



The Java[®] Tutorial

A Short Course on the Basics

Sixth Edition

Raymond Gallardo, Scott Hommel, Sowmya Kannan,
Joni Gordon, Sharon Biocca Zakhour



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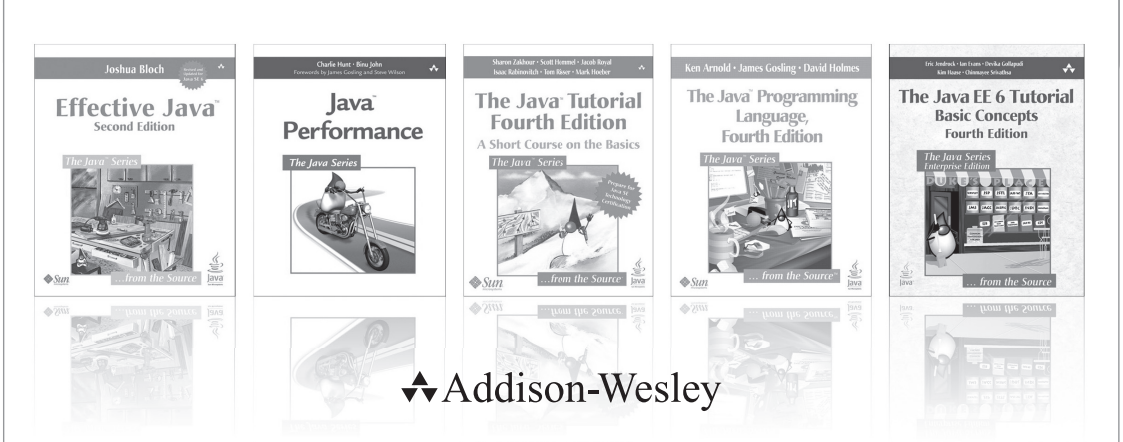
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◆◆Addison-Wesley

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Contents

Preface	xxiii
About the Authors	xxvii
Chapter 1	
Getting Started	1
The Java Technology Phenomenon	1
The Java Programming Language	2
The Java Platform	2
What Can Java Technology Do?	4
How Will Java Technology Change My Life?	4
The “Hello World!” Application	5
“Hello World!” for the NetBeans IDE	6
“Hello World!” for Microsoft Windows	15
“Hello World!” for Solaris and Linux	20
A Closer Look at the “Hello World!” Application	23
Source Code Comments	24
The HelloWorldApp Class Definition	25
The main Method	25
Common Problems (and Their Solutions)	27
Compiler Problems	27
Runtime Problems	29
Questions and Exercises: Getting Started	31

	Questions	31
	Exercises	32
	Answers	32
Chapter 2	Object-Oriented Programming Concepts	33
	What Is an Object?	34
	What Is a Class?	36
	What Is Inheritance?	38
	What Is an Interface?	39
	What Is a Package?	40
	Questions and Exercises: Object-Oriented Programming Concepts	41
	Questions	41
	Exercises	41
	Answers	41
Chapter 3	Language Basics	43
	Variables	44
	Naming	45
	Primitive Data Types	46
	Arrays	51
	Summary of Variables	57
	Questions and Exercises: Variables	57
	Operators	58
	Assignment, Arithmetic, and Unary Operators	59
	Equality, Relational, and Conditional Operators	62
	Bitwise and Bit Shift Operators	65
	Summary of Operators	66
	Questions and Exercises: Operators	67
	Expressions, Statements, and Blocks	68
	Expressions	68
	Statements	70
	Blocks	71
	Questions and Exercises: Expressions, Statements, and Blocks	71
	Control Flow Statements	72
	The if-then and if-then-else Statements	72
	The switch Statement	74
	The while and do-while Statements	79
	The for Statement	80
	Branching Statements	82
	Summary of Control Flow Statements	85
	Questions and Exercises: Control Flow Statements	86

Chapter 4	Classes and Objects	87
	Classes	88
	Declaring Classes	89
	Declaring Member Variables	90
	Defining Methods	92
	Providing Constructors for Your Classes	94
	Passing Information to a Method or a Constructor	95
	Objects	99
	Creating Objects	100
	Using Objects	104
	More on Classes	107
	Returning a Value from a Method	107
	Using the this Keyword	109
	Controlling Access to Members of a Class	110
	Understanding Class Members	112
	Initializing Fields	116
	Summary of Creating and Using Classes and Objects	118
	Questions and Exercises: Classes	119
	Questions and Exercises: Objects	120
	Nested Classes	121
	Why Use Nested Classes?	122
	Static Nested Classes	122
	Inner Classes	123
	Shadowing	123
	Serialization	124
	Inner Class Example	125
	Local and Anonymous Classes	127
	Modifiers	127
	Local Classes	127
	Anonymous Classes	131
	Lambda Expressions	136
	When to Use Nested Classes, Local Classes, Anonymous Classes, and Lambda Expressions	155
	Questions and Exercises: Nested Classes	156
	Enum Types	157
	Questions and Exercises: Enum Types	161
Chapter 5	Annotations	163
	Annotations Basics	164
	The Format of an Annotation	164

	Where Annotations Can Be Used	165
	Declaring an Annotation Type	165
	Predefined Annotation Types	167
	Annotation Types Used by the Java Language	167
	Annotations That Apply to Other Annotations	169
	Type Annotations and Pluggable Type Systems	170
	Repeating Annotations	171
	Step 1: Declare a Repeatable Annotation Type	172
	Step 2: Declare the Containing Annotation Type	172
	Retrieving Annotations	173
	Design Considerations	173
	Questions and Exercises: Annotations	173
	Questions	173
	Exercise	174
	Answers	174
Chapter 6	Interfaces and Inheritance	175
	Interfaces	175
	Interfaces in Java	176
	Interfaces as APIs	177
	Defining an Interface	177
	Implementing an Interface	178
	Using an Interface as a Type	180
	Evolving Interfaces	181
	Default Methods	182
	Summary of Interfaces	192
	Questions and Exercises: Interfaces	193
	Inheritance	193
	The Java Platform Class Hierarchy	194
	An Example of Inheritance	195
	What You Can Do in a Subclass	196
	Private Members in a Superclass	196
	Casting Objects	197
	Multiple Inheritance of State, Implementation, and Type	198
	Overriding and Hiding Methods	199
	Polymorphism	203
	Hiding Fields	206
	Using the Keyword super	206
	Object as a Superclass	208
	Writing Final Classes and Methods	212
	Abstract Methods and Classes	212

	Summary of Inheritance	216
	Questions and Exercises: Inheritance	216
Chapter 7	Generics	219
	Why Use Generics?	220
	Generic Types	220
	A Simple Box Class	220
	A Generic Version of the Box Class	221
	Type Parameter Naming Conventions	221
	Invoking and Instantiating a Generic Type	222
	The Diamond	223
	Multiple Type Parameters	223
	Parameterized Types	224
	Raw Types	224
	Generic Methods	226
	Bounded Type Parameters	227
	Multiple Bounds	228
	Generic Methods and Bounded Type Parameters	229
	Generics, Inheritance, and Subtypes	229
	Generic Classes and Subtyping	230
	Type Inference	232
	Type Inference and Generic Methods	232
	Type Inference and Instantiation of Generic Classes	233
	Type Inference and Generic Constructors	
	of Generic and Nongeneric Classes	234
	Target Types	235
	Wildcardcards	236
	Upper-Bounded Wildcardcards	236
	Unbounded Wildcardcards	237
	Lower-Bounded Wildcardcards	238
	Wildcardcards and Subtyping	239
	Wildcard Capture and Helper Methods	240
	Guidelines for Wildcard Use	243
	Type Erasure	244
	Erasure of Generic Types	245
	Erasure of Generic Methods	246
	Effects of Type Erasure and Bridge Methods	247
	Nonreifiable Types and Varargs Methods	249
	Restrictions on Generics	252
	Cannot Instantiate Generic Types with Primitive Types	252
	Cannot Create Instances of Type Parameters	253

	Cannot Declare Static Fields Whose Types Are Type Parameters	254
	Cannot Use Casts or instanceof with Parameterized Types	254
	Cannot Create Arrays of Parameterized Types	255
	Cannot Create, Catch, or Throw	
	Objects of Parameterized Types	255
	Cannot Overload a Method Where the Formal Parameter	
	Types of Each Overload Erase to the Same Raw Type	256
	Questions and Exercises: Generics	256
	Answers	258
Chapter 8	Packages	259
	Creating and Using Packages	259
	Creating a Package	261
	Naming a Package	262
	Using Package Members	263
	Managing Source and Class Files	267
	Summary of Creating and Using Packages	269
	Questions and Exercises: Creating and Using Packages	269
	Questions	269
	Exercises	270
	Answers	270
Chapter 9	Numbers and Strings	271
	Numbers	271
	The Numbers Classes	272
	Formatting Numeric Print Output	274
	Beyond Basic Arithmetic	279
	Autoboxing and Unboxing	283
	Summary of Numbers	286
	Questions and Exercises: Numbers	286
	Characters	287
	Escape Sequences	288
	Strings	288
	Creating Strings	289
	String Length	290
	Concatenating Strings	291
	Creating Format Strings	292
	Converting between Numbers and Strings	292
	Manipulating Characters in a String	295
	Comparing Strings and Portions of Strings	300
	The StringBuilder Class	302
	Summary of Characters and Strings	306
	Questions and Exercises: Characters and Strings	307

Chapter 10	Exceptions	309
	What Is an Exception?	310
	The Catch or Specify Requirement	311
	The Three Kinds of Exceptions	311
	Bypassing Catch or Specify	312
	Catching and Handling Exceptions	313
	The try Block	314
	The catch Blocks	315
	The finally Block	316
	The try-with-resources Statement	317
	Putting It All Together	320
	Specifying the Exceptions Thrown by a Method	323
	How to Throw Exceptions	324
	The throw Statement	325
	Throwable Class and Its Subclasses	325
	Error Class	326
	Exception Class	326
	Chained Exceptions	326
	Creating Exception Classes	328
	Unchecked Exceptions: The Controversy	329
	Advantages of Exceptions	330
	Advantage 1: Separating Error-Handling	
	Code from “Regular” Code	331
	Advantage 2: Propagating Errors Up the Call Stack	332
	Advantage 3: Grouping and Differentiating Error Types	334
	Summary	335
	Questions and Exercises: Exceptions	336
	Questions	336
	Exercises	337
	Answers	337
Chapter 11	Basic I/O and NIO.2	339
	I/O Streams	339
	Byte Streams	340
	Character Streams	342
	Buffered Streams	345
	Scanning and Formatting	346
	I/O from the Command Line	352
	Data Streams	354
	Object Streams	357
	File I/O (Featuring NIO.2)	359
	What Is a Path? (And Other File System Facts)	359

The Path Class	362
File Operations	370
Checking a File or Directory	374
Deleting a File or Directory	375
Copying a File or Directory	376
Moving a File or Directory	377
Managing Metadata (File and File Store Attributes)	378
Reading, Writing, and Creating Files	386
Random Access Files	393
Creating and Reading Directories	395
Links, Symbolic or Otherwise	399
Walking the File Tree	401
Finding Files	407
Watching a Directory for Changes	410
Other Useful Methods	416
Legacy File I/O Code	418
Summary	421
Questions and Exercises: Basic I/O	422
Questions	422
Exercises	422
Answers	422
Chapter 12 Collections	423
Introduction to Collections	424
What Is a Collections Framework?	424
Benefits of the Java Collections Framework	425
Interfaces	426
The Collection Interface	428
Traversing Collections	429
Collection Interface Bulk Operations	432
Collection Interface Array Operations	432
The Set Interface	433
The List Interface	438
The Queue Interface	446
The Deque Interface	448
The Map Interface	449
Object Ordering	458
The SortedSet Interface	464
The SortedMap Interface	467
Summary of Interfaces	469
Questions and Exercises: Interfaces	470

Aggregate Operations	471
Pipelines and Streams	472
Differences between Aggregate Operations and Iterators	474
Reduction	474
Parallelism	480
Side Effects	484
Questions and Exercises: Aggregate Operations	487
Implementations	489
Set Implementations	492
List Implementations	493
Map Implementations	495
Queue Implementations	496
Deque Implementations	498
Wrapper Implementations	499
Convenience Implementations	502
Summary of Implementations	504
Questions and Exercises: Implementations	504
Algorithms	505
Sorting	505
Shuffling	508
Routine Data Manipulation	508
Searching	508
Composition	509
Finding Extreme Values	509
Custom Collection Implementations	509
Reasons to Write an Implementation	510
How to Write a Custom Implementation	511
Interoperability	513
Compatibility	513
API Design	515
Chapter 13 Concurrency	519
Processes and Threads	520
Processes	520
Threads	520
Thread Objects	521
Defining and Starting a Thread	521
Pausing Execution with Sleep	522
Interrupts	523
Joins	525
The SimpleThreads Example	525

Synchronization	527
Thread Interference	527
Memory Consistency Errors	528
Synchronized Methods	529
Intrinsic Locks and Synchronization	531
Atomic Access	533
Liveness	533
Deadlock	534
Starvation and Livelock	535
Guarded Blocks	535
Immutable Objects	539
A Synchronized Class Example	540
A Strategy for Defining Immutable Objects	541
High-Level Concurrency Objects	543
Lock Objects	544
Executors	546
Concurrent Collections	552
Atomic Variables	553
Concurrent Random Numbers	554
Questions and Exercises: Concurrency	555
Question	555
Exercises	555
Answers	556
Chapter 14 Regular Expressions	557
Introduction	558
What Are Regular Expressions?	558
How Are Regular Expressions Represented in This Package?	558
Test Harness	559
String Literals	560
Metacharacters	561
Character Classes	562
Simple Classes	562
Predefined Character Classes	566
Quantifiers	568
Zero-Length Matches	569
Capturing Groups and Character Classes with Quantifiers	572
Differences among Greedy, Reluctant, and Possessive Quantifiers	573
Capturing Groups	574
Numbering	574
Backreferences	575

Boundary Matchers	576
Methods of the Pattern Class	578
Creating a Pattern with Flags	578
Embedded Flag Expressions	580
Using the matches(String,CharSequence) Method	580
Using the split(String) Method	581
Other Utility Methods	582
Pattern Method Equivalents in java.lang.String	582
Methods of the Matcher Class	583
Index Methods	583
Study Methods	584
Replacement Methods	584
Using the start and end Methods	585
Using the matches and lookingAt Methods	586
Using replaceFirst(String) and replaceAll(String)	587
Using appendReplacement(StringBuffer,String) and appendTail(StringBuffer)	588
Matcher Method Equivalents in java.lang.String	589
Methods of the PatternSyntaxException Class	589
Unicode Support	591
Matching a Specific Code Point	591
Unicode Character Properties	591
Questions and Exercises: Regular Expressions	592
Questions	592
Exercise	593
Answers	593
Chapter 15 The Platform Environment	595
Configuration Utilities	595
Properties	596
Command-Line Arguments	600
Environment Variables	601
Other Configuration Utilities	602
System Utilities	603
Command-Line I/O Objects	603
System Properties	604
The Security Manager	607
Miscellaneous Methods in System	608
PATH and CLASSPATH	609
Update the PATH Environment Variable (Microsoft Windows)	609
Update the PATH Variable (Solaris, Linux, and OS X)	611
Checking the CLASSPATH Variable (All Platforms)	612

