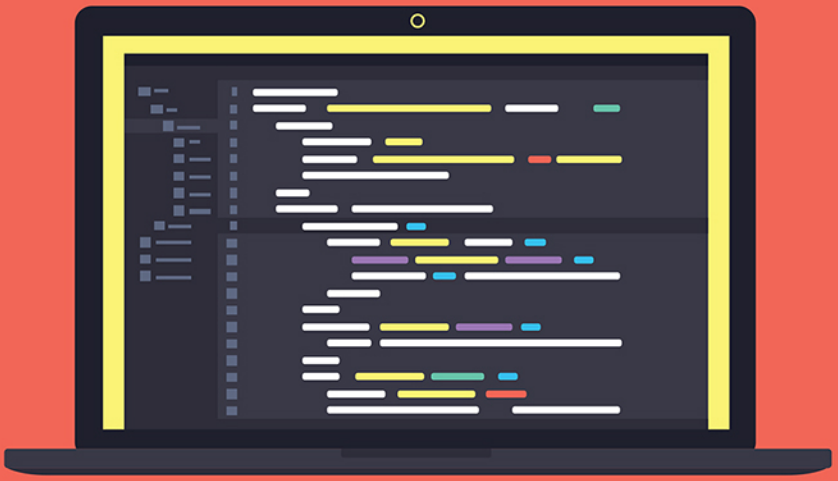
GLOBAL EDITION

Java™ How to Program

Late Objects

ELEVENTH EDITION

Paul Deitel • Harvey Deitel



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LATE OBJECTS

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Introducing
JShell

Use with
Java™ SE 8
or Java™ SE 9

Java™

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Introducing JShell

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In memory of Dr. Henry Heimlich:
Barbara Deitel used your Heimlich maneuver to save Abbey Deitel's life. Our family is forever grateful to you.

Harvey, Barbara, Paul and Abbey Deitel

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Contents

The online chapters and appendices listed at the end of this Table of Contents are located on the book's Companion Website (`http://www.pearsonglobaleditions.com`)—see the inside front cover of your book for details.

Online Chapters and Appendices

The online chapters and appendices are located on the book's Companion Website. See the book's inside front cover for details.

Foreword

Throughout my career I've met and interviewed many expert Java developers who've learned from Paul and Harvey, through one or more of their college textbooks, professional books, videos and corporate training. Many Java User Groups have joined together around the Deitels' publications, which are used internationally in university courses and professional training programs. You are joining an elite group.

How do I become an expert Java developer?

This is one of the most common questions I receive at talks for university students and at events with Java professionals. Students want to become expert developers—and this is a great time to be one.

The market is wide open, full of opportunities and fascinating projects, especially for those who take the time to learn, practice and master software development. The world needs good, focused expert developers.

So, how do you do it? First, let's be clear: Software development is hard. But do not be discouraged. Mastering it opens the door to great opportunities. Accept that it's hard, embrace the complexity, enjoy the ride. There are no limits to how much you can expand your skills.

Software development is an amazing skill. It can take you anywhere. You can work in any field. From nonprofits making the world a better place, to bleeding-edge biological technologies. From the frenetic daily run of the financial world to the deep mysteries of religion. From sports to music to acting. Everything has software. The success or failure of initiatives everywhere will depend on developers' knowledge and skills.

The push for you to get the relevant skills is what makes *Java How to Program, 11/e* so compelling. Written for students and new developers, it's easy to follow. It's written by authors who are educators and developers, with input over the years from some of the world's leading academics and professional Java experts—Java Champions, open-source Java developers, even creators of Java itself. Their collective knowledge and experience will guide you. Even seasoned Java professionals will learn and grow their expertise with the wisdom in these pages.

How can this book help you become an expert?

Java was released in 1995—Paul and Harvey had the first edition of *Java How to Program* ready for Fall 1996 classes. Since that groundbreaking book, they've produced ten more editions, keeping current with the latest developments and idioms in the Java software-engineering community. You hold in your hands the map that will enable you to rapidly develop your Java skills.

The Deitels have broken down the humongous Java world into well-defined, specific goals. Put in your full attention, and consciously "beat" each chapter. You'll soon find

yourself moving nicely along your road to excellence. And with both Java 8 and Java 9 in the same book, you'll have up-to-date skills on the latest Java technologies.

Most importantly, this book is not just meant for you to read—it's meant for you to practice. Be it in the classroom or at home after work, experiment with the abundant sample code and practice with the book's extraordinarily rich and diverse collection of exercises. Take the time to do all that is in here and you'll be well on your way to achieving a level of expertise that will challenge professional developers out there. After working with Java for more than 20 years, I can tell you that this is not an exaggeration.

For example, one of my favorite chapters is Lambdas and Streams. The chapter covers the topic in detail and the exercises shine—many real-world challenges that developers will encounter every day and that will help you sharpen your skills. After solving these exercises, novices and experienced developers alike will deeply understand these important Java features. And if you have a question, don't be shy—the Deitels publish their email address in every book they write to encourage interaction.

That's also why I love the chapter about JShell—the new Java 9 tool that enables interactive Java. JShell allows you to explore, discover and experiment with new concepts, language features and APIs, make mistakes—accidentally and intentionally—and correct them, and rapidly prototype new code. It may prove to be the most important tool for leveraging your learning and productivity. Paul and Harvey give a full treatment of JShell that both students and experienced developers will be able to put to use immediately.

I'm impressed with the care that the Deitels always take care to accommodate readers at all levels. They ease you into difficult concepts and deal with the challenges that professionals will encounter in industry projects.

There's lots of information about Java 9, the important new Java release. You can jump right in and learn the latest Java features. If you're still working with Java 8, you can ease into Java 9 at your own pace—be sure to begin with the extraordinary JShell coverage.

Another example is the amazing coverage of JavaFX—Java's latest GUI, graphics and multimedia capabilities. JavaFX is the recommended toolkit for new projects. But if you'll be working on legacy projects that use the older Swing API, those chapters are still available to you.

Make sure to dig in on Paul and Harvey's treatment of concurrency. They explain the basic concepts so clearly that the intermediate and advanced examples and discussions will be easy to master. You will be ready to maximize your applications' performance in an increasingly multi-core world.

