collection of statements. This text integrates practices that serve as the foundation of good programming skills. These practices are used in all examples and are reinforced in the discussions. Students learn how to solve problems as well as how to implement solutions. We introduce and integrate basic software engineering techniques throughout the text. The **Software Failure** vignettes reiterate these lessons by demonstrating the perils of not following these sound practices.
- *Examples.* Students learn by example. This text is filled with fully implemented examples that demonstrate specific concepts. We have intertwined small, readily understandable examples with larger, more realistic ones. There is a balance between graphics and nongraphics programs. The **VideoNotes** provide additional examples in a live presentation format.

- *Graphics and GUIs.* Graphics can be a great motivator for students, and their use can serve as excellent examples of object-orientation. As such, we use them throughout the text in a well-defined set of sections that we call the Graphics Track. The book fully embraces the JavaFX API, the preferred and fully-supported approach to Java graphics and GUIs. Students learn to build GUIs in the appropriate way by using a natural progression of topics. The Graphics Track can be avoided entirely for those who do not choose to use graphics.

Chapter Breakdown

Chapter 1 (Introduction) introduces computer systems in general, including basic architecture and hardware, networking, programming, and language translation. Java is introduced in this chapter, and the basics of general program development, as well as object-oriented programming, are discussed. This chapter contains broad introductory material that can be covered while students become familiar with their development environment.

Chapter 2 (Data and Expressions) explores some of the basic types of data used in a Java program and the use of expressions to perform calculations. It discusses the conversion of data from one type to another and how to read input interactively from the user with the help of the standard `Scanner` class.

Chapter 3 (Using Classes and Objects) explores the use of predefined classes and the objects that can be created from them. Classes and objects are used to manipulate character strings, produce random numbers, perform complex calculations, and format output. Enumerated types are also discussed.

Chapter 4 (Writing Classes) explores the basic issues related to writing classes and methods. Topics include instance data, visibility, scope, method parameters, and return types. Encapsulation and constructors are covered as well. Some of the more involved topics are deferred to or revisited in Chapter 6.

Chapter 5 (Conditionals and Loops) covers the use of boolean expressions to make decisions. Then the `if` statement and `while` loop are explored in detail. Once loops are established, the concept of an iterator is introduced and the `Scanner` class is revisited for additional input parsing and the reading of text files. Finally, the `ArrayList` class introduced, which provides the option for managing a large number of objects.

Chapter 6 (More Conditionals and Loops) examines the rest of Java's conditional (`switch`) and loop (`do`, `for`) statements. All related statements for conditionals and loops are discussed, including the enhanced version of the `for` loop. The for-each loop is also used to process iterators and `ArrayList` objects.

Chapter 7 (Object-Oriented Design) reinforces and extends the coverage of issues related to the design of classes. Techniques for identifying the classes and objects needed for a problem and the relationships among them are discussed. This chapter also covers static class members, interfaces, and the design of enumerated type classes. Method design issues and method overloading are also discussed.

Chapter 8 (Arrays) contains extensive coverage of arrays and array processing. The nature of an array as a low-level programming structure is contrasted to the higher-level object management approach. Additional topics include command-line arguments, variable length parameter lists, and multidimensional arrays.

Chapter 9 (Inheritance) covers class derivations and associated concepts such as class hierarchies, overriding, and visibility. Strong emphasis is put on the proper use of inheritance and its role in software design.

Chapter 10 (Polymorphism) explores the concept of binding and how it relates to polymorphism. Then we examine how polymorphic references can be accomplished using either inheritance or interfaces. Sorting is used as an example of polymorphism. Design issues related to polymorphism are examined as well.

Chapter 11 (Exceptions) explores the class hierarchy from the Java standard library used to define exceptions, as well as the ability to define our own exception objects. We also discuss the use of exceptions when dealing with input and output and examine an example that writes a text file.

Chapter 12 (Recursion) covers the concept, implementation, and proper use of recursion. Several examples from various domains are used to demonstrate how recursive techniques make certain types of processing elegant.

Chapter 13 (Collections) introduces the idea of a collection and its underlying data structure. Abstraction is revisited in this context and the classic data structures are explored. Generic types are introduced as well. This chapter serves as an introduction to a CS2 course.

Supplements

Student Online Resources

These student resources can be accessed at the book's Companion Website, "www.pearsonglobaleditions.com/Lewis"

- Source Code for all the programs in the text
- Links to Java development environments
- VideoNotes: short step-by-step videos demonstrating how to solve problems from design through coding. VideoNotes allow for self-paced instruction with easy navigation including the ability to select, play, rewind, fast-forward, and stop within each VideoNote exercise. Margin icons in your textbook let you know when a VideoNote video is available for a particular concept or homework problem.

Online Practice and Assessment with Pearson MyLab Programming

Pearson MyLab Programming helps students fully grasp the logic, semantics, and syntax of programming. Through practice exercises and immediate, personalized feedback, Pearson MyLab Programming 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, Pearson MyLab Programming consists of hundreds of small practice exercises 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 submitted by students for review.