	Questions and Exercises: The Platform Environment	613
	Question	613
	Exercise	614
	Answers	614
Chapter 16	Packaging Programs in JAR Files	615
	Using JAR Files: The Basics	616
	Creating a JAR File	616
	Viewing the Contents of a JAR File	620
	Extracting the Contents of a JAR File	622
	Updating a JAR File	623
	Running JAR-Packaged Software	625
	Working with Manifest Files: The Basics	627
	Understanding the Default Manifest	627
	Modifying a Manifest File	628
	Setting an Application's Entry Point	629
	Adding Classes to the JAR File's Class Path	630
	Setting Package Version Information	631
	Sealing Packages within a JAR File	633
	Enhancing Security with Manifest Attributes	634
	Signing and Verifying JAR Files	635
	Understanding Signing and Verification	636
	Signing JAR Files	639
	Verifying Signed JAR Files	641
	Using JAR-Related APIs	642
	An Example: The JarRunner Application	643
	The JarClassLoader Class	643
	The JarRunner Class	646
	Questions and Exercises: Packaging Programs in JAR Files	648
	Questions	648
	Answers	648
Chapter 17	Java Web Start	649
	Additional References	650
	Developing a Java Web Start Application	650
	Creating the Top JPanel Class	651
	Creating the Application	652
	Benefits of Separating Core Functionality from the Final Deployment Mechanism	652
	Retrieving Resources	653
	Deploying a Java Web Start Application	653
	Setting Up a Web Server	656

Displaying a Customized Loading Progress Indicator	656
Developing a Customized Loading Progress Indicator	657
Specifying a Customized Loading Progress Indicator for a Java Web Start Application	659
Running a Java Web Start Application	660
Running a Java Web Start Application from a Browser	660
Running a Java Web Start Application from the Java Cache Viewer	660
Running a Java Web Start Application from the Desktop	661
Java Web Start and Security	661
Dynamic Downloading of HTTPS Certificates	662
Common Java Web Start Problems	662
“My Browser Shows the Java Network Launch Protocol (JNLP) File for My Application as Plain Text”	663
“When I Try to Launch My JNLP File, I Get the Following Error”	663
Questions and Exercises: Java Web Start	663
Questions	663
Exercises	664
Answers	664
Chapter 18 Applets	665
Getting Started with Applets	666
Defining an Applet Subclass	666
Methods for Milestones	667
Life Cycle of an Applet	668
Applet’s Execution Environment	670
Developing an Applet	670
Deploying an Applet	673
Doing More with Applets	677
Finding and Loading Data Files	677
Defining and Using Applet Parameters	678
Displaying Short Status Strings	681
Displaying Documents in the Browser	682
Invoking JavaScript Code from an Applet	683
Invoking Applet Methods from JavaScript Code	686
Handling Initialization Status with Event Handlers	689
Manipulating DOM of Applet’s Web Page	691
Displaying a Customized Loading Progress Indicator	693
Writing Diagnostics to Standard Output and Error Streams	698
Developing Draggable Applets	698
Communicating with Other Applets	701

	Working with a Server-Side Application	703
	What Applets Can and Cannot Do	705
	Solving Common Applet Problems	707
	“My Applet Does Not Display”	707
	“The Java Console Log Displays java.lang.ClassNotFoundException”	708
	“I Was Able to Build the Code Once, but Now the Build Fails Even Though There Are No Compilation Errors”	708
	“When I Try to Load a Web Page That Has an Applet, My Browser Redirects Me to www.java.com without Any Warning”	708
	“I Fixed Some Bugs and Rebuilt My Applet’s Source Code. When I Reload the Applet’s Web Page, My Fixes Are Not Showing Up”	708
	Questions and Exercises: Applets	708
	Questions	708
	Exercises	709
	Answers	709
Chapter 19	Doing More with Java Rich Internet Applications	711
	Setting Trusted Arguments and Secure Properties	711
	System Properties	713
	JNLP API	714
	Accessing the Client Using the JNLP API	715
	Cookies	719
	Types of Cookies	719
	Cookie Support in RIAs	719
	Accessing Cookies	720
	Customizing the Loading Experience	722
	Security in Rich Internet Applications	722
	Guidelines for Securing RIAs	724
	Follow Secure Coding Guidelines	724
	Test with the Latest Version of the JRE	724
	Include Manifest Attributes	725
	Use a Signed JNLP File	725
	Sign and Time Stamp JAR Files	725
	Use the HTTPS Protocol	726
	Avoid Local RIAs	726
	Questions and Exercises: Doing More with Rich Internet Applications	726
	Questions	726

	Exercise	726
	Answers	727
Chapter 20	Deployment in Depth	729
	User Acceptance of RIAs	729
	Deployment Toolkit	731
	Location of Deployment Toolkit Script	731
	Deploying an Applet	732
	Deploying a Java Web Start Application	735
	Checking the Client JRE Software Version	738
	Java Network Launch Protocol	739
	Structure of the JNLP File	739
	Deployment Best Practices	748
	Reducing the Download Time	748
	Avoiding Unnecessary Update Checks	749
	Ensuring the Presence of the JRE Software	751
	Questions and Exercises: Deployment in Depth	753
	Questions	753
	Exercise	753
	Answers	753
Chapter 21	Date-Time	755
	Date-Time Overview	756
	Date-Time Design Principles	756
	Clear	756
	Fluent	757
	Immutable	757
	Extensible	757
	The Date-Time Packages	757
	Method Naming Conventions	758
	Standard Calendar	759
	Overview	759
	DayOfWeek and Month Enums	760
	DayOfWeek	760
	Month	762
	Date Classes	762
	LocalDate	763
	YearMonth	763
	MonthDay	764
	Year	764
	Date and Time Classes	764
	LocalTime	764

LocalDateTime	765
Time Zone and Offset Classes	766
ZoneId and ZoneOffset	766
The Date-Time Classes	767
Instant Class	770
Parsing and Formatting	772
Parsing	772
Formatting	773
The Temporal Package	774
Temporal and TemporalAccessor	774
ChronoField and IsoFields	775
ChronoUnit	775
Temporal Adjuster	776
Temporal Query	778
Period and Duration	780
Duration	781
ChronoUnit	781
Period	782
Clock	783
Non-ISO Date Conversion	784
Converting to a Non-ISO-Based Date	784
Converting to an ISO-Based Date	786
Legacy Date-Time Code	787
Interoperability with Legacy Code	787
Mapping java.util Date and Time	
Functionality to java.time	788
Date and Time Formatting	789
Summary	789
Questions and Exercises: Date-Time	791
Questions	791
Exercises	791
Answers	791
Chapter 22 Introduction to JavaFX	793
Appendix Preparation for Java Programming Language Certification	795
Programmer Level I Exam	795
Section 1: Java Basics	795
Section 2: Working with Java Data Types	796
Section 3: Using Operators and Decision Constructs	797
Section 4: Creating and Using Arrays	797
Section 5: Using Loop Constructs	798

Section 6: Working with Methods and Encapsulation	798
Section 7: Working with Inheritance	799
Section 8: Handling Exceptions	799
Section 9: Working with Selected Classes from the Java API	800
Programmer Level II Exam	801
Java SE 8 Upgrade Exam	801
Section 1: Lambda Expressions	801
Section 2: Using Built-In Lambda Types	801
Section 3: Filtering Collections with Lambdas	802
Section 4: Collection Operations with Lambda	803
Section 5: Parallel Streams	803
Section 6: Lambda Cookbook	804
Section 7: Method Enhancements	804
Section 8: Use Java SE 8 Date/Time API	804
Section 9: JavaScript on Java with Nashorn	805
Index	807

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Preface

Since the acquisition of Sun Microsystems by Oracle Corporation in early 2010, it has been an exciting time for the Java language. As evidenced by the activities of the Java Community Process program, the Java language continues to evolve. The publication of this sixth edition of *The Java® Tutorial* reflects version 8 of the Java Platform Standard Edition (Java SE) and references the Application Programming Interface (API) of that release.

This edition introduces new features added to the platform since the publication of the fifth edition (under release 7):

- Lambda expressions enable you to treat functionality as a method argument or code as data. Lambda expressions let you express instances of single-method interfaces (referred to as functional interfaces) more compactly. See the new section in Chapter 4, “Lambda Expressions.”
- Type annotations can be used in conjunction with pluggable type systems for improved type checking, and repeating annotations enable the application of the same annotation to a declaration or type use. See the new sections in Chapter 5, “Type Annotations and Pluggable Type Systems” and “Repeating Annotations.”
- Default methods are methods in an interface that have an implementation. They enable new functionality to be added to the interfaces of libraries and ensure binary compatibility with code written for older versions of those interfaces. See the new section in Chapter 6, “Default Methods.”

- Aggregate operations enable you to perform functional-style operations on streams of elements—in particular, bulk operations on collections such as sequential or parallel map-reduce transformations. See the new section in Chapter 12, “Aggregate Operations.”
- Improvements have been added that focus on limiting attackers from using malicious applets and rich Internet applications (RIAs). See the following new and updated sections:
 - Chapter 16, “Packaging Programs in JAR Files”
 - Chapter 19, “Security in Rich Internet Applications” and “Guidelines for Securing Rich Internet Applications”
 - Chapter 20, “Deployment Best Practices”
- Date-Time APIs enable you to represent dates and times and manipulate date and time values. They support the International Organization for Standardization (ISO) calendar system as well as other commonly used global calendars. See the new Chapter 21.

If you plan to take one of the Java SE 8 certification exams, this book can help. The appendix, “Preparation for Java Programming Language Certification,” lists the three exams that are available, detailing the items covered by each exam, cross-referenced to places in the book where you can find more information about each topic. Note that this is one source, among others, that you will want to use to prepare for your exam. Check the online tutorial for the latest certification objectives and cross-references to sections of the tutorial.

All of the material has been thoroughly reviewed by members of Oracle Java engineering to ensure that the information is accurate and up to date. This book is based on the online tutorial hosted on Oracle Corporation’s web site at the following URL:

<http://docs.oracle.com/javase/tutorial/>

The information in this book, often referred to as “the core tutorial,” is required by most beginning to intermediate programmers. Once you have mastered this material, you can explore the rest of the Java platform documentation on the web site. If you are interested in developing sophisticated RIAs, check out JavaFX, the Java graphical user interface (GUI) toolkit, which comes with the Java SE Development Kit (JDK). To learn more, see Chapter 22, “Introduction to JavaFX.”

As always, our goal is to create an easy-to-read, practical programmers’ guide to help you learn how to use the rich environment provided by Java to build applications, applets, and components. Go forth and program!

Who Should Read This Book?

This book is geared toward both novice and experienced programmers:

- *New programmers* can benefit most from reading the book from beginning to end, including the step-by-step instructions for compiling and running your first program in Chapter 1, “Getting Started.”
- *Programmers experienced with procedural languages* such as C may want to start with the material on object-oriented concepts and features of the Java programming language.
- *Experienced programmers* may want to jump feet first into the more advanced topics, such as generics, concurrency, or deployment.

This book contains information to address the learning needs of programmers with various levels of experience.

How to Use This Book

This book is designed so you can read it straight through or skip around from topic to topic. The information is presented in a logical order, and forward references are avoided wherever possible.

The examples in this book are compiled against the JDK 8 release. *You need to download this release (or later) in order to compile and run most examples.*

Some material referenced in this book is available online—for example, the downloadable examples, the solutions to the questions and exercises, the JDK 8 guides, and the API specification.

You will see footnotes like the following:

`8/docs/api/java/lang/Class.html`

and

`tutorial/java/generics/examples/BoxDemo.java`

The Java documentation home on the Oracle web site is at the following location:

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

To locate the footnoted files online, prepend the URL for the Java documentation home:

`http://docs.oracle.com/javase/8/docs/api/java/lang/Class.html`

<http://docs.oracle.com/javase/tutorial/java/generics/examples/BoxDemo.java>

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Language Basics

Chapter Contents

Variables	44
Operators	58
Expressions, Statements, and Blocks	68
Control Flow Statements	72

You've already learned that objects store their state in fields. However, the Java programming language uses the term *variable* as well. The first section of this chapter discusses this relationship, plus variable naming rules and conventions, basic data types (primitive types, character strings, and arrays), default values, and literals.

The second section describes the operators of the Java programming language. It presents the most commonly used operators first and the less commonly used operators last. Each discussion includes code samples that you can compile and run.

Operators may be used for building expressions, which compute values; expressions are the core components of statements, and statements may be grouped into blocks. The third section discusses expressions, statements, and blocks using example code that you've already seen.

The final section describes the control flow statements supported by the Java programming language. It covers the decision-making, looping, and branching statements that enable your programs to conditionally execute particular blocks of code.

Note that each section contains its own questions and exercises to test your understanding.

Variables

As you learned in the previous chapter, an object stores its state in *fields*:

3

```
int cadence = 0;
int speed = 0;
int gear = 1;
```

In Chapter 2, the section “What Is an Object?” introduced you to fields, but you probably have still a few questions, such as, What are the rules and conventions for naming a field? Besides `int`, what other data types are there? Do fields have to be initialized when they are declared? Are fields assigned a default value if they are not explicitly initialized? We’ll explore the answers to such questions in this chapter, but before we do, there are a few technical distinctions you must first become aware of. In the Java programming language, the terms *field* and *variable* are both used; this is a common source of confusion among new developers because both often seem to refer to the same thing. The Java programming language defines the following kinds of variables:

- *Instance variables (nonstatic fields)*. Technically speaking, objects store their individual states in “nonstatic fields”—that is, fields declared without the `static` keyword. Nonstatic fields are also known as *instance variables* because their values are unique to each *instance* of a class (to each object, in other words); for example, the `currentSpeed` of one bicycle is independent of the `currentSpeed` of another.
- *Class variables (static fields)*. A *class variable* is any field declared with the `static` modifier; this tells the compiler that there is exactly one copy of this variable in existence, regardless of how many times the class has been instantiated. For example, a field defining the number of gears for a particular kind of bicycle could be marked as `static` since conceptually the same number of gears will apply to all instances. The code `static int numGears = 6;` would create such a static field. Additionally, the keyword `final` could be added to indicate that the number of gears will never change.
- *Local variables*. Similar to how an object stores its state in fields, a method will often store its temporary state in *local variables*. The syntax for declaring a local variable is similar to declaring a field (e.g., `int count = 0;`). There is no special keyword designating a variable as local; that determination comes entirely from the location in which the variable is declared—which is between the opening and closing braces of a method. As such, local variables are only visible to the methods in which they are declared; they are not accessible from the rest of the class.

- *Parameters.* You’ve already seen examples of parameters, both in the `Bicycle` class and in the `main` method of the “Hello World!” application. Recall that the signature for the `main` method is `public static void main(String[] args)`. Here, the `args` variable is the parameter to this method. The important thing to remember is that parameters are always classified as *variables*, not *fields*. This applies to other parameter-accepting constructs as well (such as constructors and exception handlers) that you’ll learn about later in the chapter.

That said, the remainder of the chapters use the following general guidelines when discussing fields and variables. If we are talking about *fields in general* (excluding local variables and parameters), we may simply use the term *fields*. If the discussion applies to *all of the above*, we may simply use the term *variables*. If the context calls for a distinction, we will use specific terms (such as *static field* or *local variables*) as appropriate. You may also occasionally see the term *member* used as well. A type’s fields, methods, and nested types are collectively called its *members*.

Naming

Every programming language has its own set of rules and conventions for the kinds of names that you’re allowed to use, and the Java programming language is no different. The rules and conventions for naming your variables can be summarized as follows:

- Variable names are case sensitive. A variable’s name can be any legal identifier—an unlimited-length sequence of Unicode letters and digits, beginning with a letter, the dollar sign (`$`), or the underscore character (`_`). The convention, however, is to always begin your variable names with a letter, not `$` or `_`. Additionally, the dollar sign character, by convention, is never used at all. You may find some situations where autogenerated names will contain the dollar sign, but your variable names should always avoid using it. A similar convention exists for the underscore character; while it’s technically legal to begin your variable’s name with `_`, this practice is discouraged. White space is not permitted.
- Subsequent characters may be letters, digits, dollar signs, or underscore characters. Conventions (and common sense) apply to this rule as well. When choosing a name for your variables, use full words instead of cryptic abbreviations. Doing so will make your code easier to read and understand. In many cases, it will also make your code self-documenting; fields named `cadence`, `speed`, and `gear`, for example, are much more intuitive than abbreviated versions, such as

s, c, and g. Also keep in mind that the name you choose must not be a keyword or reserved word.

- If the name you choose consists of only one word, spell that word in all lowercase letters. If it consists of more than one word, capitalize the first letter of each subsequent word. The names `gearRatio` and `currentGear` are prime examples of this convention. If your variable stores a constant value, such as `static final int NUM_GEAR = 6`, the convention changes slightly, capitalizing every letter and separating subsequent words with the underscore character. By convention, the underscore character is never used elsewhere.