I encourage you to participate in the worldwide Java community. There are many helpful folks out there who stand ready to help you. Ask questions, get answers and answer your peers' questions. Along with this book, the Internet and the academic and professional communities will help speed you on your way to becoming an expert Java developer. I wish you success!

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Java Specialist at ToolsCloud
President of SouJava (the Brazilian Java Society)
SouJava representative at the Java Community Process

Preface

Welcome to the Java programming language and ***Java How to Program, Late Objects, Eleventh Edition***! This book presents leading-edge computing technologies for students, instructors and software developers. It's appropriate for introductory academic and professional course sequences based on the curriculum recommendations of the **ACM** and the **IEEE** professional societies,[1] and for *Advanced Placement (AP) Computer Science* exam preparation.[2] It also will help you prepare for most topics covered by the following Oracle Java Standard Edition 8 (Java SE 8) Certifications:[3]

- Oracle Certified Associate, Java SE 8 Programmer
- Oracle Certified Professional, Java SE 8 Programmer

If you haven't already done so, please read the bullet points and reviewer comments on the back cover and inside back cover—these concisely capture the essence of the book. In this Preface we provide more detail for students, instructors and professionals.

Our primary goal is to prepare college students to meet the Java programming challenges they'll encounter in upper-level courses and in industry. We focus on software engineering best practices. At the heart of the book is the Deitel signature **live-code approach**—we present most concepts in the context of hundreds of complete working programs that have been tested on **Windows®**, **macOS®** and **Linux®**. The complete code examples are accompanied by live sample executions.

New and Updated Features

In the following sections, we discuss the key features and updates we've made for *Java How to Program, 11/e*, including:

- Flexibility Using **Java SE 8 or the New Java SE 9** (which includes Java SE 8)
- *Java How to Program, 11/e*'s **Modular Organization**
- Introduction and Programming Fundamentals
- Flexible Coverage of **Java SE 9**: **JShell**, the **Module System** and Other Java SE 9 Topics
- **Object-Oriented Programming**
- Flexible **JavaFX/Swing** GUI, Graphics, Animation and Video Coverage

1. *Computer Science Curricula 2013 Curriculum Guidelines for Undergraduate Degree Programs in Computer Science*, December 20, 2013, The Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM), IEEE Computer Society.
2. `https://apstudent.collegeboard.org/apcourse/ap-computer-science-a/exam-practice`
3. `http://bit.ly/OracleJavaSE8Certification` (At the time of this writing, the Java SE 9 certification exams were not yet available.)

- **Data Structures** and **than**
- Flexible **Lambdas and Streams** Coverage
- **Concurrency** and **Multi-Core Performance**
- **Database: JDBC** and **JPA**
- **Web-Application Development** and **Web Services**
- Optional Online Object-**Oriented Design Case Study**

Flexibility Using Java SE 8 or the New Java SE 9

8
9

To meet the needs of our diverse audiences, we designed the book for college and professional courses based on **Java SE 8 or Java SE 9**, which from this point forward we'll refer to simply as Java 8 and Java 9, respectively. Each feature first introduced in Java 8 or Java 9 is accompanied by an 8 or 9 icon in the margin, like those to the left of this paragraph. The new Java 9 capabilities are covered in clearly marked, *easy-to-include-or-omit* chapters and sections—some in the print book and some online. Figures 1 and 2 list some key Java 8 and Java 9 features that we cover, respectively.

Java 8 features	
Lambdas and streams	Date & Time API (`java.time`)
Type-inference improvements	Parallel array sorting
`@FunctionalInterface` annotation	Java concurrency API improvements
Bulk data operations for Java Collections—`filter`, `map` and `reduce`	`static` and `default` methods in interfaces
Library enhancements to support lambdas (e.g., `java.util.stream`, `java.util.function`)	Functional interfaces that define only one `abstract` method and can include `static` and `default` methods

Fig. 1 | Some key features we cover that were introduced in Java 8.

Java 9 features	
In the Print Book	***On the Companion Website***
New JShell chapter	Module system
_ is no longer allowed as an identifier	HTML5 Javadoc enhancements
`private` interface methods	`Matcher` class's new method overloads
Effectively `final` variables can be used in `try`-with-resources statements	`CompletableFuture` enhancements
	JavaFX 9 skin APIs and other enhancements
Mention of the Stack Walking API	Mentions of:
Mention of JEP 254, Compact Strings	Overview of Java 9 security enhancements
Collection factory methods	G1 garbage collector
	Object serialization security enhancements
	Enhanced deprecation

Fig. 2 | Some key new features we cover that were introduced in Java 9.

Java How to Program, Late Objects, 11/e's Modular Organization

The book's modular organization helps instructors plan their syllabi.

Java How to Program, Late Objects, 11/e, is appropriate for programming courses at various levels. Chapters 1–25 are popular in core CS 1 and CS 2 courses and introductory course sequences in related disciplines—these chapters appear in the **print book**. Chapters 26–36 are intended for advanced courses and are located on the book's **Companion Website**.

Part 1: Introduction
Chapter 1, Introduction to Computers, the Internet and Java
Chapter 2, Introduction to Java Applications; Input/Output and Operators

---

Chapter 25, Introduction to JShell: Java 9's REPL for Interactive Java

Part 2: Additional Programming Fundamentals
Chapter 3, Control Statements: Part 1; Assignment, ++ and -- Operators
Chapter 4, Control Statements: Part 2; Logical Operators
Chapter 5, Methods
Chapter 6, Arrays and `ArrayList`s

Chapter 14, Strings, Characters and Regular Expressions
Chapter 15, Files, Input/Output Streams, NIO and XML Serialization

Part 3: Object-Oriented Programming
Chapter 7, Introduction to Classes and Objects
Chapter 8, Classes and Objects: A Deeper Look
Chapter 9, Object-Oriented Programming: Inheritance
Chapter 10, Object-Oriented Programming: Polymorphism and Interfaces
Chapter 11, Exception Handling: A Deeper Look

Part 4: JavaFX Graphical User Interfaces, Graphics and Multimedia
Chapter 12, JavaFX Graphical User Interfaces: Part 1
Chapter 13, JavaFX GUI: Part 2

Chapter 22, JavaFX Graphics and Multimedia

Part 5: Data Structures, Generic Collections, Lambdas and Streams
Chapter 16, Generic Collections
Chapter 17, Lambdas and Streams
Chapter 18, Recursion
Chapter 19, Searching, Sorting and Big O
Chapter 20, Generic Classes and Methods: A Deeper Look
Chapter 21, Custom Generic Data Structures