Pearson MyLab Programming 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 Pearson MyLab Programming in your course, visit www.myprogramminglab.com.

Instructor Resources

The following supplements are available to qualified instructors only. Visit the Pearson Education Instructor Resource Center (www.pearsonglobaleditions.com/Lewis) for information on how to access them:

- Presentation Slides—in PowerPoint.
- Solutions to end-of-chapter Exercises.
- Solutions to end-of-chapter Programming Projects.

Features

Key Concepts. Throughout the text, the Key Concept boxes highlight fundamental ideas and important guidelines. These concepts are summarized at the end of each chapter.

Listings. All programming examples are presented in clearly labeled listings, followed by the program output, a sample run, or screen shot display as appropriate. The code is colored to visually distinguish comments and reserved words.

Syntax Diagrams. At appropriate points in the text, syntactic elements of the Java language are discussed in special highlighted sections with diagrams that clearly identify the valid forms for a statement or construct. Syntax diagrams for the entire Java language are presented in Appendix L.

Graphics Track. All processing that involves graphics and graphical user interfaces is discussed in one or two sections at the end of each chapter that we collectively refer to as the Graphics Track. This material can be skipped without loss of continuity, or focused on specifically as desired. The material in any Graphics Track section relates to the main topics of the chapter in which it is found. Graphics Track sections are indicated by a brown border on the edge of the page.

Summary of Key Concepts. The Key Concepts presented throughout a chapter are summarized at the end of the chapter.

Self-Review Questions and Answers. These short-answer questions review the fundamental ideas and terms established in the preceding section. They are designed to allow students to assess their own basic grasp of the material. The answers to these questions can be found at the end of the book in Appendix N.

Exercises. These intermediate problems require computations, the analysis or writing of code fragments, and a thorough grasp of the chapter content. While the exercises may deal with code, they generally do not require any online activity.

Programming Projects. These problems require the design and implementation of Java programs. They vary widely in level of difficulty.

Pearson MyLab Programming. Through practice exercises and immediate, personalized feedback, Pearson MyLab Programming improves the programming competence of beginning students who often struggle with the basic concepts and paradigms of popular high-level programming languages.

VideoNotes. Presented by the author, VideoNotes explain topics visually through informal videos in an easy-to-follow format, giving students the extra help they need to grasp important concepts. Look for this VideoNote icon to see which in-chapter topics and end-of-chapter Programming Projects are available as VideoNotes.

Software Failures. These between-chapter vignettes discuss real-world flaws in software design, encouraging students to adopt sound design practices from the beginning.

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I am most grateful to the faculty and students from around the world who have provided their feedback on previous editions of this book. I am pleased to see the depth of the faculty's concern for their students and the students' thirst for knowledge. Your comments and questions are always welcome.

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The ACM Special Interest Group on Computer Science Education (SIGCSE) is a tremendous resource. Their conferences provide an opportunity for educators from all levels and all types of schools to share ideas and materials. If you are an educator in any area of computing and are not involved with SIGCSE, you're missing out.