3

Primitive Data Types

The Java programming language is statically typed, which means that all variables must first be declared before they can be used. This involves stating the variable's type and name, as you've already seen:

```
int gear = 1;
```

Doing so tells your program that a field named *gear* exists, holds numerical data, and has an initial value of 1. A variable's data type determines the values it may contain plus the operations that may be performed on it. In addition to `int`, the Java programming language supports seven other *primitive data types*. A primitive type is predefined by the language and is named by a reserved keyword. Primitive values do not share state with other primitive values. The eight primitive data types supported by the Java programming language are as follows:

1. The **byte** data type is an 8-bit signed two's complement integer. It has a minimum value of -128 and a maximum value of 127 (inclusive). The `byte` data type can be useful for saving memory in large arrays, where the memory savings actually matters. It can also be used in place of `int` where its limits help clarify your code; the fact that a variable's range is limited can serve as a form of documentation.
2. The **short** data type is a 16-bit signed two's complement integer. It has a minimum value of $-32,768$ and a maximum value of $32,767$ (inclusive). As with `byte`, the same guidelines apply: you can use a `short` to save memory in large arrays in situations where the memory savings actually matter.
3. By default, the **int** data type is a 32-bit signed two's complement integer, which has a minimum value of -2^{31} and a maximum value of $2^{31} - 1$. In Java SE 8 and later, you can use the `int` data type to represent an unsigned 32-bit integer, which has a minimum value of 0 and a maximum value of $2^{32} - 1$. The `Integer` class also supports unsigned 32-bit integers. Static methods like

`compareUnsigned` and `divideUnsigned` have been added to the `Integer` class to support arithmetic operations for unsigned integers.¹

4. The **long** data type is a 64-bit two's complement integer. The signed `long` has a minimum value of -2^{63} and a maximum value of $2^{63} - 1$. In Java SE 8 and later, you can use the `long` data type to represent an unsigned 64-bit `long`, which has a minimum value of 0 and a maximum value of $2^{64} - 1$. Use this data type when you need a range of values wider than those provided by the `int` data type. The `Long` class also contains methods like `compareUnsigned` and `divideUnsigned` to support arithmetic operations for unsigned `long` values.²
5. The **float** data type is a single-precision 32-bit IEEE 754 floating-point value. Its range of values is beyond the scope of this discussion but is specified in the Floating-Point Types, Formats, and Values section of the Java Language Specification.³ As with the recommendations for the `byte` and `short` data types, use a `float` (instead of `double`) value if you need to save memory in large arrays of floating-point numbers. This data type should never be used for precise values, such as currency. For that, you will need to use the `java.math.BigDecimal` class instead.⁴ Chapter 9 covers `BigDecimal` and other useful classes provided by the Java platform.
6. The **double** data type is a double-precision 64-bit IEEE 754 floating-point value. Its range of values is beyond the scope of this discussion but is specified in the Floating-Point Types, Formats, and Values section of the Java Language Specification.⁵ For decimal values, this data type is generally the default choice. As mentioned previously, this data type should never be used for precise values, such as currency.
7. The **boolean** data type has only two possible values: `true` and `false`. Use this data type for simple flags that track true/false conditions. This data type represents one bit of information, but its "size" isn't something that's precisely defined.
8. The **char** data type is a single 16-bit Unicode character. It has a minimum value of `'\u0000'` (or 0) and a maximum value of `'\uffff'` (or 65,535 inclusive).

In addition to the eight primitive data types, the Java programming language also provides special support for character strings through the `java.lang.String`

-
1. [8/docs/api/java/lang/Integer.html](https://docs.oracle.com/javase/8/docs/api/java/lang/Integer.html)
 2. [8/docs/api/java/lang/Long.html](https://docs.oracle.com/javase/8/docs/api/java/lang/Long.html)
 3. [specs/jls/se7/html/jls-4.html#jls-4.2.3](https://docs.oracle.com/javase/7/docs/specs/jls/se7/html/jls-4.html#jls-4.2.3)
 4. [8/docs/api/java/math/BigDecimal.html](https://docs.oracle.com/javase/8/docs/api/java/math/BigDecimal.html)
 5. [specs/jls/se7/html/jls-4.html#jls-4.2.3](https://docs.oracle.com/javase/7/docs/specs/jls/se7/html/jls-4.html#jls-4.2.3)

class.⁶ Enclosing your character string within double quotes will automatically create a new `String` object—for example, `String s = "this is a string";`. `String` objects are *immutable*, which means that, once created, their values cannot be changed. The `String` class is not technically a primitive data type, but considering the special support given to it by the language, you'll probably tend to think of it as such. You'll learn more about the `String` class in Chapter 9.

Default Values

It's not always necessary to assign a value when a field is declared. Fields that are declared but not initialized will be set to a reasonable default by the compiler. Generally speaking, this default will be zero or `null`, depending on the data type. Relying on such default values, however, is generally considered bad programming style. Table 3.1 summarizes the default values for the above data types.

Local variables are slightly different; the compiler never assigns a default value to an uninitialized local variable. If you cannot initialize your local variable where it is declared, make sure to assign it a value before you attempt to use it. Accessing an uninitialized local variable will result in a compile-time error.

Literals

You may have noticed that the `new` keyword isn't used when initializing a variable of a primitive type. Primitive types are special data types built into the language; they are not objects created from a class. A *literal* is the source code representation of a fixed value; literals are represented directly in your code without requiring computation. As shown here, it's possible to assign a literal to a variable of a primitive type:

```
boolean result = true;
char capitalC = 'C';
byte b = 100;
short s = 10000;
int i = 100000;
```

Integer Literals

An integer literal is of type `long` if it ends with the letter `L` or `l`; otherwise, it is of type `int`. It is recommended that you use the uppercase letter `L` because the lowercase letter `l` is hard to distinguish from the digit `1`.

Values of the integral types `byte`, `short`, `int`, and `long` can be created from `int` literals. Values of type `long` that exceed the range of `int` can be created from `long` literals. Integer literals can be expressed by these number systems:

6. <8/docs/api/java/lang/String.html>

Table 3.1 Default Values for Data Types

Data type	Default value (for fields)
byte	0
short	0
int	0
long	0L
float	0.0f
double	0.0d
boolean	false
char	'\u0000'
String (or any object)	null

- *Decimal*. Base 10, whose digits consist of the numbers 0 through 9 (This is the number system you use every day.)
- *Hexadecimal*. Base 16, whose digits consist of the numbers 0 through 9 and the letters A through F
- *Binary*. Base 2, whose digits consists of the numbers 0 and 1

For general-purpose programming, the decimal system is likely to be the only number system you'll ever use. However, if you need to use another number system, the following example shows the correct syntax. The prefix `0x` indicates hexadecimal and `0b` indicates binary:

```
// The number 26, in decimal
int decVal = 26;
// The number 26, in hexadecimal
int hexVal = 0x1a;
// The number 26, in binary
int binVal = 0b11010;
```

Floating-Point Literals

A floating-point literal is of type `float` if it ends with the letter `F` or `f`; otherwise, its type is `double` and it can optionally end with the letter `D` or `d`. The floating-point types (`float` and `double`) can also be expressed using `E` or `e` (for scientific notation), `F` or `f` (32-bit float literal), and `D` or `d` (64-bit double literal, which is the default and by convention is omitted).

```
double d1 = 123.4;
// same value as d1, but in scientific notation
double d2 = 1.234e2;
float f1 = 123.4f;
```

Character and String Literals

Literals of types `char` and `String` may contain any Unicode (UTF-16) characters. If your editor and file system allow it, you can use such characters directly in your code. If not, you can use a *Unicode escape*, such as `'\u0108'` (for a capital C with circumflex, \hat{C}) or `"S\u00ED se\u00F1or"` (for *Sí Señor* in Spanish). Always use ‘single quotes’ for `char` literals and “double quotes” for `String` literals. Unicode escape sequences may be used elsewhere in a program (such as in field names, for example), not just in `char` or `String` literals.

The Java programming language also supports a few special escape sequences for `char` and `String` literals: `\b` (backspace), `\t` (tab), `\n` (line feed), `\f` (form feed), `\r` (carriage return), `\"` (double quote), `\'` (single quote), and `\\` (backslash).

There’s also a special `null` literal that can be used as a value for any reference type. You may assign `null` to any variable except variables of primitive types. There’s little you can do with a `null` value beyond testing for its presence. Therefore, `null` is often used in programs as a marker to indicate that some object is unavailable.

Finally, there’s also a special kind of literal called a *class literal*, formed by taking a type name and appending `.class` (e.g., `String.class`). This refers to the object (of type `Class`) that represents the type itself.

Using Underscore Characters in Numeric Literals

Any number of underscore characters (`_`) can appear anywhere between digits in a numerical literal. This feature enables you, for example, to separate groups of digits in numeric literals, which can improve the readability of your code.

For instance, if your code contains numbers with many digits, you can use an underscore character to separate digits in groups of three, similar to how you would use a punctuation mark like a comma or a space as a separator.

The following example shows other ways you can use the underscore in numeric literals:

```
long creditCardNumber = 1234_5678_9012_3456L;
long socialSecurityNumber = 999_99_9999L;
float pi = 3.14_15F;
long hexBytes = 0xFF_EC_DE_5E;
long hexWords = 0xCAFE_BABE;
long maxLong = 0x7fff_ffff_ffff_ffffL;
byte nybbles = 0b0010_0101;
long bytes = 0b11010010_01101001_10010100_10010010;
```

You can place underscores only between digits; you cannot place underscores in the following places:

- At the beginning or end of a number
- Adjacent to a decimal point in a floating-point literal
- Prior to an F or L suffix
- In positions where a string of digits is expected

The following examples demonstrate valid and invalid underscore placements (which are bold) in numeric literals:

```
// Invalid: cannot put underscores
// adjacent to a decimal point
float pi1 = 3_.1415F;
// Invalid: cannot put underscores
// adjacent to a decimal point
float pi2 = 3._1415F;
// Invalid: cannot put underscores
// prior to an L suffix
long socialSecurityNumber1 = 999_99_9999_L;

// OK (decimal literal)
int x1 = 5_2;
// Invalid: cannot put underscores
// At the end of a literal
int x2 = 52_;
// OK (decimal literal)
int x3 = 5_____2;

// Invalid: cannot put underscores
// in the 0x radix prefix
int x4 = 0_x52;
// Invalid: cannot put underscores
// at the beginning of a number
int x5 = 0x_52;
// OK (hexadecimal literal)
int x6 = 0x5_2;
// Invalid: cannot put underscores
// at the end of a number
int x7 = 0x52_;
```

Arrays

An *array* is a container object that holds a fixed number of values of a single type. The length of an array is established when the array is created. After creation, its length is fixed. You have seen an example of arrays already, in the `main` method of the “Hello World!” application. This section discusses arrays in greater detail.

Each item in an array is called an *element*, and each element is accessed by its numerical *index*. As shown in the preceding illustration, numbering begins with 0. The ninth element, for example, would therefore be accessed at index 8.

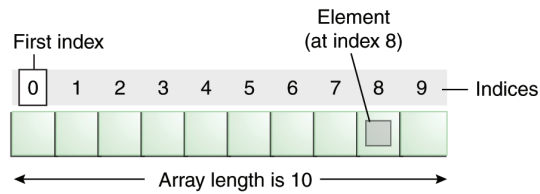


Figure 3.1 An Array of Ten Elements

The following program, `ArrayDemo`, creates an array of integers, puts some values in the array, and prints each value to standard output:

```
class ArrayDemo {
    public static void main(String[] args) {
        // declares an array of integers
        int[] anArray;

        // allocates memory for 10 integers
        anArray = new int[10];

        // initialize first element
        anArray[0] = 100;
        // initialize second element
        anArray[1] = 200;
        // and so forth
        anArray[2] = 300;
        anArray[3] = 400;
        anArray[4] = 500;
        anArray[5] = 600;
        anArray[6] = 700;
        anArray[7] = 800;
        anArray[8] = 900;
        anArray[9] = 1000;

        System.out.println("Element at index 0: "
            + anArray[0]);
        System.out.println("Element at index 1: "
            + anArray[1]);
        System.out.println("Element at index 2: "
            + anArray[2]);
        System.out.println("Element at index 3: "
            + anArray[3]);
        System.out.println("Element at index 4: "
            + anArray[4]);
        System.out.println("Element at index 5: "
            + anArray[5]);
        System.out.println("Element at index 6: "
            + anArray[6]);
        System.out.println("Element at index 7: "
            + anArray[7]);
        System.out.println("Element at index 8: "
            + anArray[8]);
        System.out.println("Element at index 9: "
            + anArray[9]);
    }
}
```


Here is the output from this program:

```
Element at index 0: 100
Element at index 1: 200
Element at index 2: 300
Element at index 3: 400
Element at index 4: 500
Element at index 5: 600
Element at index 6: 700
Element at index 7: 800
Element at index 8: 900
Element at index 9: 1000
```

In a real-world programming situation, you would probably use one of the supported *looping constructs* to iterate through each element of the array, rather than write each line individually as in the preceding example. However, the example clearly illustrates the array syntax. You will learn about the various looping constructs (`for`, `while`, and `do-while`) later in the “Control Flow” section.

Declaring a Variable to Refer to an Array

The preceding program declares an array (named `anArray`) with the following code:

```
// declares an array of integers
int[] anArray;
```

Like declarations for variables of other types, an array declaration has two components: the array’s type and the array’s name. An array’s type is written as *type* `[]`, where *type* is the data type of the contained elements; the brackets are special symbols indicating that this variable holds an array. The size of the array is not part of its type (which is why the brackets are empty). An array’s name can be anything you want, provided that it follows the rules and conventions as previously discussed in the “Naming” section. As with variables of other types, the declaration does not actually create an array; it simply tells the compiler that this variable will hold an array of the specified type. Similarly, you can declare arrays of other types:

```
byte[] anArrayOfBytes;
short[] anArrayOfShorts;
long[] anArrayOfLongs;
float[] anArrayOfFloats;
double[] anArrayOfDoubles;
boolean[] anArrayOfBooleans;
char[] anArrayOfChars;
String[] anArrayOfStrings;
```

You can also place the brackets after the array’s name:

```
// this form is discouraged
float anArrayOfFloats[];
```

However, convention discourages this form; the brackets identify the array type and should appear with the type designation.

Creating, Initializing, and Accessing an Array

3

One way to create an array is with the `new` operator. The next statement in the `ArrayDemo` program allocates an array with enough memory for ten integer elements and assigns the array to the `anArray` variable:

```
// create an array of integers
anArray = new int[10];
```

If this statement is missing, then the compiler prints an error like the following and compilation fails:

```
ArrayDemo.java:4: Variable anArray may not have been initialized.
```

The next few lines assign values to each element of the array:

```
anArray[0] = 100; // initialize first element
anArray[1] = 200; // initialize second element
anArray[2] = 300; // and so forth
```

Each array element is accessed by its numerical index:

```
System.out.println("Element 1 at index 0: " + anArray[0]);
System.out.println("Element 2 at index 1: " + anArray[1]);
System.out.println("Element 3 at index 2: " + anArray[2]);
```

Alternatively, you can use the shortcut syntax to create and initialize an array:

```
int[] anArray = {
    100, 200, 300,
    400, 500, 600,
    700, 800, 900, 1000
};
```

Here the length of the array is determined by the number of values provided between braces and separated by commas.

You can also declare an array of arrays (also known as a *multidimensional* array) by using two or more sets of brackets, such as `String[][]` names. Each element, therefore, must be accessed by a corresponding number of index values.