Part 6: Concurrency; Networking
Chapter 23, Concurrency

Chapter 28, Networking

Part 7: Database-Driven Desktop Development
Chapter 24, Accessing Databases with JDBC

Chapter 29, Java Persistence API (JPA)

Part 8: Web App Development and Web Services
Chapter 30, JavaServer™ Faces Web Apps: Part 1
Chapter 31, JavaServer™ Faces Web Apps: Part 2
Chapter 32, REST Web Services

Part 9: Other Java 9 Topics
Chapter 36, Java Module System and Other Java 9 Features

Part 10: (Optional) Object-Oriented Design
Chapter 33, ATM Case Study, Part 1: Object-Oriented Design with the UML
Chapter 34, ATM Case Study Part 2: Implementing an Object-Oriented Design

Part 11: (Optional) Swing Graphical User Interfaces and Java 2D Graphics
Chapter 26, Swing GUI Components: Part 1
Chapter 27, Graphics and Java 2D

Chapter 35, Swing GUI Components: Part 2

Introduction and Programming Fundamentals (Parts 1 and 2)

Chapters 1 through 7 provide a friendly, example-driven treatment of traditional introductory programming topics. This book features a **late objects approach**—see the section "Object-Oriented Programming" later in this Preface. Note in the preceding outline that Part 1 includes the (optional) Chapter 25 on Java 9's new JShell. Instructors and students who cover JShell will appreciate how its interactivity makes Java "come alive," leveraging the learning process—see the next section.

9 Flexible Coverage of Java 9: JShell, the Module System and Other Java 9 Topics

JShell: Java 9's REPL (Read-Eval-Print-Loop) for Interactive Java
JShell provides a friendly environment that enables you to quickly explore, discover and experiment with Java's language features and its extensive libraries. JShell replaces the tedious cycle of editing, compiling and executing with its **read-evaluate-print-loop**. Rather than complete programs, you write JShell commands and Java code snippets. When you enter a snippet, JShell *immediately*

- **reads** it,
- **evaluates** it and

- **prints** messages that help you see the effects of your code, then it
- **loops** to perform this process again for the next snippet.

As you work through Chapter 25's scores of examples and exercises, you'll see how JShell and its **instant feedback** keep your attention, enhance your performance and speed the learning and software development processes.

As a student you'll find JShell easy and fun to use. It will help you learn Java features faster and more deeply and will help you verify that these features work the way they're supposed to. As an instructor, you'll appreciate how JShell encourages your students to dig in, and that it **leverages the learning process**. As a professional you'll appreciate how JShell helps you rapidly prototype key code segments and how it helps you discover and experiment with new APIs. **If you're staying with Java 8 for a while, you can install JDKs 8 and 9 side-by-side and use JShell on JDK 9 for experimentation. The JDK 9 section of the Before You Begin that follows this Preface shows how to manage multiple JDKs on Windows, macOS and Linux.**

The **JShell** content is packaged modularly in Chapter 25. The chapter:

1. is **easy to include or omit**.
2. is organized as a series of 16 sections, many of which are designed to be covered after a specific earlier chapter of the book (Fig. 3).
3. offers rich coverage of JShell's capabilities. It's **example-intensive**—you should do each of the examples. Get JShell into your fingertips. You'll appreciate how quickly and conveniently you can do things.
4. includes **dozens of Self-Review Exercises, each with an answer**. These exercises can be done after you read **Chapter 2** and **Section 25.3**. As you do each of them, flip the page and check your answer. This will help you master the basics of JShell quickly. Then as you do each of the **examples** in the remainder of the chapter you'll master the vast majority of JShell's capabilities.

JShell discussions	Can be covered after
Section 25.3 introduces **JShell**, including starting a session, executing statements, declaring variables, evaluating expressions, JShell's **type-inference** capabilities and more. Section 25.4 discusses command-line input with **`Scanner`** in JShell.	Chapter 2, Introduction to Java Applications; Input/Output and Operators
Section 25.5 discusses how to declare and use **classes** in JShell, including how to load a Java source-code file containing an existing class declaration. Section 25.6 shows how to use JShell's **auto-completion** capabilities to discover a class's capabilities and JShell commands.	Chapter 7, Introduction to Classes and Objects

Fig. 3 | Chapter 25 JShell discussions that are designed to be covered after specific earlier chapters. (Part 1 of 2.)

JShell discussions	Can be covered after
Section 25.7 presents additional JShell auto-completion capabilities for **experimentation and discovery**, including viewing method parameters, documentation and method overloads. Section 25.8 shows how to declare and use methods in JShell, including **forward referencing** a method that does not yet exist in the JShell session.	Chapter 5, Methods
Section 25.9 shows how **exceptions** are handled in JShell.	Chapter 6, Arrays and `ArrayLists`
Section 25.10 shows how to add existing **packages** to the classpath and import them for use in JShell.	Chapter 21, Custom Generic Data Structures
The remaining JShell sections are reference material that can be covered after Section 25.10. Topics include using an external editor, a summary of JShell commands, getting help in JShell, additional features of `/edit` command, `/reload` command, `/drop` command, feedback modes, other JShell features configurable with `/set`, keyboard shortcuts for snippet editing, how JShell reinterprets Java for interactive use and IDE JShell support.	

Fig. 3 | Chapter 25 JShell discussions that are designed to be covered after specific earlier chapters. (Part 2 of 2.)

9 ***New Chapter—The Java Module System and Other Java 9 Topics***
Because Java 9 was still under development when this book was published, we included an online chapter on the book's Companion Website that discusses Java 9's module system and various other Java 9 topics. This **online content will be available before Fall 2017 courses**.

Object-Oriented Programming (Part 3)

Object-oriented programming. We use a **late objects approach**, covering programming fundamentals such as data types, variables, operators, control stattements, methods and arrays in the early chapters. Then students develop their first customized classes and objects in Chapter 7. [For courses that require an **early-objects approach**, you may want to consider our sister book ***Java How to Program, Early Objects, 11/e***.]

Real-world case studies. The object-oriented programing presentation in the classes chapters features `Account`, `Time`, `Employee`, `GradeBook` and `Card` shuffling-and-dealing case studies.