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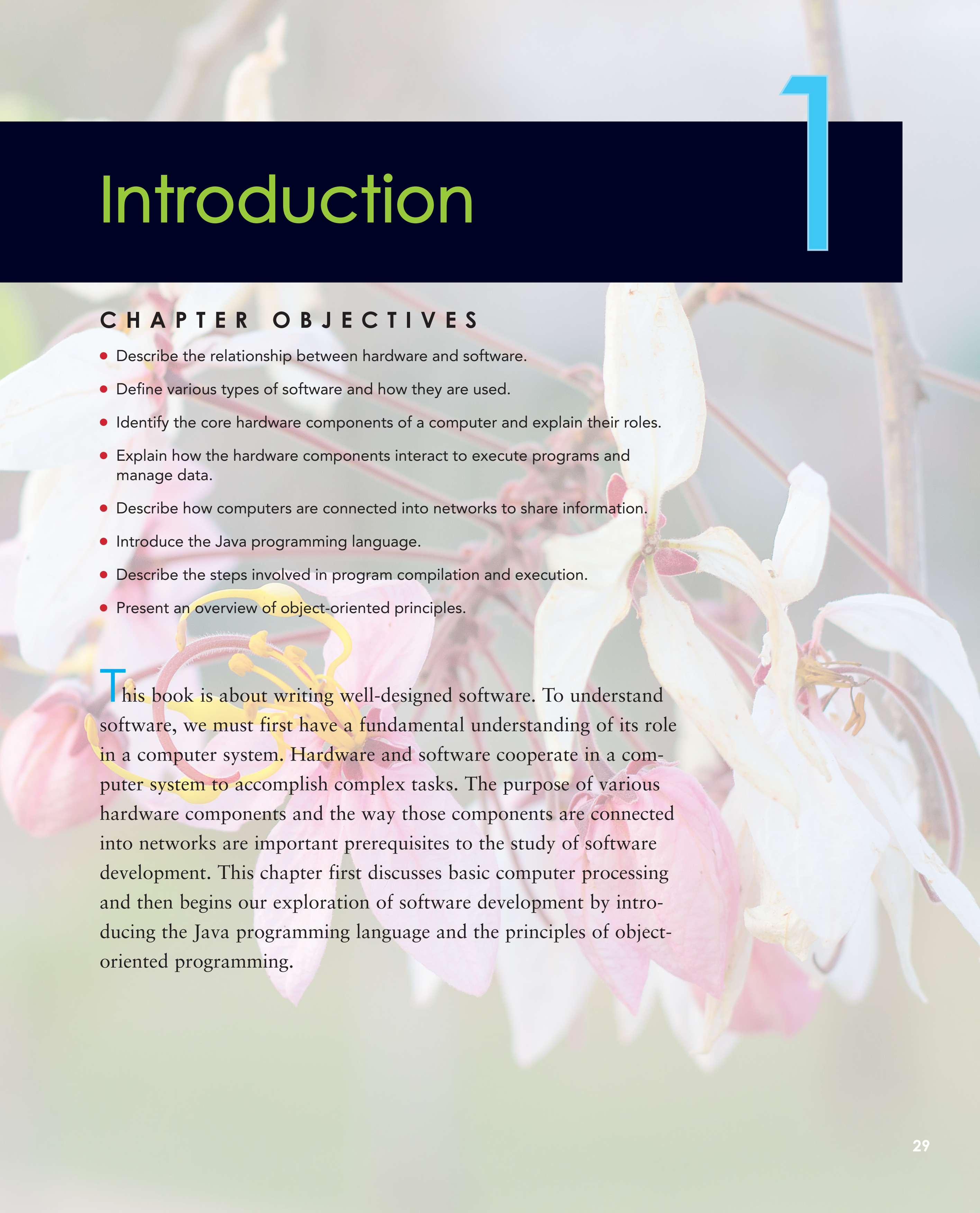

1 Introduction

CHAPTER OBJECTIVES

- Describe the relationship between hardware and software.
- Define various types of software and how they are used.
- Identify the core hardware components of a computer and explain their roles.
- Explain how the hardware components interact to execute programs and manage data.
- Describe how computers are connected into networks to share information.
- Introduce the Java programming language.
- Describe the steps involved in program compilation and execution.
- Present an overview of object-oriented principles.

This book is about writing well-designed software. To understand software, we must first have a fundamental understanding of its role in a computer system. Hardware and software cooperate in a computer system to accomplish complex tasks. The purpose of various hardware components and the way those components are connected into networks are important prerequisites to the study of software development. This chapter first discusses basic computer processing and then begins our exploration of software development by introducing the Java programming language and the principles of object-oriented programming.

1.1 Computer Processing

All computer systems, whether it's a desktop, laptop, tablet, smartphone, gaming console, or a special-purpose device such as a car's navigation system, share certain characteristics. The details vary, but they all process data in similar ways. While the majority of this book deals with the development of software, we'll begin with an overview of computer processing to set the context. It's important to establish some fundamental terminology and see how key pieces of a computer system interact.

A computer system is made up of hardware and software. The *hardware* components of a computer system are the physical, tangible pieces that support the computing effort. They include chips, boxes, wires, keyboards, speakers, disks, memory cards, universal serial bus (USB) flash drives (also called jump drives), cables, plugs, printers, mice, monitors, routers, and so on. If you can physically touch it and it can be considered part of a computer system, then it is computer hardware.

KEY CONCEPT

A computer system consists of hardware and software that work in concert to help us solve problems.

The hardware components of a computer are essentially useless without instructions to tell them what to do. A *program* is a series of instructions that the hardware executes one after another. *Software* consists of programs and the data that programs use. Software is the intangible counterpart to the physical hardware components. Together they form a tool that we can use to help solve problems.

The key hardware components in a computer system are

- central processing unit (CPU)
- input/output (I/O) devices
- main memory
- secondary memory devices

Each of these hardware components is described in detail in the next section. For now, let's simply examine their basic roles. The *central processing unit (CPU)* is a device that executes the individual commands of a program. *Input/output (I/O) devices*, such as the keyboard, mouse, trackpad, and monitor, allow a human being to interact with the computer.

Programs and data are held in storage devices called memory, which fall into two categories: main memory and secondary memory. *Main memory* is the storage device that holds the software while it is being processed by the CPU. *Secondary memory* devices store software in a relatively permanent manner. The most important secondary memory device of a typical computer system is the hard disk that resides inside the main computer box. A USB flash drive is also an important secondary memory device. A typical USB flash drive cannot store nearly as much information as a hard disk. USB flash drives have the advantage of portability; they can be removed temporarily or moved from computer to computer as needed.