In the Java programming language, a multidimensional array is an array whose components are themselves arrays. This is unlike arrays in C or Fortran. A consequence of this is that the rows are allowed to vary in length, as shown in the following `MultiDimArrayDemo` program:

```
class MultiDimArrayDemo {
    public static void main(String[] args) {
        String[][] names = {
            {"Mr. ", "Mrs. ", "Ms. "},
            {"Smith", "Jones"}
        };
        // Mr. Smith
        System.out.println(names[0][0] + names[1][0]);
        // Ms. Jones
        System.out.println(names[0][2] + names[1][1]);
    }
}
```

Here is the output from this program:

```
Mr. Smith
Ms. Jones
```

Finally, you can use the built-in `length` property to determine the size of any array. The following code prints the array's size to standard output:

```
System.out.println(anArray.length);
```

Copying Arrays

The `System` class has an `arraycopy()` method that you can use to efficiently copy data from one array into another:

```
public static void arraycopy(Object src, int srcPos,
                             Object dest, int destPos, int length)
```

The two `Object` arguments specify the array to copy *from* and the array to copy *to*. The three `int` arguments specify the starting position in the source array, the starting position in the destination array, and the number of array elements to copy.

The following program, `ArrayCopyDemo`, declares an array of `char` elements, spelling the word *decaffeinated*. It uses the `System.arraycopy()` method to copy a subsequence of array components into a second array:

```
class ArrayCopyDemo {
    public static void main(String[] args) {
        char[] copyFrom = { 'd', 'e', 'c', 'a', 'f', 'f', 'e',
                           'i', 'n', 'a', 't', 'e', 'd' };
        char[] copyTo = new char[7];

        System.arraycopy(copyFrom, 2, copyTo, 0, 7);
        System.out.println(new String(copyTo));
    }
}
```

Here is output from this program:

```
caffein
```

3

Array Manipulations

Arrays are a powerful and useful concept in programming. Java SE provides methods to perform some of the most common manipulations related to arrays. For instance, the `ArrayCopyDemo` example uses the `arraycopy()` method of the `System` class instead of manually iterating through the elements of the source array and placing each one into the destination array. This is performed behind the scenes, enabling the developer to use just one line of code to call the method.

For your convenience, Java SE provides several methods for performing array manipulations (common tasks such as copying, sorting, and searching arrays) in the `java.util.Arrays` class.⁷ For instance, the previous example can be modified to use the `copyOfRange()` method of the `java.util.Arrays` class, as you can see in the `ArrayCopyOfDemo` example. The difference is that using the `copyOfRange()` method does not require you to create the destination array before calling the method because the destination array is returned by the method:

```
class ArrayCopyOfDemo {
    public static void main(String[] args) {

        char[] copyFrom = {'d', 'e', 'c', 'a', 'f', 'f', 'e',
            'i', 'n', 'a', 't', 'e', 'd'};

        char[] copyTo = java.util.Arrays.copyOfRange(copyFrom, 2, 9);

        System.out.println(new String(copyTo));
    }
}
```

As you can see, the output from this program is the same (`caffein`), although it requires fewer lines of code.

Some other useful operations provided by methods in the `java.util.Arrays` class are as follows:

- Search an array for a specific value to get the index at which it is placed (the `binarySearch()` method).
- Compare two arrays to determine if they are equal or not (the `equals()` method).
- Fill an array to place a specific value at each index (the `fill()` method).

7. 8/docs/api/java/util/Arrays.html

- Sort an array into ascending order. This can be done either sequentially, using the `sort()` method, or concurrently, using the `parallelSort()` method introduced in Java SE 8. Parallel sorting of large arrays on multiprocessor systems is faster than sequential array sorting.

Summary of Variables

The Java programming language uses both *fields* and *variables* as part of its terminology. Instance variables (nonstatic fields) are unique to each instance of a class. Class variables (static fields) are fields declared with the `static` modifier; there is exactly one copy of a class variable, regardless of how many times the class has been instantiated. Local variables store temporary state inside a method. Parameters are variables that provide extra information to a method; both local variables and parameters are always classified as *variables* (not *fields*). When naming your fields or variables, there are rules and conventions that you should (or must) follow.

The eight primitive data types are `byte`, `short`, `int`, `long`, `float`, `double`, `boolean`, and `char`. The `java.lang.String` class represents character strings.⁸ The compiler will assign a reasonable default value for fields of these types; for local variables, a default value is never assigned. A literal is the source code representation of a fixed value. An array is a container object that holds a fixed number of values of a single type. The length of an array is established when the array is created. After creation, its length is fixed.

Questions and Exercises: Variables

Questions

1. The term *instance variable* is another name for ____.
2. The term *class variable* is another name for ____.
3. A local variable stores temporary state; it is declared inside a ____.
4. A variable declared within the opening and closing parenthesis of a method signature is called a ____.
5. What are the eight primitive data types supported by the Java programming language?
6. Character strings are represented by the class ____.
7. An ____ is a container object that holds a fixed number of values of a single type.

8. [8/docs/api/java/lang/String.html](https://docs/api/java/lang/String.html)

Exercises

1. Create a small program that defines some fields. Try creating some illegal field names and see what kind of error the compiler produces. Use the naming rules and conventions as a guide.
2. In the program you created in Exercise 1, try leaving the fields uninitialized and print out their values. Try the same with a local variable and see what kind of compiler errors you can produce. Becoming familiar with common compiler errors will make it easier to recognize bugs in your code.

Answers

You can find answers to these questions and exercises at http://docs.oracle.com/javase/tutorial/java/nutsandbolts/QandE/answers_variables.html.

Operators

Now that you've learned how to declare and initialize variables, you probably want to know how to *do something* with them. Learning the operators of the Java programming language is a good place to start. Operators are special symbols that perform specific operations on one, two, or three *operands* and then return a result.

As we explore the operators of the Java programming language, it may be helpful for you to know ahead of time which operators have the highest precedence. The operators in Table 3.2 are listed according to precedence order. The closer to the top of the table an operator appears, the higher its precedence. Operators with higher precedence are evaluated before operators with relatively lower precedence. Operators on the same line have equal precedence. When operators of equal precedence appear in the same expression, a rule must govern which is evaluated first. All binary operators except for the assignment operators are evaluated from left to right; assignment operators are evaluated right to left.

In general-purpose programming, certain operators tend to appear more frequently than others; for example, the assignment operator (=) is far more common than the unsigned right shift operator (>>>). With that in mind, the following discussion focuses first on the operators that you're most likely to use on a regular basis and ends focusing on those that are less common. Each discussion is accompanied by sample code that you can compile and run. Studying its output will help reinforce what you've just learned.

Table 3.2 Operator Precedence

Operators	Precedence
Postfix	<i>expr</i> ++ <i>expr</i> --
unary	++ <i>expr</i> -- <i>expr</i> + <i>expr</i> - <i>expr</i> ~ !
multiplicative	* / %
additive	+ -
shift	<< >> >>>
relational	< > <= >= instanceof
equality	== !=
bitwise AND	&
bitwise exclusive OR	^
bitwise inclusive OR	
logical AND	&&
logical OR	
ternary	? :
assignment	= += -= *= /= %= &= ^= = <<= >>= >>>=

Assignment, Arithmetic, and Unary Operators

The Simple Assignment Operator

One of the most common operators that you'll encounter is the simple assignment operator, `=`. You saw this operator in the `Bicycle` class; it assigns the value on its right to the operand on its left:

```
int cadence = 0;
int speed = 0;
int gear = 1;
```

This operator can also be used on objects to assign *object references*, as discussed in Chapter 4, "Creating Objects."

The Arithmetic Operators

The Java programming language provides operators that perform addition, subtraction, multiplication, and division. There's a good chance you'll recognize them by their counterparts in basic mathematics. The only symbol that might look new to you is `%`, which divides one operand by another and returns the remainder as its result.

Table 3.3 Arithmetic Operators

Operator	Description
+	Additive operator (also used for String concatenation)
-	Subtraction operator
*	Multiplication operator
/	Division operator
%	Remainder operator

The following program, `ArithmeticDemo`, tests the arithmetic operators:

```
class ArithmeticDemo {  
    public static void main (String[] args) {  
        int result = 1 + 2;  
        // result is now 3  
        System.out.println("1 + 2 = " + result);  
        int original_result = result;  
  
        result = result - 1;  
        // result is now 2  
        System.out.println(original_result + " - 1 = " + result);  
        original_result = result;  
  
        result = result * 2;  
        // result is now 4  
        System.out.println(original_result + " * 2 = " + result);  
        original_result = result;  
  
        result = result / 2;  
        // result is now 2  
        System.out.println(original_result + " / 2 = " + result);  
        original_result = result;  
  
        result = result + 8;  
        // result is now 10  
        System.out.println(original_result + " + 8 = " + result);  
        original_result = result;  
  
        result = result % 7;  
        // result is now 3  
        System.out.println(original_result + " % 7 = " + result);  
    }  
}
```

This program prints the following:

```
1 + 2 = 3  
3 - 1 = 2  
2 * 2 = 4  
4 / 2 = 2  
2 + 8 = 10  
10 % 7 = 3
```


You can also combine the arithmetic operators with the simple assignment operator to create *compound assignments*. For example, `x+=1`; and `x=x+1`; both increment the value of `x` by 1.

The `+` operator can also be used for concatenating (joining) two strings together, as shown in the following `ConcatDemo` program:

```
class ConcatDemo {
    public static void main(String[] args){
        String firstString = "This is";
        String secondString = " a concatenated string.";
        String thirdString = firstString + secondString;
        System.out.println(thirdString);
    }
}
```

By the end of this program, the variable `thirdString` contains "This is a concatenated string.", which gets printed to standard output.

The Unary Operators

The unary operators require only one operand; they perform various operations such as incrementing/decrementing a value by one, negating an expression, or inverting the value of a boolean.

The following program, `UnaryDemo`, tests the unary operators:

```
class UnaryDemo {
    public static void main(String[] args) {
        int result = +1;
        // result is now 1
        System.out.println(result);

        result--;
        // result is now 0
        System.out.println(result);

        result++;
        // result is now 1
        System.out.println(result);

        result = -result;
        // result is now -1
        System.out.println(result);

        boolean success = false;
        // false
        System.out.println(success);
        // true
        System.out.println(!success);
    }
}
```

Table 3.4 Unary Operators

Operator	Description
+	Unary plus operator; indicates positive value (numbers are positive without this, however)
-	Unary minus operator; negates an expression
++	Increment operator; increments a value by 1
--	Decrement operator; decrements a value by 1
!	Logical complement operator; inverts the value of a boolean

The increment/decrement operators can be applied before (prefix) or after (postfix) the operand. The code `result++;` and `++result;` will both end in `result` being incremented by one. The only difference is that the prefix version (`++result`) evaluates to the incremented value, whereas the postfix version (`result++`) evaluates to the original value. If you are just performing a simple increment/decrement operation, it doesn't really matter which version you choose. But if you use this operator in part of a larger expression, the one you choose may make a significant difference.

The following program, `PrePostDemo`, illustrates the prefix/postfix unary increment operator:

```
class PrePostDemo {
    public static void main(String[] args){
        int i = 3;
        i++;
        // prints 4
        System.out.println(i);
        ++i;
        // prints 5
        System.out.println(i);
        // prints 6
        System.out.println(++i);
        // prints 6
        System.out.println(i++);
        // prints 7
        System.out.println(i);
    }
}
```

Equality, Relational, and Conditional Operators

The Equality and Relational Operators

The equality and relational operators determine if one operand is greater than, less than, equal to, or not equal to another operand. The majority of these operators will probably look familiar to you as well. Keep in mind that you must use `==`, not `=`, when testing if two primitive values are equal:

```
== equal to
!= not equal to
> greater than
>= greater than or equal to
< less than
<= less than or equal to
```

The following program, `ComparisonDemo`, tests the comparison operators:

```
class ComparisonDemo {
    public static void main(String[] args){
        int value1 = 1;
        int value2 = 2;
        if(value1 == value2)
            System.out.println("value1 == value2");
        if(value1 != value2)
            System.out.println("value1 != value2");
        if(value1 > value2)
            System.out.println("value1 > value2");
        if(value1 < value2)
            System.out.println("value1 < value2");
        if(value1 <= value2)
            System.out.println("value1 <= value2");
    }
}
```

Here is the output:

```
value1 != value2
value1 < value2
value1 <= value2
```

The Conditional Operators

The `&&` and `||` operators perform *Conditional-AND* and *Conditional-OR* operations on two boolean expressions. These operators exhibit *short-circuiting* behavior, which means that the second operand is evaluated only if needed:

```
&& Conditional-AND
|| Conditional-OR
```

The following program, `ConditionalDemo1`, tests these operators:

```
class ConditionalDemo1 {
    public static void main(String[] args){
        int value1 = 1;
        int value2 = 2;
        if((value1 == 1) && (value2 == 2))
            System.out.println("value1 is 1 AND value2 is 2");
        if((value1 == 1) || (value2 == 1))
```

```

        System.out.println("value1 is 1 OR value2 is 1");
    }
}

```

3

Another conditional operator is `?:`, which can be thought of as shorthand for an `if-then-else` statement (discussed in the “Control Flow Statements” section of this chapter). This operator is also known as the *ternary operator* because it uses three operands. In the following example, this operator should be read as follows: “If `someCondition` is true, assign the value of `value1` to `result`. Otherwise, assign the value of `value2` to `result`.”

The following program, `ConditionalDemo2`, tests the `?:` operator:

```

class ConditionalDemo2 {
    public static void main(String[] args){
        int value1 = 1;
        int value2 = 2;
        int result;
        boolean someCondition = true;
        result = someCondition ? value1 : value2;

        System.out.println(result);
    }
}

```

Because `someCondition` is true, this program prints 1 to the screen. Use the `?:` operator instead of an `if-then-else` statement if it makes your code more readable (e.g., when the expressions are compact and without side effects, such as in assignments).

The Type Comparison Operator `instanceof`

The `instanceof` operator compares an object to a specified type. You can use it to test if an object is an instance of a class, an instance of a subclass, or an instance of a class that implements a particular interface.

The following program, `InstanceofDemo`, defines a parent class (named `Parent`), a simple interface (named `MyInterface`), and a child class (named `Child`) that inherits from the parent and implements the interface.

```

class InstanceofDemo {
    public static void main(String[] args) {

        Parent obj1 = new Parent();
        Parent obj2 = new Child();

        System.out.println("obj1 instanceof Parent: "
            + (obj1 instanceof Parent));
        System.out.println("obj1 instanceof Child: "
            + (obj1 instanceof Child));
    }
}

```

```
        System.out.println("obj1 instanceof MyInterface: "
            + (obj1 instanceof MyInterface));
        System.out.println("obj2 instanceof Parent: "
            + (obj2 instanceof Parent));
        System.out.println("obj2 instanceof Child: "
            + (obj2 instanceof Child));
        System.out.println("obj2 instanceof MyInterface: "
            + (obj2 instanceof MyInterface));
    }
}

class Parent {}
class Child extends Parent implements MyInterface {}
interface MyInterface {}
```

Here is the output:

```
obj1 instanceof Parent: true
obj1 instanceof Child: false
obj1 instanceof MyInterface: false
obj2 instanceof Parent: true
obj2 instanceof Child: true
obj2 instanceof MyInterface: true
```

When using the `instanceof` operator, keep in mind that `null` is not an instance of anything.

Bitwise and Bit Shift Operators

The Java programming language also provides operators that perform bitwise and bit shift operations on integral types. The operators discussed in this section are less commonly used. Therefore their coverage is brief; the intent is to simply make you aware that these operators exist.

The unary bitwise complement operator (`~`) inverts a bit pattern; it can be applied to any of the integral types, making every 0 a 1 and every 1 a 0. For example, a byte contains 8 bits; applying this operator to a value whose bit pattern is 00000000 would change its pattern to 11111111.

The signed left shift operator (`<<`) shifts a bit pattern to the left, and the signed right shift operator (`>>`) shifts a bit pattern to the right. The bit pattern is given by the left-hand operand, and the number of positions to shift is given by the right-hand operand. The unsigned right shift operator (`>>>`) shifts a zero into the leftmost position, while the leftmost position after `>>` depends on sign extension.

The bitwise `&` operator performs a bitwise AND operation. The bitwise `^` operator performs a bitwise exclusive OR operation. The bitwise `|` operator performs a bitwise inclusive OR operation.