Inheritance, Interfaces, Polymorphism and Composition. We use additional real-world case studies—including class `Time`, an `Employee` class hierarchy, and a `Payable` interface implemented in disparate `Employee` and `Invoice` classes—to illustrate these OO concepts and explain situations in which each is preferred in building industrial-strength applications. We also explain the use of current idioms, such as "**programming to an interface not an implementation**" and "**preferring composition to inheritance**."

Exception handling. We integrate basic exception handling beginning in Chapter 6 then present a deeper treatment in Chapter 11. Exception handling is important for building **mission-critical** and **business-critical** applications. To use a Java component, you need to

know not only how that component behaves when "things go well," but also what exceptions that component "throws" when "things go poorly" and how your code should handle those exceptions.

Classes `Arrays` *and* `ArrayList`. Chapter 6 covers class `Arrays`—which contains methods for performing common array manipulations—and class `ArrayList`—which implements a dynamically resizable array-like data structure. This follows our philosophy of getting lots of practice using existing classes while learning how to define your own. The chapter's rich selection of exercises includes a substantial project on **building your own computer** through the technique of software simulation. Chapter 21 includes a follow-on project on **building your own compiler** that can compile high-level language programs into machine language code that will actually execute on your computer simulator. Students in first and second programming courses, respectively, enjoy these challenges.

Flexible JavaFX GUI, Graphics, Animation and Video Coverage (Part 4) and Optional Swing Coverage (Part 11)

Students enjoy building applications with **GUI**, **graphics**, **animations** and **videos**. Instructors teaching introductory courses can choose the amount of GUI, graphics, animation and video they'd like to cover—from none at all to the four options discussed below. Those who want to use the newer **JavaFX GUI, graphics, animation and video** capabilities (today's most popular options for college courses and professionals) in their courses can choose from:

- a **deep treatment** of **JavaFX GUI**, **graphics (2D and 3D)**, **animation** and **video** in Chapters 12, 13 and 22, or
- a **lighter treatment** of **JavaFX GUI** and **2D graphics** on the Companion Website that can be taught anytime after Chapter 7.

Those who want to continue using the older **Swing GUI** and **Java 2D graphics** in their courses can choose from the following options on the Companion Website:

- a **deep treatment** of **Swing GUI** and **Java 2D graphics** in online Chapters 26, 27 and 35, or
- a **lighter treatment** of **Swing GUI** and **Java 2D graphics** that can be taught anytime after Chapter 7.

Let's consider these four options in more detail.

Deep Treatment of JavaFX GUI, Graphics, Animation and Video in Chapters 12, 13, 22
For this 11th edition, we've significantly updated our **JavaFX** presentation and moved all three chapters into the print book, replacing our **Swing GUI and graphics coverage** (which is now on the book's **Companion Website** for instructors who want to continue with Swing).

In Chapters 12–13, we use **JavaFX** and **Scene Builder**—a drag-and-drop tool for creating JavaFX GUIs quickly and conveniently—to build several apps that demonstrate various JavaFX GUI layouts, controls and event-handling capabilities. In **Swing**, drag-and-drop tools and their generated code are *IDE dependent*. Scene Builder is a standalone tool that you can use separately or with any of the Java IDEs to do **portable drag-and-drop GUI design**.

In Chapter 22, we present **JavaFX 2D and 3D graphics**, **animation** and **video** capabilities. We also provide **36 programming exercises and projects** that students will find

challenging and entertaining, including many **game-programming exercises**. **Chapter 22 can be covered immediately after Section 13.3**. We also use JavaFX in several GUI-based examples in Chapter 23, Concurrency and Chapter 24, Accessing Databases with JDBC.

Lighter Treatment of JavaFX GUI and 2D Graphics
For instructors who like to introduce a lighter treatment of JavaFX GUI and graphics earlier than Chapter 12, we've placed on the book's Companion Website a lighter case study (Fig. 4)[1] that can be taught anytime after Chapter 7. The goal is to create a simple polymorphic drawing application in which the user can select a shape to draw and the shape's characteristics (such as its color, stroke thickness and whether it's hollow or filled) then drag the mouse to position and size the shape. The case study builds gradually toward that goal, with the reader implementing a polymorphic drawing app, then adding a more robust user interface. For courses that include these case study sections, instructors can opt to cover none, some or all of the deeper treatment in Chapters 12, 13 and 22.

Part	What you'll do
1. A Simple GUI	Display text and an image.
2. Event Handling and Drawing Lines	In response to a `Button` click, draw lines using JavaFX graphics capabilities.
3. Drawing Rectangles and Ovals	Draw rectangles and ovals.
4. Colors and Filled Shapes	Draw filled shapes in multiple colors.
5. Drawing Arcs	Draw a rainbow of colored arcs.
6. Using Objects with Graphics	Store shapes as objects then have those objects to draw themselves on the screen.
7. Drawing with Polymorphism	Identify the similarities between shape classes and create and use a shape class hierarchy.
8. Interactive Polymorphic Drawing Application	In capstone Exercise 13.9 you'll enable users to select each shape to draw, configure its properties (such as color and fill), and drag the mouse to position and size the shape.

Fig. 4 | Optional JavaFX GUI and Graphics Case Study.

Deep Treatment Swing GUI and 2D Graphics
Swing is still widely used, but Oracle will provide only minor updates going forward. For instructors and readers who wish to continue using Swing, we've moved to the book's **Companion Website** the 10th edition's

- Chapter 26, Swing GUI Components: Part 1
- Chapter 27, Graphics and Java 2D
- Chapter 35, Swing GUI Components: Part 2.

See the "Companion Website" section later in this Preface.

1. The deeper graphics treatment in Chapter 22 uses JavaFX shape types that can be added directly to the GUI using **Scene Builder**.

Lighter Treatment of Swing GUI and 2D Graphics
We've also moved to the Companion Website the older Swing-based version of the lighter JavaFX case study in Fig. 4.

Integrating Swing GUI Components in JavaFX GUIs
If you move to JavaFX, you still can use your favorite Swing capabilities. For example, in Chapter 24, we demonstrate how to display database data in a Swing `JTable` component that's embedded in a JavaFX GUI via a JavaFX 8 `SwingNode`. As you explore Java further, you'll see that you also can incorporate JavaFX capabilities into your Swing GUIs.