The following program, `BitDemo`, uses the bitwise AND operator to print the number 2 to standard output:

```
class BitDemo {
    public static void main(String[] args) {
        int bitmask = 0x000F;
        int val = 0x2222;
        // prints "2"
        System.out.println(val & bitmask);
    }
}
```

3

Summary of Operators

The following quick reference summarizes the operators supported by the Java programming language.

Simple Assignment Operator

= Simple assignment operator

Arithmetic Operators

- + Additive operator (also used for `String` concatenation)
- Subtraction operator
- * Multiplication operator
- / Division operator
- % Remainder operator

Unary Operators

- + Unary plus operator; indicates positive value, although numbers can be positive without this
- Unary minus operator; negates an expression
- ++ Increment operator; increments a value by 1
- Decrement operator; decrements a value by 1
- ! Logical complement operator; inverts the value of a boolean

Equality and Relational Operators

- == Equal to
- != Not equal to
- > Greater than
- >= Greater than or equal to
- < Less than
- <= Less than or equal to

Conditional Operators

`&&` Conditional AND

`||` Conditional OR

`?:` Ternary (shorthand for `if-then-else` statement)

Type Comparison Operator

`instanceof` Compares an object to a specified type

Bitwise and Bit Shift Operators

`~` Unary bitwise complement

`<<` Signed left shift

`>>` Signed right shift

`>>>` Unsigned right shift

`&` Bitwise AND

`^` Bitwise exclusive OR

`|` Bitwise inclusive OR

Questions and Exercises: Operators

Questions

1. Consider the following code snippet:

```
arrayOfInts[j] > arrayOfInts[j+1]
```

Which operators does the code contain?

2. Consider the following code snippet.

```
int i = 10;
int n = i++%5;
```

- a. What are the values of `i` and `n` after the code is executed?
 - b. What are the final values of `i` and `n` if instead of using the postfix increment operator (`i++`), you use the prefix version (`++i`)?
3. To invert the value of a `boolean`, which operator would you use?
 4. Which operator is used to compare two values, `=` or `==` ?
 5. Explain the following code sample: `result = someCondition ? value1 : value2;`

Exercises

1. Change the following program to use compound assignments:

```
class ArithmeticDemo {
    public static void main (String[] args){
        int result = 1 + 2; // result is now 3
        System.out.println(result);

        result = result - 1; // result is now 2
        System.out.println(result);

        result = result * 2; // result is now 4
        System.out.println(result);

        result = result / 2; // result is now 2
        System.out.println(result);

        result = result + 8; // result is now 10
        result = result % 7; // result is now 3
        System.out.println(result);
    }
}
```

2. In the following program, explain why the value 6 is printed twice in a row:

```
class PrePostDemo {
    public static void main(String[] args){
        int i = 3;
        i++;
        System.out.println(i); // "4"
        ++i;
        System.out.println(i); // "5"
        System.out.println(++i); // "6"
        System.out.println(i++); // "6"
        System.out.println(i); // "7"
    }
}
```

Answers

You can find answers to these questions and exercises at http://docs.oracle.com/javase/tutorial/java/nutsandbolts/QandE/answers_operators.html.

Expressions, Statements, and Blocks

Now that you understand variables and operators, it's time to learn about *expressions*, *statements*, and *blocks*. Operators may be used in building expressions, which compute values. Expressions are the core components of statements, and statements may be grouped into blocks.

Expressions

An *expression* is a construct made up of variables, operators, and method invocations, which are constructed according to the syntax of the language that evaluates

to a single value. You've already seen examples of expressions, illustrated in bold as follows:

```
int cadence = 0;  
anArray[0] = 100;  
System.out.println("Element 1 at index 0: " + anArray[0]);  
  
int result = 1 + 2; // result is now 3  
if (value1 == value2)  
    System.out.println("value1 == value2");
```

The data type of the value returned by an expression depends on the elements used in the expression. The expression `cadence = 0` returns an `int` because the assignment operator returns a value of the same data type as its left-hand operand; in this case, `cadence` is an `int`. As you can see from the other expressions, an expression can return other types of values as well, such as `boolean` or `String`.

The Java programming language allows you to construct compound expressions from various smaller expressions as long as the data type required by one part of the expression matches the data type of the other. Here's an example of a compound expression:

```
1 * 2 * 3
```

In this particular example, the order in which the expression is evaluated is unimportant because the result of multiplication is independent of order; the outcome is always the same, regardless of the order of the numbers being multiplied. However, this is not true for all expressions. For example, the following expression gives different results, depending on whether you perform the addition or the division operation first:

```
x + y / 100 // ambiguous
```

You can specify exactly how an expression will be evaluated using balanced parentheses: `(` and `)`. For example, to make the previous expression unambiguous, you could write the following:

```
(x + y) / 100 // unambiguous, recommended
```

If you don't explicitly indicate the order for the operations to be performed, the order is determined by the precedence assigned to the operators in use within the expression. Operators that have a higher precedence get evaluated first. For example, the division operator has a higher precedence than the addition operator. Therefore the following two statements are equivalent:

```
x + y / 100
```

```
x + (y / 100) // unambiguous, recommended
```

3

When writing compound expressions, be explicit and indicate with parentheses which operators should be evaluated first. This practice makes code easier to read and maintain.

Statements

Statements are roughly equivalent to sentences in natural languages. A *statement* forms a complete unit of execution. The following types of expressions can be made into a statement by terminating the expression with a semicolon (;):

- Assignment expressions
- Any use of ++ or --
- Method invocations
- Object creation expressions

Such statements are called *expression statements*. Here are some examples of expression statements:

```
// assignment statement
aValue = 8933.234;
// increment statement
aValue++;
// method invocation statement
System.out.println("Hello World!");
// object creation statement
Bicycle myBike = new Bicycle();
```

In addition to expression statements, there are two other kinds of statements: *declaration statements* and *control flow statements*. A *declaration statement* declares a variable. You've seen many examples of declaration statements already:

```
// declaration statement
double aValue = 8933.234;
```

Finally, *control flow statements* regulate the order in which statements get executed. You'll learn about control flow statements in the next section, "Control Flow Statements."

Blocks

A *block* is a group of zero or more statements between balanced braces and can be used anywhere a single statement is allowed. The following example, `BlockDemo`, illustrates the use of blocks:

```
class BlockDemo {
    public static void main(String[] args) {
        boolean condition = true;
        if (condition) { // begin block 1
            System.out.println("Condition is true.");
        } // end block one
        else { // begin block 2
            System.out.println("Condition is false.");
        } // end block 2
    }
}
```

Questions and Exercises: Expressions, Statements, and Blocks

Questions

1. Operators may be used in building ____, which compute values.
2. Expressions are the core components of ____.
3. Statements may be grouped into ____.
4. The following code snippet is an example of a ____ expression:
$$1 * 2 * 3$$
5. Statements are roughly equivalent to sentences in natural languages, but instead of ending with a period, a statement ends with a ____.
6. A block is a group of zero or more statements between balanced ____ and can be used anywhere a single statement is allowed.

Exercise

1. Identify the following kinds of expression statements:
 - `aValue = 8933.234;`
 - `aValue++;`
 - `System.out.println("Hello World!");`
 - `Bicycle myBike = new Bicycle();`

Answers

You can find answers to these questions and exercises at http://docs.oracle.com/javase/tutorial/java/nutsandbolts/QandE/answers_expressions.html.

3

Control Flow Statements

The statements inside your source files are generally executed from top to bottom, in the order that they appear. *Control flow statements*, however, break up the flow of execution by employing decision making, looping, and branching, enabling your program to *conditionally* execute particular blocks of code. This section describes the decision-making statements (*if-then*, *if-then-else*, *switch*), the looping statements (*for*, *while*, *do-while*), and the branching statements (*break*, *continue*, *return*) supported by the Java programming language.

The if-then and if-then-else Statements

The if-then Statement

The *if-then* statement is the most basic of all the control flow statements. It tells your program to execute a certain section of code *only if* a particular test evaluates to true. For example, the `Bicycle` class could allow the brakes to decrease the bicycle's speed *only if* the bicycle is already in motion. One possible implementation of the `applyBrakes` method could be as follows:

```
void applyBrakes() {
    // the "if" clause: bicycle must be moving
    if (isMoving){
        // the "then" clause: decrease current speed
        currentSpeed--;
    }
}
```

If this test evaluates to false (meaning that the bicycle is not in motion), control jumps to the end of the *if-then* statement.

In addition, the opening and closing braces are optional, provided that the “then” clause contains only one statement:

```
void applyBrakes() {
    // same as above, but without braces
    if (isMoving)
        currentSpeed--;
}
```

Deciding when to omit the braces is a matter of personal taste. Omitting them can make the code more brittle. If a second statement is later added to the “then” clause,

a common mistake would be forgetting to add the newly required braces. The compiler cannot catch this sort of error; you'll just get the wrong results.

The if-then-else Statement

The if-then-else statement provides a secondary path of execution when an "if" clause evaluates to `false`. You could use an if-then-else statement in the `applyBrakes` method to take some action if the brakes are applied when the bicycle is not in motion. In this case, the action is to simply print an error message stating that the bicycle has already stopped.

```
void applyBrakes() {
    if (isMoving) {
        currentSpeed--;
    } else {
        System.err.println("The bicycle has already stopped!");
    }
}
```

The following program, `IfElseDemo`, assigns a grade based on the value of a test score: an A for a score of 90% or above, a B for a score of 80% or above, and so on:

```
class IfElseDemo {
    public static void main(String[] args) {

        int testscore = 76;
        char grade;

        if (testscore >= 90) {
            grade = 'A';
        } else if (testscore >= 80) {
            grade = 'B';
        } else if (testscore >= 70) {
            grade = 'C';
        } else if (testscore >= 60) {
            grade = 'D';
        } else {
            grade = 'F';
        }
        System.out.println("Grade = " + grade);
    }
}
```

The output from the program is as follows:

```
Grade = C
```

You may have noticed that the value of `testscore` can satisfy more than one expression in the compound statement: `76 >= 70` and `76 >= 60`. However, once a condition is satisfied, the appropriate statements are executed (`grade = 'C'`;) and the remaining conditions are not evaluated.

The switch Statement

Unlike `if-then` and `if-then-else` statements, the `switch` statement can have a number of possible execution paths. A `switch` works with the `byte`, `short`, `char`, and `int` primitive data types. It also works with *enumerated types* (discussed in Chapter 4, “Enum Types”), the `String` class, and a few special classes that wrap certain primitive types: `Character`, `Byte`, `Short`, and `Integer` (discussed in Chapter 9).

The following code example, `SwitchDemo`, declares an `int` named `month` whose value represents a month. The code displays the name of the month, based on the value of `month`, using the `switch` statement:

```
public class SwitchDemo {
    public static void main(String[] args) {

        int month = 8;
        String monthString;
        switch (month) {
            case 1: monthString = "January";
                    break;
            case 2: monthString = "February";
                    break;
            case 3: monthString = "March";
                    break;
            case 4: monthString = "April";
                    break;
            case 5: monthString = "May";
                    break;
            case 6: monthString = "June";
                    break;
            case 7: monthString = "July";
                    break;
            case 8: monthString = "August";
                    break;
            case 9: monthString = "September";
                    break;
            case 10: monthString = "October";
                    break;
            case 11: monthString = "November";
                    break;
            case 12: monthString = "December";
                    break;
            default: monthString = "Invalid month";
                    break;
        }
        System.out.println(monthString);
    }
}
```

In this case, `August` is printed to standard output.

The body of a `switch` statement is known as a *switch block*. A statement in the `switch` block can be labeled with one or more `case` or `default` labels. The `switch`

statement evaluates its expression and then executes all statements that follow the matching case label.

You could also display the name of the month with `if-then-else` statements:

```
int month = 8;
if (month == 1) {
    System.out.println("January");
} else if (month == 2) {
    System.out.println("February");
}
// ... and so on
```

The choice between `if-then-else` statements or a `switch` statement depends on readability and the expression that the statement is testing. An `if-then-else` statement can test expressions based on ranges of values or conditions, whereas a `switch` statement tests expressions based only on a single integer, enumerated value, or `String` object.

Another point of interest is the `break` statement. Each `break` statement terminates the enclosing `switch` statement. Control flow continues with the first statement following the `switch` block. The `break` statements are necessary because without them, statements in `switch` blocks *fall through*: All statements after the matching case label are executed in sequence, regardless of the expression of subsequent case labels, until a `break` statement is encountered. The program `SwitchDemoFallThrough` shows statements in a `switch` block that fall through; it displays the month corresponding to the integer `month` and the months that follow in the year:

```
public class SwitchDemoFallThrough {
    public static void main(String[] args) {
        java.util.ArrayList<String> futureMonths =
            new java.util.ArrayList<String>();

        int month = 8;

        switch (month) {
            case 1: futureMonths.add("January");
            case 2: futureMonths.add("February");
            case 3: futureMonths.add("March");
            case 4: futureMonths.add("April");
            case 5: futureMonths.add("May");
            case 6: futureMonths.add("June");
            case 7: futureMonths.add("July");
            case 8: futureMonths.add("August");
            case 9: futureMonths.add("September");
            case 10: futureMonths.add("October");
            case 11: futureMonths.add("November");
            case 12: futureMonths.add("December");
                    break;
            default: break;
        }
    }
}
```

```

    if (futureMonths.isEmpty()) {
        System.out.println("Invalid month number");
    } else {
        for (String monthName : futureMonths) {
            System.out.println(monthName);
        }
    }
}
}
}

```

3

This is the output from the code:

```

August
September
October
November
December

```

Technically, the final `break` is not required because flow falls out of the `switch` statement. Using a `break` is recommended so that modifying the code is easier and less error prone. The `default` section handles all values that are not explicitly handled by one of the `case` sections.

The following code example, `SwitchDemo2`, shows how a statement can have multiple `case` labels. The code example calculates the number of days in a particular month:

```

class SwitchDemo2 {
    public static void main(String[] args) {

        int month = 2;
        int year = 2000;
        int numDays = 0;

        switch (month) {
            case 1: case 3: case 5:
            case 7: case 8: case 10:
            case 12:
                numDays = 31;
                break;
            case 4: case 6:
            case 9: case 11:
                numDays = 30;
                break;
            case 2:
                if (((year % 4 == 0) &&
                    !(year % 100 == 0))
                    || (year % 400 == 0))
                    numDays = 29;
                else
                    numDays = 28;
                break;
            default:
                System.out.println("Invalid month.");
        }
    }
}

```



```
        break;
    }
    System.out.println("Number of Days = "
        + numDays);
}
}
```

This is the output from the code:

```
Number of Days = 29
```

Using Strings in switch Statements

You can use a `String` object in the `switch` statement's expression. The following code example, `StringSwitchDemo`, displays the number of the month based on the value of the `String` named `month`:

```
public class StringSwitchDemo {
    public static int getMonthNumber(String month) {
        int monthNumber = 0;
        if (month == null) {
            return monthNumber;
        }
        switch (month.toLowerCase()) {
            case "january":
                monthNumber = 1;
                break;
            case "february":
                monthNumber = 2;
                break;
            case "march":
                monthNumber = 3;
                break;
            case "april":
                monthNumber = 4;
                break;
            case "may":
                monthNumber = 5;
                break;
            case "june":
                monthNumber = 6;
                break;
            case "july":
                monthNumber = 7;
                break;
            case "august":
                monthNumber = 8;
                break;
            case "september":
                monthNumber = 9;
                break;
        }
    }
}
```

```
        case "october":
            monthNumber = 10;
            break;
        case "november":
            monthNumber = 11;
            break;
        case "december":
            monthNumber = 12;
            break;
        default:
            monthNumber = 0;
            break;
    }

    return monthNumber;
}

public static void main(String[] args) {

    String month = "August";

    int returnedMonthNumber =
        StringSwitchDemo.getMonthNumber(month);

    if (returnedMonthNumber == 0) {
        System.out.println("Invalid month");
    } else {
        System.out.println(returnedMonthNumber);
    }
}
}
```

The output from this code is 8.

The `String` in the `switch` expression is compared with the expressions associated with each case label, as if the `String.equals`⁹ method was being used. In order for the `StringSwitchDemo` example to accept any month regardless of case, `month` is converted to lowercase (with the `toLowerCase`¹⁰ method) and all the strings associated with the case labels are in lowercase.

Note

This example checks if the expression in the `switch` statement is null. Ensure that the expression in any `switch` statement is not null to prevent a `NullPointerException` from being thrown.

9. [8/docs/api/java/lang/String.html#equals-java.lang.Object-](https://docs.oracle.com/javase/8/docs/api/java/lang/String.html#equals-java.lang.Object-)

10. [8/docs/api/java/lang/String.html#toLowerCase--](https://docs.oracle.com/javase/8/docs/api/java/lang/String.html#toLowerCase-)

The while and do-while Statements

The while statement continually executes a block of statements while a particular condition is true. Its syntax can be expressed as follows:

```
while (expression) {
    statement(s)
}
```

The while statement evaluates *expression*, which must return a boolean value. If the expression evaluates to true, the while statement executes the *statement(s)* in the while block. The while statement continues testing the expression and executing its block until the expression evaluates to false. Using the while statement to print the values from 1 through 10 can be accomplished via the following WhileDemo program:

```
class WhileDemo {
    public static void main(String[] args){
        int count = 1;
        while (count < 11) {
            System.out.println("Count is: " + count);
            count++;
        }
    }
}
```

You can implement an infinite loop using the while statement as follows:

```
while (true){
    // your code goes here
}
```

The Java programming language also provides a do-while statement, which can be expressed as follows:

```
do {
    statement(s)
} while (expression);
```

The difference between do-while and while is that do-while evaluates its expression at the bottom of the loop instead of the top. Therefore, the statements within the do block are always executed at least once, as shown in the following DoWhileDemo program:

```
class DoWhileDemo {
    public static void main(String[] args){
        int count = 1;
        do {
```

```
        System.out.println("Count is: " + count);
        count++;
    } while (count < 11);
}
}
```

The for Statement

The `for` statement provides a compact way to iterate over a range of values. Programmers often refer to it as the *for loop* because of the way it repeatedly loops until a particular condition is satisfied. The general form of the `for` statement can be expressed as follows:

```
for (initialization; termination; increment) {
    statement(s)
}
```

When using this version of the `for` statement, keep the following in mind:

- The *initialization* expression initializes the loop; it's executed once as the loop begins.
- When the *termination* expression evaluates to `false`, the loop terminates.
- The *increment* expression is invoked after each iteration through the loop; it is perfectly acceptable for this expression to increment *or* decrement a value.

The following program, `ForDemo`, uses the general form of the `for` statement to print the numbers 1 through 10 to standard output:

```
class ForDemo {
    public static void main(String[] args){
        for(int i=1; i<11; i++){
            System.out.println("Count is: " + i);
        }
    }
}
```

Here is the output of this program:

```
Count is: 1
Count is: 2
Count is: 3
Count is: 4
Count is: 5
Count is: 6
Count is: 7
Count is: 8
Count is: 9
Count is: 10
```

Notice how the code declares a variable within the initialization expression. The scope of this variable extends from its declaration to the end of the block governed by the `for` statement, so it can be used in the termination and increment expressions as well. If the variable that controls a `for` statement is not needed outside the loop, it's best to declare the variable in the initialization expression. The names `i`, `j`, and `k` are often used to control `for` loops; declaring them within the initialization expression limits their life span and reduces errors.

The three expressions of the `for` loop are optional; an infinite loop can be created as follows:

```
// infinite loop
for ( ; ; ) {
    // your code goes here
}
```

The `for` statement also has another form designed for iteration through collections and arrays. This form is sometimes referred to as the *enhanced for* statement and can be used to make your loops more compact and easier to read. To demonstrate, consider the following array, which holds the numbers 1 through 10:

```
int[] numbers = {1,2,3,4,5,6,7,8,9,10};
```

The following program, `EnhancedForDemo`, uses the enhanced `for` to loop through the array:

```
class EnhancedForDemo {
    public static void main(String[] args){
        int[] numbers =
            {1,2,3,4,5,6,7,8,9,10};
        for (int item : numbers) {
            System.out.println("Count is: " + item);
        }
    }
}
```

In this example, the variable `item` holds the current value from the numbers array. The output from this program is the same as before:

```
Count is: 1
Count is: 2
Count is: 3
Count is: 4
Count is: 5
Count is: 6
Count is: 7
Count is: 8
Count is: 9
Count is: 10
```

We recommend using this form of the `for` statement instead of the general form whenever possible.

3

Branching Statements

The `break` Statement

The `break` statement has two forms: labeled and unlabeled. You saw the unlabeled form in the previous discussion of the `switch` statement. You can also use an unlabeled `break` to terminate a `for`, `while`, or `do-while` loop, as shown in the following `BreakDemo` program:

```
class BreakDemo {
    public static void main(String[] args) {

        int[] arrayOfInts =
            { 32, 87, 3, 589,
              12, 1076, 2000,
              8, 622, 127 };
        int searchfor = 12;

        int i;
        boolean foundIt = false;

        for (i = 0; i < arrayOfInts.length; i++) {
            if (arrayOfInts[i] == searchfor) {
                foundIt = true;
                break;
            }
        }

        if (foundIt) {
            System.out.println("Found " + searchfor + " at index " + i);
        } else {
            System.out.println(searchfor + " not in the array");
        }
    }
}
```

This program searches for the number 12 in an array. The `break` statement, shown in boldface, terminates the `for` loop when that value is found. Control flow then transfers to the statement after the `for` loop. This program's output is as follows:

```
Found 12 at index 4
```

An unlabeled `break` statement terminates the innermost `switch`, `for`, `while`, or `do-while` statement, but a labeled `break` terminates an outer statement. The following program, `BreakWithLabelDemo`, is similar to the previous program but uses nested `for` loops to search for a value in a two-dimensional array. When the value is found, a labeled `break` terminates the outer `for` loop (labeled `search`):

```
class BreakWithLabelDemo {
    public static void main(String[] args) {

        int[][] arrayOfInts = {
            { 32, 87, 3, 589 },
            { 12, 1076, 2000, 8 },
            { 622, 127, 77, 955 }
        };
        int searchfor = 12;

        int i;
        int j = 0;
        boolean foundIt = false;

    search:
        for (i = 0; i < arrayOfInts.length; i++) {
            for (j = 0; j < arrayOfInts[i].length;
                j++) {
                if (arrayOfInts[i][j] == searchfor) {
                    foundIt = true;
                    break search;
                }
            }
        }

        if (foundIt) {
            System.out.println("Found " + searchfor + " at " + i + ", " + j);
        } else {
            System.out.println(searchfor + " not in the array");
        }
    }
}
```

This is the output of the program:

```
Found 12 at 1, 0
```

The `break` statement terminates the labeled statement; it does not transfer the flow of control to the label. Control flow is transferred to the statement immediately following the labeled (terminated) statement.

The `continue` Statement

The `continue` statement skips the current iteration of a `for`, `while`, or `do-while` loop. The unlabeled form skips to the end of the innermost loop's body and evaluates the boolean expression that controls the loop. The following program, `ContinueDemo`, steps through a `String`, counting the occurrences of the letter `p`. If the current character is not a `p`, the `continue` statement skips the rest of the loop and proceeds to the next character. If it is a `p`, the program increments the letter count:

```
class ContinueDemo {
    public static void main(String[] args) {
```

```

String searchMe = "peter piper picked a " + "peck of pickled peppers";
int max = searchMe.length();
int numPs = 0;

for (int i = 0; i < max; i++) {
    // interested only in p's
    if (searchMe.charAt(i) != 'p')
        continue;

    // process p's
    numPs++;
}
System.out.println("Found " + numPs + " p's in the string.");
}
}

```

Here is the output of this program:

```
Found 9 p's in the string.
```

To see this effect more clearly, try removing the `continue` statement and recompiling. When you run the program again, the count will be wrong, saying that it found 35 *p*'s instead of 9.

A labeled `continue` statement skips the current iteration of an outer loop marked with the given label. The following example program, `ContinueWithLabelDemo`, uses nested loops to search for a substring within another string. Two nested loops are required: one to iterate over the substring and another to iterate over the string being searched. The following program, `ContinueWithLabelDemo`, uses the labeled form of the `continue` statement to skip an iteration in the outer loop:

```

class ContinueWithLabelDemo {
    public static void main(String[] args) {

        String searchMe = "Look for a substring in me";
        String substring = "sub";
        boolean foundIt = false;

        int max = searchMe.length() -
            substring.length();

    test:
        for (int i = 0; i <= max; i++) {
            int n = substring.length();
            int j = i;
            int k = 0;
            while (n-- != 0) {
                if (searchMe.charAt(j++) != substring.charAt(k++)) {
                    continue test;
                }
            }
        }
    }
}

```



```
        foundIt = true;
        break test;
    }
    System.out.println(foundIt ? "Found it" : "Didn't find it");
}
}
```

Here is the output from this program:

```
Found it
```

The return Statement

The last of the branching statements is the `return` statement. The `return` statement exits from the current method, and control flow returns to where the method was invoked. The `return` statement has two forms: one that returns a value and another that doesn't. To return a value, simply put the value (or an expression that calculates the value) after the `return` keyword:

```
return ++count;
```

The data type of the returned value must match the type of the method's declared return value. When a method is declared `void`, use the form of `return` that doesn't return a value:

```
return;
```

Chapter 4 covers everything you need to know about writing methods.

Summary of Control Flow Statements

The `if-then` statement is the most basic of all the control flow statements. It tells your program to execute a certain section of code *only if* a particular test evaluates to `true`. The `if-then-else` statement provides a secondary path of execution when an "if" clause evaluates to `false`. Unlike `if-then` and `if-then-else`, the `switch` statement allows for any number of possible execution paths. The `while` and `do-while` statements continually execute a block of statements while a particular condition is `true`. The difference between `do-while` and `while` is that `do-while` evaluates its expression at the bottom of the loop instead of the top. Therefore, the statements within the `do` block are always executed at least once. The `for` statement provides a compact way to iterate over a range of values. It has two forms, one of which was designed for looping through collections and arrays.

Questions and Exercises: Control Flow Statements

Questions

1. The most basic control flow statement supported by the Java programming language is the ___ statement.
2. The ___ statement allows for any number of possible execution paths.
3. The ___ statement is similar to the while statement but evaluates its expression at the ___ of the loop.
4. How do you write an infinite loop using the for statement?
5. How do you write an infinite loop using the while statement?

Exercises

1. Consider the following code snippet:

```
if (aNumber >= 0)
    if (aNumber == 0)
        System.out.println("first string");
    else System.out.println("second string");
System.out.println("third string");
```

- a. What output do you think the code will produce if aNumber is 3?
- b. Write a test program containing the previous code snippet; make aNumber 3. What is the output of the program? Is it what you predicted? Explain why the output is what it is; in other words, what is the control flow for the code snippet?
- c. Using only spaces and line breaks, reformat the code snippet to make the control flow easier to understand.
- d. Use braces, { and }, to further clarify the code.

Answers

You can find answers to these questions and exercises at http://docs.oracle.com/javase/tutorial/java/nutsandbolts/QandE/answers_flow.html.

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Index

Symbols

- (minus sign)
 - operator, 59–62, 279
 - in regular expressions, 562–64
- operator, 59, 61, 62
- _ (underscore)
 - in constant names, 114
 - in numeric literals, 50–51
 - in package names, 263
 - in predefined character classes, 566
 - in variable names, 45–46
- , (comma)
 - in numbers, 50, 276, 278
 - in regular expressions, 572
- ;(semicolon)
 - in class paths, 212, 269, 610
 - declaring abstract methods, 159
 - listing enum types, 159
 - in statements, 28, 70, 319
 - terminating method signatures, 176, 178
- : (colon), in class paths, 269
- ! operator, 59
- !/ separator, 644, 645
- != operator, 59, 63, 66
- ? (question mark)
 - in regular expressions, 236, 372–73
- ?: operator, 64, 67
- / (forward slash)
 - file name separator, 267, 360, 417, 621
 - operator, 59–60, 279–80
- // in comments, 12, 25
- /* in comments, 24
- /** in comments, 24
- /= operator, 59
- .(dot)
 - in class paths, 364, 612
 - in JAR file commands, 620, 630
 - in method invocations, 87, 104–7
 - in numbers, 278, 287, 299
 - in regular expressions, 561, 568
 - in variable names, 105
- ... (ellipsis), 96–97
- ^ (caret)
 - operator, 59, 66–67
 - in regular expressions, 563, 576–77, 579
- ^= operator, 59
- ~ operator, 59, 65
- ' (single quote), escape sequence for, 50, 288
- " (double quote)
 - escape sequence for, 50, 288
 - in literals, 288
- () (parentheses)
 - in declarations, 92, 106, 317
 - in expressions, 69, 797
 - in generics, 222
 - in interfaces, 133
 - in regular expressions, 573–74
- [] (square brackets)
 - in arrays, 53–54
 - in regular expressions, 373, 568, 592
- { } (braces)
 - in blocks, 71, 72, 117, 127
 - in declarations, 89–90, 90–92, 127–28
 - in lambda expressions, 147
 - in methods, 44
 - in regular expressions, 373, 571–72

- @ (at)
 - in annotations, 164, 166
 - in Javadoc, 167
- \$ (dollar sign)
 - in DecimalFormat patterns, 278
 - in variable names, 45
- * (asterisk)
 - in import statements, 264
 - operator, 59
 - in regular expressions, 372, 407
- */ in comments, 24
- *= operator, 59
- \ (backslash)
 - in escape sequences, 50, 288–89, 360, 566
 - file name separator, 267, 417
 - in regular expressions, 373, 561
- & (ampersand) operator, 59, 66–67
- && operator, 59, 63, 66–67
- &= operator, 59
- # (pound sign)
 - in DecimalFormat patterns, 278
 - in regular expressions, 561
- % (percent sign)
 - format specifier, 275, 350
 - operator, 59, 279–80
- %= operator, 59
- + (plus sign)
 - operator, 59, 66–67, 279–80
 - in regular expressions, 561
- ++ operator, 59, 61–62, 66–67, 70
- += operator, 59
- < operator, 59, 62–63
- << operator, 59, 66–67
- <<= operator, 59
- <= operator, 59, 62–63, 66–67
- <> (angle brackets), 141, 221, 223, 224–27, 232
- = operator, 59
- = operator, 59
- == operator, 59, 62–63, 66–67
- > operator, 59, 62–63, 66–67
- >= operator, 59, 62–63, 66–67
- >> operator, 59, 66–67
- >>= operator, 59
- >>> operator, 59, 66–67
- >>>= operator, 59
- > (arrow token), 147, 487
- | (vertical bar)
 - in exception handling, 316
 - operator, 59, 66–67
 - in regular expressions, 579
- |= operator, 59
- || operator, 59, 63, 66–67

A

- abs method, 280
- abstract classes, 212–14
 - example, 214–15
 - as an implementation of a service, 603
 - implementations, 512
 - methods, 212–13
 - numeric wrapper classes, 272
 - versus interfaces, 213–14
- Abstract Window Toolkit (AWT), 265
 - AWT Event Dispatcher, 652, 672
- AbstractMap class, 214
- access control list (ACL), 380
- access modifiers
 - classes and, 90–95, 111
 - constants and, 178
 - default, 110–11
 - fields and, 196
 - interfaces and, 177–78
 - levels of, 110–12
 - methods and, 92, 196, 206
 - package-private, 111
 - private keyword, 89, 110–11, 196–97
 - protected, 111–12
 - public, 89, 110–11, 196–97
- AccessControlException, 608
- accessor methods, 290, 295, 296, 381, 382, 467
- accumulator function, 476–77
- acos method, 282–83
- add method, 429, 434, 442, 446
- addAll method
 - in the Collection interface, 428–29, 430, 432, 452
 - in the List interface, 438, 439
 - in the Map interface, 452
- addFirst method, 448–49, 494, 498
- addLast method, 448–49, 494, 498
- aggregate operations, xxiv, 145–46, 450, 471–72
 - bulk operations vs., 430–31
 - iterators vs., 474
 - side effects of, 484–87
 - traversing collections with, 429–30
- algorithms (collections), 423–25, 500–509
 - in the Collections class, 508–9
 - composition, 509
 - finding extreme values with, 509
 - generic, 220, 229
 - listing data, 445
 - polymorphism, defined, 424
 - routine data manipulation, 508
 - searching data, 508–9
 - shuffling data, 508