Data Structures and Generic Collections (Part 5)

Data structures presentation. The chapters of Part 5 form the core of a second programming course emphasizing data structures. We begin with generic collection class `ArrayList` in Chapter 6. Our later data structures discussions (Chapters 16–21) provide a deeper treatment of generic collections—showing how to use many additional built-in collections of the Java API.

We discuss **recursion**, which is important for many reasons including implementing tree-like, data-structure classes. For computer-science majors and students in related disciplines, we discuss **searching and sorting algorithms** for manipulating the contents of collections, and provide a friendly introduction to **Big O**—a means of describing mathematically how hard an algorithm might have to work to solve a problem. Most programmers should use the built-in searching and sorting capabilities of the collections classes.

We then show how to implement **custom generic methods and classes**, including **custom generic data structures** (this, too, is intended for computer-science majors—in industry, most programmers should use the pre-built generic collections). **Lambdas and streams** (introduced in Chapter 17) are especially useful for working with generic collections.

Flexible Lambdas and Streams Coverage (Chapter 17)

The most significant new features in Java 8 were lambdas and streams. This book has several audiences, including

- those who'd like a significant treatment of lambdas and streams
- those who want a basic introduction with a few simple examples
- those who do not want to use lambdas and streams yet.

For this reason, we've placed most of the lambdas and streams treatment in Chapter 17, which is architected as a series of *easy-to-include-or-omit* sections that are keyed to the book's earlier sections and chapters. We do integrate lambdas and streams into a few examples *after* Chapter 17, because their capabilities are so compelling.

In Chapter 17, you'll see that lambdas and streams can help you write programs faster, more concisely, more simply, with fewer bugs and that are easier to **parallelize** (to realize performance improvements on **multi-core systems**) than programs written with previous techniques. You'll see that "functional programming" with lambdas and streams complements object-oriented programming.

Many of Chapter 17's sections are written so they can be covered earlier in the book (Fig. 5)—we suggest that students begin by covering Sections 17.1—17.7 after Chapter 6 and that professionals begin by covering Sections 17.1—17.5 after Chapter 4. After reading Chapter 17, you'll be able to cleverly reimplement many examples throughout the book.

Lambdas and streams discussions	Can be covered after
Sections 17.1—17.5 introduce basic lambda and streams capabilities that you can use to **replace counting loops**, and discuss the mechanics of how streams are processed.	Chapter 4, Control Statements: Part 2; Logical Operators
Section 17.6 introduces **method references** and additional streams capabilities.	Chapter 5, Methods
Section 17.7 introduces streams capabilities that process **one-dimensional arrays**.	Chapter 6, Arrays and `ArrayLists`
Sections 17.8—17.10 demonstrate additional streams capabilities and present various **functional interfaces used in streams processing**.	Chapter 10, Object-Oriented Programming: Polymorphism and Interfaces—Section 10.10 introduces Java 8 interface features (**`default` methods**, **`static` methods** and the concept of **functional interfaces**) for the functional interfaces that support lambdas and streams.
Section 17.11 uses lambdas and streams to **process collections of `String` objects**.	Chapter 14, Strings, Characters and Regular Expressions
Section 17.12 uses lambdas and streams to **process a `List<Employee>`**.	Chapter 16, Generic Collections
Section 17.13 uses lambdas and streams to **process lines of text from a file**.	Chapter 15, Files, Input/Output Streams, NIO and XML Serialization
Section 17.14 introduces streams of random values	All earlier Chapter 17 sections.
Section 17.15 introduces infinite streams	All earlier Chapter 17 sections.
Section 17.16 uses lambdas to implement **JavaFX event-listener interfaces**.	Chapter 12, JavaFX Graphical User Interfaces: Part 1
Chapter 23, Concurrency, shows that programs using lambdas and streams are often easier to **parallelize** so they can take advantage of **multi-core architectures** to enhance performance. The chapter demonstrates **parallel stream processing** and shows that **`Arrays` method `parallelSort`** improves performance on **multi-core architectures** when sorting large arrays.	

Fig. 5 | Java 8 lambdas and streams discussions and examples.

Concurrency and Multi-Core Performance (Part 6)

We were privileged to have as a reviewer of *Java How to Program, 10/e* Brian Goetz, co-author of *Java Concurrency in Practice* (Addison-Wesley). We updated Chapter 23, Concurrency, with Java 8 technology and idiom. We added a **`parallelSort`** vs. `sort` example that uses the **Java 8 Date/Time API** to time each operation and demonstrate `parallelSort`'s better performance on a **multi-core** system. We included a **Java 8 parallel vs. sequential stream processing** example, again using the Date/Time API to show performance improvements. We added a Java 8 **`CompletableFuture`** example that demonstrates sequential and parallel execution of long-running calculations and we discuss **`Completable-`**

Future enhancements in the online Java 9 chapter. Finally, we added several new exercises, including one that demonstrates the problems with parallelizing Java 8 streams that apply non-associative operations and several that have the reader investigate and use the **Fork/Join framework** to **parallelize recursive algorithms**.

JavaFX concurrency. In this edition, we converted Chapter 23's Swing-based GUI examples to JavaFX. We now use **JavaFX concurrency** features, including class `Task` to execute long-running tasks in separate threads and display their results in the JavaFX application thread, and the `Platform` class's `runLater` method to schedule a `Runnable` for execution in the JavaFX application thread.

Database: JDBC and JPA (Part 7)

JDBC. Chapter 24 covers the widely used **JDBC**and uses the **Java DB database management system**. The chapter introduces **Structured Query Language** (**SQL**) and features a case study on developing a JavaFX database-driven address book that demonstrates **prepared statements**. In JDK 9, Oracle no longer bundles Java DB, which is simply an Oracle-branded version of Apache Derby. JDK 9 users can download and use Apache Derby instead (`https://db.apache.org/derby/`).

Java Persistence API. Chapter 29 covers the newer **Java Persistence API** (**JPA**)—a standard for **object relational mapping** (**ORM**) that uses JDBC "under the hood." ORM tools can look at a database's **schema** and generate a set of classes that enabled you to interact with a database without having to use JDBC and SQL directly. This speeds database-application development, reduces errors and produces more portable code.

Web Application Development and Web Services (Part 8)

Java Server Faces (JSF). Chapters 30–31 introduce the **JavaServer™ Faces** (**JSF**) technology for building web-based applications. Chapter 30 includes examples on building web application GUIs, validating forms and session tracking. Chapter 31 discusses data-driven JSF applications—including a **multi-tier web address book application** that allows users to add and search for contacts.

Web services. Chapter 32 now concentrates on creating and consuming **REST-based web services**. Most of today's web services use REST, which is simpler and more flexible than older web-services technologies that often required manipulating data in only XML format. REST can use a variety of formats, such as JSON, HTML, plain text, media files and XML.

Optional Online Object-Oriented Design Case Study (Part 10)

Developing an Object-Oriented Design and Java Implementation of an ATM. Chapters 33–34 include an *optional* case study on object-oriented design using the UML (Unified Modeling Language™)—the industry-standard graphical language for modeling object-oriented systems. We design and implement the software for a simple automated teller machine (ATM). We analyze a typical **requirements document** that specifies the system to be built. We determine the **classes** needed to implement that system, the **attributes** the classes need to have, the **behaviors** the classes need to exhibit and specify how the classes must **interact** with one another to meet the system requirements. From the design we produce a **complete Java implementation**. Students often report having a "light-bulb moment"—the case study helps them "tie it all together" and understand object orientation more deeply.

Teaching Approach

Java How to Program, 11/e, contains hundreds of complete working code examples. We stress program clarity and concentrate on building well-engineered software.

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

```
comments appear in light gray like this
keywords appear bold black like this
constants and literal values appear in bold dark gray like this
all other code appears in black like this
```

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 easier reference. We emphasize on-screen components in the **bold Helvetica** font (e.g., the **File** menu) and emphasize Java program text in the `Lucida` font (for example, `int x = 5;`).

Objectives. The list of chapter objectives provides a high-level overview of the chapter's contents.

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

Summary Bullets. We present a section-by-section bullet-list summary of the chapter. For ease of reference, we generally 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. All of the exercises in the optional ATM case study are fully solved.

Exercises. The chapter exercises include:

- simple recall of important terminology and concepts
- What's wrong with this code?
- What does this code do?
- writing individual statements and small portions of methods and classes
- writing complete methods, classes and programs
- major projects
- in many chapters, **Making a Difference exercises** that encourage you to use computers and the Internet to research and address significant social problems.
- In this edition, we added new exercises to our **game-programming** set (**SpotOn**, **Horse Race**, **Cannon**, **15 Puzzle**, **Hangman**, **Block Breaker**, **Snake** and **Word Search**), as well as others on the **JavaMoney API**, `final` instance variables, combining composition and inheritance, working with interfaces, drawing fractals, recursively searching directories, visualizing sorting algorithms and implementing parallel recursive algorithms with the Fork/Join framework. Many of these require students to research additional Java features online and use them.

Index. We've included an extensive index. Defining occurrences of key terms are highlighted with a **bold** page number. The print book index mentions only those terms used in the print book. **The online chapters index on the Companion Website includes all the print book terms and the online chapter terms.**

Programming Wisdom

We include hundreds of programming tips to help you focus on important aspects of program development. These represent the best we've gleaned from a combined nine 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 bugs and removing them from your programs; many describe aspects of Java 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.*

Look-and-Feel Observation

The Look-and-Feel Observations *highlight graphical-user-interface conventions. These observations help you design attractive, user-friendly graphical user interfaces that conform to industry norms.*

What are JEPs, JSRs and the JCP?

Throughout the book we encourage you to research various aspects of Java online. Some acronyms you're likely to see are JEP, JSR and JCP.

JEPs (JDK Enhancement Proposals) are used by Oracle to gather proposals from the Java community for changes to the Java language, APIs and tools, and to help create the roadmaps for future Java Standard Edition (Java SE), Java Enterprise Edition (Java EE)

and Java Micro Edition (Java ME) platform versions and the JSRs (Java Specification Requests) that define them. The complete list of JEPs can be found at

```
http://openjdk.java.net/jeps/0
```

JSRs (Java Specification Requests) are the formal descriptions of Java platform features' technical specifications. Each new feature that gets added to Java (Standard Edition, Enterprise Edition or Micro Edition) has a JSR that goes through a review and approval process before the feature is added to Java. Sometimes JSRs are grouped together into an umbrella JSR. For example JSR 337 is the umbrella for Java 8 features, and JSR 379 is the umbrella for Java 9 features. The complete list of JSRs can be found at

```
https://www.jcp.org/en/jsr/all
```

The **JCP (Java Community Process)** is responsible for developing JSRs. JCP expert groups create the JSRs, which are publicly available for review and feedback. You can learn more about the JCP at:

```
https://www.jcp.org
```

Secure Java Programming

It's difficult to build industrial-strength systems that stand up to attacks from viruses, worms, and other forms of "malware." Today, via the Internet, such attacks can be instantaneous and global in scope. Building security into software from the beginning of the development cycle can greatly reduce vulnerabilities. We audited our book against the CERT Oracle Secure Coding Standard for Java

```
http://bit.ly/CERTOracleSecureJava
```

and adhered to various secure coding practices as appropriate for a textbook at this level.

The CERT® Coordination Center (`www.cert.org`) was created to analyze and respond promptly to attacks. CERT—the Computer Emergency Response Team—is a government-funded organization within the Carnegie Mellon University Software Engineering Institute™. CERT publishes and promotes secure coding standards for various popular programming languages to help software developers implement industrial-strength systems by employing programming practices that prevent system attacks from succeeding.

We'd like to thank Robert C. Seacord. A few years back, when Mr. Seacord was the Secure Coding Manager at CERT and an adjunct professor in the Carnegie Mellon University School of Computer Science, he was a technical reviewer for our book, *C How to Program, 7/e*, where he scrutinized our C programs from a security standpoint, recommending that we adhere to the *CERT C Secure Coding Standard*. This experience also influenced our coding practices in *C++ How to Program, 10/e* and *Java How to Program, 11/e*.

Companion Website: Source Code, VideoNotes, Online Chapters and Online Appendices

All the source code for the book's code examples is available at the book's **Companion Website**, which also contains extensive **VideoNotes** and the online chapters and appendices:

```
www.pearsonglobaleditions.com
```

See the book's inside front cover for information on accessing the Companion Website.

In the extensive **VideoNotes**, co-author Paul Deitel patiently explains most of the programs in the book's core chapters. Students like viewing the VideoNotes for reinforcement of core concepts and for additional insights.