- sorting data, 505–8
- work stealing, 549
- ampersand. *See* &
- Anagrams example, 456, 507
- angle brackets. *See* <>
- annotations, 163–74
 - cardinality of type, 173
 - container, 172
 - declaring, 165–67, 172
 - design considerations, 173
 - elements and, 164
 - formatting of, 164–65
 - legacy code, 173
 - meta-annotations, 169–70
 - predefined, 165, 167–70
 - repeating, 164–65, 171–73
 - retrieving, 173
 - type. *See* type annotations
 - used by the Java language, 167–68
 - where to use, 165
- anonymous classes, 131–36
 - declaring and accessing, 131–34
 - examples of, 134–36
 - GUI applications and, 134
 - specifying search criteria code in, 140
 - syntax of, 132–33
 - when to use, 155
- APIs (Application Programming Interfaces), 138
 - array-based versus collection-based, 502
 - compatibility of, 513–15
 - design of, 515–17
 - interfaces as, 177
 - JAR-related, 642–648
 - Java core, 4, 34, 40
 - logging, 328
 - Reflection API, 173
- append method, 253, 302–4
- appendReplacement method, 584–85, 588
- appendTail method, 584, 588
- Applet class, 665, 667, 672, 680–81, 684
- applet tag, 626, 673–76
 - deploying with, 676
 - JAR files and, 626
 - JNLP and, 676, 734–35, 748
 - manually coding, 676
- AppletContext interface, 677, 682–83, 702, 706
- applets, 665–709
 - API of, 677
 - background color of, 733
 - common problems, 707–8
 - communicating with other applets, 701–3
 - core functionality versus deployment mechanism, 673–74
 - debugging, 698
 - defining and using applet parameters, 678–80
 - deploying, 673–76, 733–35
 - developing, 670–73
 - directories of, 673–75, 678
 - displaying documents, 682–83
 - displaying short status strings, 681
 - draggable, 698–701
 - event handling and, 689–90
 - execution environment of, 670
 - finding and loading data files, 677
 - GUIs in, 671
 - JavaScript functions and, 670, 676–77, 701–3
 - leaving and returning to web pages, 669
 - life cycle of, 668–69
 - loading, 669
 - milestones, 667–68
 - packing in JAR files, 673–75
 - parameters in, 668–670
 - qualified names, 659, 697
 - quitting the browser, 669
 - reloading, 669
 - sandbox, 706–7
 - security and, 596, 634, 677
 - server-side applications, 703–5
 - signed, 31, 654
 - threads in, 670
- appletviewer application, 608
- Application-Library-Allowable-Codebase attribute, 635
- Application-Name attribute, 634
- applications. *See* rich Internet applications (RIAs)
- archive attribute, 708, 733
- args variable, 45, 274–75, 601, 646–47
- arguments
 - arbitrary number of, 96–97
 - command-line. *See* command-line arguments
 - glob, 372–73
 - number of, 95
 - primitive data types, 96, 98
 - reference data types, 98
 - versus parameters, 95
- arithmetic operators, 59–60, 61, 66
- ArithmeticDemo example, 60, 68
- ArrayBlockingQueue class, 497
- arraycopy method, 55–56, 608, 648
- ArrayCopyDemo example, 55–56
- ArrayDemo example, 52–54, 55
- ArrayDeque class, 498
- arrays, 51–57
 - assigning values to, 54
 - of characters, 288–89
 - comparing, 56

- arrays (*continued*)
 - copying, 55–56
 - creating, 54–55
 - filling, 56
 - List view of, 502
 - looping through, 85
 - multidimensional, 54–55
 - searching, 56
 - sorting, 57
 - arrow token. *See* ->
 - asin method, 282
 - as a convenience implementation, 502
 - upward compatibility and, 513
 - writing a custom implementation, 511
 - asList method, 237–38, 440
 - assert statement, 120
 - assignments
 - checking with assert, 120
 - compound, 61, 67
 - conditional operators and, 63–64
 - asterisk. *See* *
 - at. *See* @
 - at prefix, 758
 - atan method, 282–83
 - atomic file operations, 372, 377, 392, 496, 500
 - access, 533
 - actions, 533
 - methods, 496
 - synchronization, 500–501, 533, 553–54
 - variables, 553–54
 - ATOMIC_MOVE enum, 372, 377
 - AtomicCounter example, 554
 - AtomicInteger class, 272, 554
 - Attributes class, 645
 - autoboxing, 223, 253, 271–72, 283–84, 285, 288
 - AutoCloseable interface, 317, 320
 - autoflush, 346
- B**
- backslash. *See* \
 - backspace, 50, 289
 - BadThreads example, 555
 - BasicMathDemo example, 279
 - BasicService interface, 664
 - between method, 781
 - BicycleDemo example, 37
 - BigDecimal class, 47, 272, 347, 357, 359
 - BigInteger class, 272, 347, 459
 - binary numbers, 49, 273–74
 - binarySearch method, 56, 445, 508–9
 - bit shift operators, 65, 67, 797
 - BitDemo example, 65–66
 - bitwise operators, 65, 67, 579, 797
 - precedence, 58
 - BlockDemo example, 71
 - BlockingQueue implementation, 447, 497, 498, 552
 - blocks, 68, 128–29
 - boolean data type, 47
 - default value of, 48
 - unary operations on, 61
 - BorderLayout class, 651–52, 657–58, 672, 694–95
 - boxing. *See* autoboxing; unboxing
 - braces. *See* {}
 - branching statements, 43, 72, 82–85, 798
 - break statements, 75–76, 82–83
 - BreakDemo example, 82
 - BreakWithLabelDemo example, 82–83
 - brittle applications, 138
 - browsers. *See* web browsers
 - BufferedInputStream class, 345, 356
 - BufferedOutputStream class, 345, 355, 390
 - BufferedReader class, 317–18, 344–48, 386–89, 718
 - BufferedWriter class, 318–20, 345, 370–71, 386, 389, 718
 - buffers, 345–46
 - bugs. *See* errors
 - byte data type, 46
 - data streams and, 390
 - default value of, 49
 - switch statement and, 74
 - byte streams, 340–42
 - buffered, 346
 - character streams and, 342–43
 - classes, 348–49
 - closing, 341–42
 - I/O streams and, 352, 354–55
 - standard streams and, 352
 - using, 341
 - when not to use, 342
 - bytecodes, 2, 5, 7, 16, 18, 20
 - in the HelloWorld example, 13, 16, 18, 20, 29–30
 - type erasure and, 244–45
 - byteValue method, 273, 286
- C**
- CA. *See* Signer Certificate Authority (CA)
 - keystore
 - Calendar class, 358
 - call stack
 - exception handling, 310–11, 315, 321, 323
 - propagating errors up, 332–33

- Callable objects, 547–48
- Caller-Allowable-Codebase attribute, 635, 686
- capturing groups, 572–73
- cascading style sheets (CSSs), 793
- catch blocks, 315–16, 321, 336, 370, 800
- Catch or Specify Requirement, 309–12, 330, 799
 - bypassing, 312
- cd command, 18, 21–22, 29–30
- ceil method, 280
- char data type, 47
- character and string literals, 50, 288–90
 - converting to strings, 288–90
 - in data streams, 354–55
 - default value of, 48
 - escape sequences in, 50, 288–90
 - generic methods and bounded type parameters, 229
 - getting by index, 295
 - translating individual tokens, 347–48
 - wrapper class. *See* Character class
- Character class, 287–89, 306
 - implementing Comparable, 459
 - restrictions on generics, 252–56
 - switch statement and, 74
 - useful methods in, 289
 - as a wrapper class, 287
- character classes, 564–68
 - intersections of, 565
 - negation of, 563
 - predefined, 566–68
 - quantifiers and, 572–73
 - ranges of, 563–64
 - regular expressions and, 562, 567
 - simple, 562–63
 - subtractions of, 565–66
 - unions of, 564–65
- character streams, 342–45
- charAt method, 84, 290, 305, 307
- CharSequence interface, 192–93, 296–98, 303, 388, 581–83, 772, 774
- Checker Framework, 171
- ChessAlgorithm example, 212
- ChronoField enum, 774–75
- ChronoUnit enum, 774–76, 778, 781
- Class class, 216–17
- class files, 19, 28, 30, 125, 267–68
- class library. *See* Java Application Programming Interface (API)
- class paths, 268, 269, 603–4, 613, 630–31, 686, 702, 719
- class variables. *See* fields, static
- ClassCastException, 248–50, 252, 458–59, 462, 502, 694, 800
- classes, 36–38, 88–89, 118–19. *See also*
 - inheritance; nested classes
 - abstract, 212–16
 - access modifiers and, 90–91
 - adapter, 517
 - base or parent. *See* superclasses
 - child, derived, or extended. *See* subclasses
 - constructors for, 94–95
 - declaring, 89–90, 127–28
 - final, 212
 - hierarchy of, 194
 - inner, 130–31. *See also* inner classes
 - instantiating, 101
 - interfaces implemented by, 90, 178
 - local, 127–31, 139–40, 155
 - methods and, 92–94
 - naming, 92
 - numbers, 272–74
 - passing information, 95–99
 - static initialization blocks in, 117
 - variables (static fields), 44, 57
 - wrapper, 272, 283–87, 306, 797
- ClassNotFoundException, 357, 646, 648, 708
- CLASSPATH system variable, 29–30, 268–69, 595, 609, 611–13, 706
- ClipboardService interface, 715
- Clock class, 783
- clone method, 209, 490
- Cloneable interface, 209, 213–14
- CloneNotSupportedException, 208–9
- close method, 319–20, 347, 370
- Closeable interface, 313, 317, 320, 370
- cmd command, 17
- code
 - case sensitivity in, 12, 17, 22, 45
 - error handling, 331–32
 - error-prone, 76, 107, 171, 335
 - platform-independent, 4, 31
 - readability of, 31, 64, 94, 122, 155, 267, 311, 329, 346
- Codebase attribute, manifest file, 634, 724
- codebase attribute, JNLP file, 733, 734, 737
- CollationKey class, 459
- collect method, 476–80
- Collection interface, 428–29, 432
 - array operations, 432–33
 - backward compatibility and, 514
 - bulk operations, 432
 - implementations of, 502

- Collection interface (*continued*)
 - views, 452–54
 - wrappers for, 499–500
- collections, 423–517
 - concurrent, 552–53
 - hierarchy of, 265
 - internal delegation and, 474
 - older APIs and, 225, 432–33, 512–13
 - ordered, 427, 438, 469, 495
 - read-only access to, 490
 - synchronized, 490, 500–501
 - traversing, 429–30
- Collections class, 224, 230, 439, 445, 504, 508–9
 - backward compatibility and, 224–25, 230–31
 - methods in, 499–500
 - polymorphic algorithms in, 424
- Collectors class, 478–79
- colon. *See* :
- combiner function, 477
- comma. *See* ,
- command-line arguments, 292–93, 600–601
 - analogies to applet parameters, 678
 - echoing, 600
 - numeric, 601
 - test harnesses and, 559–60
 - URLs and, 646–47
- comments, 24
 - annotations and, 165–67
 - Pattern class methods, 578, 580
- Comparable interface, 369, 458, 462
- Comparator interface, 189–92, 461–64, 497, 506–7, 509, 796, 798
- compare method, 462
- compareTo method
 - custom uses, 458–61
 - for objects, 369
 - for primitive data types, 273
 - for strings, 301
- compareToIgnoreCase method, 154, 301
- ComparisonDemo example, 63
- comparisons
 - between classes, 459
 - of numbers, 59–62
 - of object, 64–65
- compatibility, 513–15
 - backward, 514–15
 - binary, 183, 187
 - cross-platform, 794
 - upward, 513–14
- compile method, 559, 578
- compilers, 124, 198, 234
 - information for, 163
- ComputeResult class, 307
- concat method, 291
- ConcatDemo example, 61
- concurrency, 519–56
 - collections, 552–53
 - high-level objects, 543–55
 - random numbers, 554
- ConcurrentHashMap implementation, 214, 496, 553
- ConcurrentMap interface, 482, 491, 496, 552–53
- ConcurrentNavigableMap interface, 553
- ConcurrentSkipListMap interface, 553
- conditional operators, 62–64, 67, 797
- ConditionalDemo1 example, 63
- ConditionalDemo2 example, 64
- constants, 115
 - compile-time, 115
 - data streams and, 354–55
 - embedded flag expressions, 580
 - empty, 503–4
 - enum types and, 157–61
 - importing, 265–66
 - interfaces and, 176, 177–78
 - naming, 45–46, 157–58
 - numbers and, 278–79, 286
 - for upper and lower bounds, 238–39, 272
 - variables, 130–31
- constructors, 87–89, 95–99
 - calling, 108–10
 - chaining, 208
 - conversion, 428–29
 - declaring, 89, 94–95
 - default, 95
 - for enum types, 159
 - generic, 234
 - inheritance and, 194, 207–8
 - methods and, 95, 212
 - no-argument, 95, 104, 110, 207, 783
 - synchronization and, 530
- Consumer interface, 142–43, 146
- containers. *See* collections
- contains method, 296, 297, 428, 599
- containsAll method, 429, 430, 430–32, 454, 494
- containsKey method, 449, 451, 599
- containsValue method, 214, 449, 451
- continue statements, 83–84
- ContinueDemo example, 83
- ContinueWithLabelDemo example, 84
- control flow statements, 72–86
 - branching, 82–85
 - decision-making, 72
- controlling access. *See* access modifiers
- converters, 275–76

- Cookie Applet Example, 722
- cookies
 - accessing, 719–22
 - kinds of, 719
 - rich Internet applications (RIAs) and, 719–20, 722
- copy method, 243, 376
- CopyBytes example, 341–42, 343
- CopyCharacters example, 343–44, 345
- CopyLines example, 344–45
- copyOfRange method, 56
- CopyOnWriteArrayList implementation, 494
- CopyOnWriteArraySet implementation, 493–94
- core collection interfaces, 423, 426–28, 469–70, 500–501, 513. *See also* by individual type
 - compatibility of, 513–14
 - hierarchy of, 265
 - implementations of, 499–502
- cos method, 266, 279
- Countdown example, 447
- Counter example, 527
- CreateObjectDemo example, 99–100, 105–6
- createTempFile method, 393, 421
- currentTimeMillis method, 609
- customized loading screens
 - in applets, 722
 - in Java Web Start applications, 656–61
- D**
- data encapsulation, 33, 35
- data types, 46–51, 95–96, 341–42. *See also* by individual type
 - reference, 95–96
 - returned by expressions, 68–69, 91–92
 - switch statement and, 74
- DataInput interface, 355–57
- DataInputStream class, 355–56
- DataOutput interface, 355, 356, 357
- DataOutputStream class, 355, 356
- DataStreams example, 355–57
- dates, 153, 621. *See also* Date-Time package
- Date-Time package, xxiv, 755–91
 - basic representations of time, 759–60
 - calendar systems, xxiv, 755–56, 759, 788
 - clarity in, 756
 - clocks, 783–84
 - date-time classes, 764–70
 - design principles, 756–57
 - duration, 781
 - epochs, 759, 770
 - extensibility of, 757
 - fluent interface of, 757
 - formatting 773–74
 - human vs. machine time, 770
 - immutability of, 757
 - Instant class and, 770–71
 - legacy date-time code, 787–90
 - method naming conventions, 758
 - non-ISO date conversions, 784–87
 - packages, 757–58, 774–80
 - parsing 772–73
 - period, 782–83
 - temporal-based classes, 760–61
 - time zone and offset classes, 766–70
- DateTimeFormatter class, 772
- DayOfWeek enum, 760–62
- Deadlock example, 534
- deadlocks, 491, 533–35, 544
- Deal example, 444–45
- decimal number system, 48, 49, 273
- DecimalFormat class, 272, 277–78
- declaration statements, 70, 317
- declarations. *See* by individual type
- decode method, 274
- default keyword, 185
- default methods, xxiii, 182–92
 - binary compatibility, 183
 - defining implementations for, 182–84
 - defining new methods as, 182
 - extending interfaces that contain, 185–86
 - integrating into existing libraries, 187–92
- DelayQueue class, 497
- delete method, 304, 375, 419
- deleteOnExit method, 420
- deployment, 729–53
 - applets, 673–77
 - best practices, 748
 - Java Web Start applications, 653–56
- Deployment Toolkit, 653–56, 673–76
- @Deprecated annotation type, 167–68
- @deprecated Javadoc tag, 167
- Deque interface, 448–49
 - basic operations, 498
 - concurrent implementations, 499
 - implementations of, 498–99
 - methods, 448–49
- destroy method, 668
- diamond, 223–24, 233–34, 428
- dir command, 18, 29
- directories
 - changing, 17–19, 27
 - checking, 374–75
 - copying, 376–77
 - creating, 20–22, 395–96
 - deleting, 375