Software Used in *Java How to Program, 11/e*

All the software you'll need for this book is available free for download from the Internet. See the **Before You Begin** section that follows this Preface for links to each download. We wrote most of the examples using the free Java Standard Edition Development Kit (JDK) 8. For the optional Java 9 content, we used the OpenJDK's early access version of JDK 9. All of the Java 9 programs run on the early access versions of JDK 9. All of the programs were tested on Windows, macOS and Linux. Several online chapters use the Netbeans IDE.

8
9

Java Documentation Links

Throughout the book, we provide links to Java documentation where you can learn more about various topics that we present. For Java 8 documentation, the links begin with

8

```
http://docs.oracle.com/javase/8/
```

and for Java 9 documentation, the links currently begin with

9

```
http://download.java.net/java/jdk9/
```

The Java 9 documentation links will change when Oracle releases Java 9—*possibly* to links beginning with

```
http://docs.oracle.com/javase/9/
```

Java How to Program, Early Objects Version, 11/e

There are several approaches to teaching first courses in Java programming. The two most popular are the **late objects approach** and the **early objects approach**. To meet these diverse needs, we've published two versions of this book:

- *Java How to Program, Late Objects Version, 11/e* (this book), and
- *Java How to Program, Early Objects Version, 11/e*

The key difference between them is the order in which we present Chapters 1–7. The books have identical content in Chapter 8 and higher. Instructors can request an examination copy of either of these books from their Pearson representative.

Instructor Supplements

The following supplements are available to qualified instructors only through Pearson Education's Instructor Resource Center (`www.pearsonglobaleditions.com`):

- ***PowerPoint® slides*** containing all the code and figures in the text, plus bulleted items that summarize key points.
- ***Test Item File*** of multiple-choice questions and answers (approximately two per book section).
- ***Solutions Manual*** with solutions to most of the end-of-chapter exercises. **Before assigning an exercise for homework, instructors should check the IRC to be sure it includes the solution. Solutions are *not* provided for "project" exercises.**

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. If you're not a registered faculty member, contact your Pearson representative.

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Reviewers

We wish to acknowledge the efforts of our recent editions reviewers—a distinguished group of academics, Oracle Java team members, Oracle Java Champions and other industry professionals. They scrutinized the text and the programs and provided countless suggestions for improving the presentation. Any remaining faults in the book are our own.

We appreciate the guidance of JavaFX experts Jim Weaver and Johan Vos (co-authors of *Pro JavaFX 8*), Jonathan Giles and Simon Ritter on the three JavaFX chapters.

Eleventh Edition reviewers: Marty Allen (University of Wisconsin-La Crosse), Robert Field (JShell chapter only; JShell Architect, Oracle), Trisha Gee (JetBrains, Java Champion), Jonathan Giles (Consulting Member of Technical Staff, Oracle), Brian Goetz (JShell chapter only; Oracle's Java Language Architect), Edwin Harris (M.S. Instructor at The University of North Florida's School of Computing), Maurice Naftalin (Java Champion), José Antonio González Seco (Consultant), Bruno Souza (President of SouJava—the Brazilian Java Society, Java Specialist at ToolsCloud, Java Champion and SouJava representative at the Java Community Process), Dr. Venkat Subramaniam (President, Agile Developer, Inc. and Instructional Professor, University of Houston, Java Champion), Johan Vos (CTO, Cloud Products at Gluon, Java Champion).

Tenth Edition reviewers: Lance Andersen (Oracle Corporation), Dr. Danny Coward (Oracle Corporation), Brian Goetz (Oracle Corporation), Evan Golub (University of Maryland), Dr. Huiwei Guan (Professor, Department of Computer & Information Science, North Shore Community College), Manfred Riem (Java Champion), Simon Ritter (Oracle Corporation), Robert C. Seacord (CERT, Software Engineering Institute, Carnegie Mellon University), Khallai Taylor (Assistant Professor, Triton College and Adjunct Professor, Lonestar College—Kingwood), Jorge Vargas (Yumbling and a Java Champion), Johan Vos (LodgON and Oracle Java Champion) and James L. Weaver (Oracle Corporation and author of *Pro JavaFX 2*).

Earlier editions reviewers: Soundararajan Angusamy (Sun Microsystems), Joseph Bowbeer (Consultant), William E. Duncan (Louisiana State University), Diana Franklin (University of California, Santa Barbara), Edward F. Gehringer (North Carolina State University), Ric Heishman (George Mason University), Dr. Heinz Kabutz (JavaSpecialists.eu), Patty Kraft (San Diego State University), Lawrence Premkumar (Sun Microsystems), Tim Margush (University of Akron), Sue McFarland Metzger (Villanova University), Shyamal Mitra (The University of Texas at Austin), Peter Pilgrim (Consultant), Manjeet Rege, Ph.D. (Rochester Institute of Technology), Susan Rodger (Duke University), Amr Sabry (Indiana University), José Antonio González Seco (Parliament of Andalusia), Sang Shin (Sun Microsystems), S. Sivakumar (Astra Infotech Private Limited), Raghavan "Rags" Srinivas (Intuit), Monica Sweat (Georgia Tech), Vinod Varma (Astra Infotech Private Limited) and Alexander Zuev (Sun Microsystems).

A Special Thank You to Robert Field

Robert Field, Oracle's JShell Architect reviewed the new JShell chapter, responding to our numerous emails in which we asked JShell questions, reported bugs we encountered as JShell evolved and suggested improvements. It was a privilege having our content scrutinized by the person responsible for JShell.

A Special Thank You to Brian Goetz
Brian Goetz, Oracle's Java Language Architect and Specification Lead for Java 8's Project Lambda, and co-author of *Java Concurrency in Practice*, did a full-book review of the 10th edition. He provided us with an extraordinary collection of insights and constructive comments. For the 11th edition, he did a detailed review of our new JShell chapter and answered our Java questions throughout the project.

Well, there you have it! As you read the book, we'd appreciate your comments, criticisms, corrections and suggestions for improvement. Please send your questions and all other correspondence to:

```
deitel@deitel.com
```

We'll respond promptly. We hope you enjoy working with *Java How to Program, 11/e*, as much as we enjoyed researching and writing it!

Paul and Harvey Deitel

About the Authors

Paul J. Deitel, CEO and Chief Technical Officer of Deitel & Associates, Inc., is a graduate of MIT and has over 35 years of experience in computing. He holds the Java Certified Programmer and Java Certified Developer designations, and is an Oracle Java Champion. Through Deitel & Associates, Inc., he has delivered hundreds of programming courses worldwide to clients, including Cisco, IBM, Siemens, Sun Microsystems (now Oracle), Dell, Fidelity, NASA at the Kennedy Space Center, the National Severe Storm Laboratory, White Sands Missile Range, Rogue Wave Software, Boeing, SunGard Higher Education, 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/professional book/video authors.

Dr. Harvey M. Deitel, Chairman and Chief Strategy Officer of Deitel & Associates, Inc., has over 55 years of experience in computing. Dr. Deitel earned B.S. and M.S. degrees in Electrical Engineering from MIT and a Ph.D. in Mathematics from Boston University—he studied computing in each of these programs before they spun off Computer Science programs. 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., in 1991 with his son, Paul. The Deitels' publications have earned international recognition, with more than 100 translations published in Japanese, German, Russian, Spanish, French, Polish, Italian, Simplified Chinese, Traditional Chinese, Korean, Portuguese, Greek, Urdu and Turkish. Dr. Deitel has delivered hundreds of programming courses to academic, corporate, government and military clients.

About Deitel® & Associates, Inc.

Deitel & Associates, Inc., founded by Paul Deitel and Harvey Deitel, is an internationally recognized authoring and corporate training organization, specializing in computer programming languages, object technology, mobile app development and Internet and web software technology. The company's training clients include many of the world's largest companies, government agencies, branches of the military, and academic institutions. The company offers instructor-led training courses delivered at client sites worldwide on major programming languages and platforms, including Java™, Android app development, Swift and iOS app development, C++, C, Visual C#®, Visual Basic®, object technology, Internet and web programming and a growing list of additional programming and software development courses.

Through its 42-year publishing partnership with Pearson/Prentice Hall, Deitel & Associates, Inc., publishes leading-edge programming textbooks and professional books in print and e-book formats, **LiveLessons** video courses and **REVEL™** online interactive multimedia courses with integrated **MyProgrammingLab**. Deitel & Associates, Inc. and the authors can be reached at:

```
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```

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```
http://www.informit.com/store/sales.aspx
```

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Reviewers: Annette Bieniusa (University of Kaiserslautern), Bogdan Oancea (University of Bucharest), and Shaligram Prajapat (Devi Ahilya University)

Before You Begin

This section contains information you should review before using this book. In addition, we provide getting-started videos that demonstrate the instructions in this Before You Begin section.

Font and Naming Conventions

We use fonts to distinguish between on-screen components (such as menu names and menu items) and Java code or commands. Our convention is to emphasize on-screen components in a sans-serif bold **Helvetica** font (for example, **File** menu) and to emphasize Java code and commands in a sans-serif `Lucida` font (for example, `System.out.println()`).

Java SE Development Kit (JDK)

The software you'll need for this book is available free for download from the web. Most of the examples were tested with the Java SE Development Kit 8 (also known as JDK 8). The most recent JDK version is available from:

```
http://www.oracle.com/technetwork/java/javase/downloads/index.html
```

The current version of the JDK at the time of this writing is JDK 8 update 121.

Java SE 9

The Java SE 9-specific features that we discuss in optional sections and chapters require JDK 9. At the time of this writing, JDK 9 was available as an early access verion. If you're using this book before the final JDK 9 is released, see the section "Installing and Configuring JDK 9 Early Access Version" later in this Before You Begin. We also discuss in that section how you can manage multiple JDK versions on Windows, macOS and Linux.

JDK Installation Instructions

After downloading the JDK installer, be sure to carefully follow the installation instructions for your platform at:

```
https://docs.oracle.com/javase/8/docs/technotes/guides/install/
   install_overview.html
```

You'll need to update the JDK version number in any version-specific instructions. For example, the instructions refer to `jdk1.8.0`, but the current version at the time of this writing is `jdk1.8.0_121`. If you're a Linux user, your distribution's software package manager

might provide an easier way to install the JDK. For example, you can learn how to install the JDK on Ubuntu here:

```
http://askubuntu.com/questions/464755/how-to-install-openjdk-8-on-
   14-04-lts
```

Setting the PATH Environment Variable

The `PATH` environment variable on your computer designates which directories the computer searches when looking for applications, such as the applications that enable you to compile and run your Java applications (called `javac` and `java`, respectively). *Carefully follow the installation instructions for Java on your platform to ensure that you set the* `PATH` *environment variable correctly.* The steps for setting environment variables differ by operating system. Instructions for various platforms are listed at:

```
http://www.java.com/en/download/help/path.xml
```

If you do not set the `PATH` variable correctly on Windows and some Linux installations, when you use the JDK's tools, you'll receive a message like:

```
'java' is not recognized as an internal or external command,
operable program or batch file.
```

In this case, go back to the installation instructions for setting the `PATH` and recheck your steps. If you've downloaded a newer version of the JDK, you may need to change the name of the JDK's installation directory in the `PATH` variable.

JDK Installation Directory and the `bin` *Subdirectory*

The JDK's installation directory varies by platform. The directories listed below are for Oracle's JDK 8 update 121:

- JDK on Windows:
  `C:\Program Files\Java\jdk1.8.0_121`
- macOS (formerly called OS X):
  `/Library/Java/JavaVirtualMachines/jdk1.8.0_121.jdk/Contents/Home`
- Ubuntu Linux:
  `/usr/lib/jvm/java-8-oracle`

Depending on your platform, the JDK installation folder's name might differ if you're using a different JDK 8 update. For Linux, the install location depends on the installer you use and possibly the Linux version as well. We used Ubuntu Linux. The `PATH` environment variable must point to the JDK installation directory's `bin` subdirectory.

When setting the `PATH`, be sure to use the proper JDK-installation-directory name for the specific version of the JDK you installed—as newer JDK releases become available, the JDK-installation-directory name changes with a new *update version number*. For example, at the time of this writing, the most recent JDK 8 release was update 121. For this version, the JDK-installation-directory name typically ends with `_121`.

CLASSPATH Environment Variable

If you attempt to run a Java program and receive a message like

```
Exception in thread "main" java.lang.NoClassDefFoundError: YourClass
```