- directories (*continued*)
 - delimiters, 360
 - error messages involving, 29
 - filtering, 398
 - moving, 377–78
 - packages, 267–68
 - root, 363, 395
 - temporary, 396–97
 - verifying the existence of, 375
 - watching for changes, 410–16
 - documentation, 165–66
 - source code comments, 24
 - @Documented annotation type, 167, 169
 - dollar sign. *See* \$
 - dot. *See* .
 - double data type, 47
 - double quote. *See* "
 - doubleValue method, 237, 273
 - do-while statements, 53, 72, 79, 82–83, 85, 798
 - DoWhileDemo example, 79
 - DownloadService interface, 657, 664, 693, 694, 715
 - DownloadServiceListener interface, 657, 693–94, 715
 - Duration object, 780–81
 - Dynamic Tree Demo applet, 654, 674
- E**
- E
 - constant, 279
 - in scientific notation, 49
 - as type parameter naming convention, 221
 - Echo example, 600
 - element method, 438
 - elements (in collections), 427–28
 - adding, 428–29, 432, 438–39
 - checking, 431
 - counting, 433–34, 447
 - cursor position and, 441–442
 - not duplicated, 433–434
 - null, 432
 - ordering, 427, 433–434
 - removing, 429–432, 435–436
 - searching, 435–436
 - sequence of, 145
 - swapping, 439–440
 - ellipsis. *See* ...
 - emacs text editor, 20
 - emptyList method, 235, 503
 - emptyMap method, 503
 - emptySet method, 503
 - EmptyStackException, 325
 - encapsulation, 33, 35, 91, 122, 155, 796, 799
 - end method, 583
 - endsWith method, 301, 369
 - EnhancedForDemo example, 81
 - ensureCapacity method, 303, 501
 - Entry-Point attribute, 635
 - entrySet method, 449, 453–55, 512
 - enum keyword, 157
 - enum types, 87, 157–61, 493
 - constructors for, 159
 - naming, 157–58
 - enumerated types. *See* enum types
 - Enumeration collection, 259, 513, 514, 515, 599
 - compatibility and, 513–15
 - EnumMap implementation, 495
 - EnumSet implementation, 493
 - EnumTest example, 158
 - Env example, 602
 - environment, 595–614
 - properties of, 596–99
 - restricted, 661
 - environment variables, 601–2, 609–13
 - CLASSPATH, 29, 30, 609
 - common problems with, 29
 - passing to new processes, 602
 - PATH, 609–12
 - platform dependency issues, 602
 - querying, 601–2
 - EnvMap example, 601–2
 - EOFException, 335, 356
 - epochs, 759, 770
 - equality operators. *See* comparisons
 - equals method, 56, 208, 210–11, 460, 463, 496
 - equalsIgnoreCase method, 301
 - Error class, 326
 - error messages, 313–15
 - legacy file I/O code, 418
 - Microsoft Windows, 27, 29–30
 - Solaris and Linux, 27–28, 30–31
 - unchecked, 225–26
 - using to check assignments, 120
 - wildcard capture and, 241
 - errors
 - compiler, 28, 58, 101, 105, 107, 201, 229, 241, 255, 264, 330
 - compile-time, 48, 95, 172, 197, 203, 207, 220, 228, 239, 244, 253–56, 284
 - grouping and differentiating types, 334–35
 - memory consistency, 527, 528–29, 530–31, 533, 543, 553
 - propagating in, 332–34
 - runtime, 29–31

- semantic, 29
 - syntax, 28
 - escape sequences, 50, 288–89
 - in regular expressions, 578, 582
 - in Unicode, 50, 591
 - EventHandler interface, 134–35, 146
 - exception classes, 309, 324–29
 - creating, 328–29
 - grouping errors, 334–35
 - hierarchy, 329
 - PatternSyntaxException class, 589–91
 - exception handlers, 45, 310–17
 - associating with try blocks, 314–15
 - catching more than one exception type, 316
 - catching multiple exceptions, 319
 - constructing, 320–23
 - exceptions, 309–37
 - advantages of, 329–30
 - catching, 313–23
 - chained, 326–28
 - checked, 312
 - class hierarchy of, 329
 - creating exception classes, 328
 - external. *See* errors
 - in file operations, 370–71
 - kinds of, 311–12
 - logging, 328, 698
 - specifying by method, 323–24
 - suppressed, 319–20
 - throwing, 324–30
 - unchecked, 329–30
 - exclamation sign. *See* !
 - Executor interface, 546–48, 549
 - ExecutorService interface, 546–49
 - exit method, 609
 - exp method, 281
 - ExponentialDemo example, 281
 - exponents, 266
 - expression statements, 70–71
 - expressions, 68–70
 - ExtendedService interface, 664, 715
 - extends keyword, 38, 227, 236, 238
 - extensions, 603, 613, 615, 625, 638, 673, 723
- F**
- F or f in 32-bit float literals, 47
 - fields, 35–38, 206, 796. *See also* variables
 - declaring, 117
 - default values of, 48
 - final, 530
 - hiding, 206
 - inherited, 196
 - initializing, 116–18, 796
 - members versus, 45
 - nonstatic, 44, 57
 - private, 196
 - qualified names, 98
 - referencing, 104–5
 - shadowing, 97, 123–24
 - static, 44, 112–14, 216, 254, 531, 578, 645
 - static final. *See* constants
 - synchronization and, 527, 531
 - FIFO (first-in, first out), 427, 446, 469, 490, 497
 - File class, 359
 - file descriptors, 211
 - file operations, 370–74
 - atomic, 372
 - catching exceptions, 370–71
 - method chaining, 372
 - releasing system resources, 370
 - varargs in, 371–72
 - file paths, 359–62
 - checking symbolic links, 375–76
 - comparing, 369
 - converting, 366–67
 - creating, 363
 - creating a path between two, 368
 - joining two, 367
 - relative versus absolute, 360–61
 - removing redundancies from, 364–66
 - retrieving information about, 363–64
 - symbolic links and, 361–62
 - FileInputStream class, 341, 343, 356, 598, 606
 - Filename class, 298
 - FilenameDemo example, 299
 - FileNotFoundException, 312, 334–35
 - FileOpenService interface, 715–17
 - FileOutputStream class, 341, 344, 355, 598, 608
 - FileReader class, 311–12, 317–18, 343–48, 608
 - files
 - accessibility of, 376
 - basic attributes, 381
 - checking, 374–75
 - copying, 376–77
 - creating, 389–90, 392–93
 - deleting, 375
 - DOS attributes, 378
 - file stores, 418
 - finding, 407–8
 - I/O and, 359–420
 - moving, 377–78
 - POSIX file permissions, 383–84
 - random access, 339, 359, 390, 393, 420

files (*continued*)

- reading, 389–90
- setting ownership, 384
- temporary, 393
- time stamps, 382
- user-defined attributes, 385
- verifying the existence of, 375
- writing, 389–90

FileSaveService interface, 715–18

FileSystem class, 373, 386, 407, 412, 422

FileVisitor interface, 401–5

FileWriter class, 313–14, 316, 320–23, 343–45, 608

fill method, 56

final

- catch parameter, 316
- class, 212
- class variable, 44, 115
- constants, 115
- effectively, 129, 133, 149–150
- immutable objects, 541, 542
- method, 118, 212

final modifier, 115, 178

finalize method, 208, 210–11

finally block, 309, 316–17

find method, 584

FindDups example, 435–37, 470

FindDups2 example, 437

first method, 448

float data type, 47

- default value of, 48

floatValue method, 273, 293

floor method, 280

flush method, 346

for statement, 80–82, 85

- enhanced, 81, 395, 418, 470, 488, 798
- nested, 82
- skipping the current iteration, 84–85
- terminating, 80

ForDemo example, 80–81

for-each construct, 159, 429, 430, 434, 435, 472–73, 499

fork/join framework, 480, 546, 549–50, 552

form feed, 50

Format example, 352

format method, 274–75, 278, 350, 758, 772

format specifiers, 275, 350–51, 644, 772

format strings, 275, 292, 349–50

Formatter class, 350

formatting

- numeric print output, 274–78
- stream objects, 346, 349–52

forward slash. *See* /

frequency method, 451–52

from method, 758

functional interface, 141–42

@FunctionalInterface annotation type, 169

functions. *See* methods

Future object, 547

FXML scripting language, 793

G

garbage collection, 5, 106–7, 119, 120, 208, 210, 496, 540, 797

- empty references and, 208
- immutable objects and, 539–40
- memory leaks and, 5
- weak references and, 496

generic methods, 226–27

generic objects, 219–58

- bounded type parameters and, 227
- erasure of, 244–46
- instantiating, 222, 233–34
- invoking, 222
- subtyping and, 230–31
- type inference and, 232–35

generic types, 141–42, 220–26, 239, 245, 249, 252, 426

get method, 211, 313–14, 363, 758

getAbsolutePath method, 421

getApplet method, 683, 702

getCanonicalPath method, 421

getCause method, 327

getChars method, 291

getClass method, 208, 211, 216, 227

getCodeBase method, 678, 704

getDescription method, 589–90

getEnv method, 601–2

getFields method, 211

getFirst method, 449, 494, 498

getHost method, 704

getImage method, 678

getIndex method, 589–90

getInterfaces method, 211

getLast method, 449, 494, 498

getMainAttributes method, 644–45

getMainClassName method, 644–45

getMessage method, 371, 589, 590

getName method, 365

getParameter method, 680–81

getParent method, 364–66

getPattern method, 589

getProperty method, 599, 605, 711–13

getResource method, 653

- getSecurityManager method, 607
 - getSimpleName method, 211
 - getStackTrace method, 327
 - getSuperclass method, 211
 - getValue method, 645
 - globbing, 372–74
 - filtering a directory listing, 398
 - finding files, 407–10
 - graphical user interfaces (GUIs), 4, 40–41, 99–100, 134, 146–47, 425, 650–52, 665–67, 670–73
 - groupCount method, 575
 - groupingBy operation, 479, 482
 - groupingByConcurrent operation, 482
 - guarded blocks, 535–39
- H**
- hard links, 359, 399
 - hashCode method, 189, 191, 208, 210–11, 433, 439, 447, 452, 459–60
 - HashMap implementation, 214, 234, 451–52, 491, 495–96, 504
 - HashSet implementation, 433–37, 450, 454–55, 490–93
 - Hashtable collection, 428, 451, 496, 513–15, 596, 599–600
 - compatibility and, 513–14
 - concurrency through ConcurrentHashMap, 496
 - synchronization and, 490–91
 - hasNext method, 431, 441
 - headSet method, 464–67
 - heap pollution, 250
 - HelloRunnable example, 521–22
 - HelloThread example, 522
 - HelloWorld, 6–24, 656–66
 - applet, 665–66
 - JavaFX example, 146
 - for Microsoft Windows, 15–20
 - for Solaris and Linux, 20–23
 - for the NetBeans IDE, 6–15
 - hexadecimal number system, 49, 51, 211, 273–74, 286, 351, 591
 - HTML. *See also* web browsers; web pages
 - generated code, 732, 736
 - specification, 676
 - HTTP requests, 548, 719
 - HTTPS certificates, 662, 726
- I**
- IDE projects, 7–9, 14–15
 - identity element, 476, 480
 - IdentityHashMap implementation, 495–96
 - IfElseDemo example, 73
 - if-then statements, 72–73, 85, 797
 - if-then-else statements, 73, 85, 797
 - IllegalAccessException, 646
 - IllegalStateException, 446
 - immutable objects, 539–43
 - defining, 541–43
 - immutable singleton set, 503
 - ImmutableRGB example, 542–43
 - implementations, 489–505
 - abstract, 490, 510–13
 - adapter, 510–11
 - anonymous, 499
 - concurrent, 489, 491, 498–99
 - convenience, 489, 502–4
 - custom, 509–13
 - documenting, 426
 - general purpose, 489, 490, 491, 498, 502, 504, 510, 553
 - multiple inheritance of, 198
 - special purpose, 489, 493, 504
 - wrapper, 424, 499–502
 - writing, 510–13
 - implements keyword, 39, 89, 178
 - import statement, 264–66, 776
 - indexOf method, 299, 438–39, 442
 - indexOfSubList method, 445–46
 - information hiding, 36
 - inheritance, 38–39, 193–217, 797, 799
 - example, 195–96
 - multiple, 159, 198–99, 214
 - @Inherited annotation type, 170
 - init method, 667, 671–73, 690
 - initCause method, 327
 - initializer blocks, 117–18
 - inner classes, 87, 122, 123–27
 - accessing members of, 128–29
 - anonymous, 123
 - compatibility issues, 125
 - controlling access to, 122
 - example, 125–27
 - instantiating, 123
 - local, 127–31
 - serialization of, 124–25
 - InputStream class, 343–44
 - InputStreamReader class, 344, 352–53, 389, 718
 - insert method, 302
 - instance members, 87, 117–18, 122, 130
 - instance methods
 - interface methods vs., 200–202
 - instance variables, 44, 57, 87, 112–19, 122, 698

- instanceof operator, 59, 64–67, 198, 250, 254, 405, 459, 692
 - InstanceOfDemo example, 64
 - instances, 36, 44, 101–2, 112–13
 - class members and, 112–16
 - inner classes and, 123
 - testing, 64–65
 - Instant class, 770–71
 - int data type, 46
 - default value of, 48
 - switch statement and, 74
 - Integer class, 228, 273–74
 - interfaces, 39–40, 176–93
 - abstract classes and, 213–14, 799
 - as APIs, 177
 - body, 178
 - collection. *See* core collection interfaces
 - defining, 177–78
 - evolving, 181–82
 - functional, 141–42
 - implementing, 178–80
 - as a type, 180–81
 - International Organization for Standardization (ISO) calendar system, xxiv, 755–56, 759
 - internationalization, 342–43
 - Internet domain names, 262–63, 267
 - Internet Explorer. *See* web browsers
 - interoperability, 513–17
 - API design, 515–17
 - compatibility, 513–15
 - with legacy code, 418–21, 420–21
 - interprocess communication (IPC) resources, 520
 - interrupt mechanism, 423–24
 - interrupt status, 525–25
 - interrupted method, 524–25
 - InterruptedException, 447, 523–26, 536–39, 545, 555
 - intValue method, 228, 273, 284
 - invokeClass method, 646–48
 - I/O, 339–422
 - atomic, 372
 - binary, 354–55
 - buffered, 345–46
 - channel, 390–92, 393–94
 - closing, 210–11, 341–42
 - from the command line, 352–57
 - command-line objects, 603
 - exceptions, 334–35, 370–71
 - interoperability, 418–19
 - line oriented, 344–45
 - memory mapped, 386
 - method chaining, 372, 802
 - NIO.2, 339–422
 - of objects, 357
 - of primitive data type values, 354–55
 - random access, 393–94
 - scanning and formatting, 246–352
 - streams, 339–40, 603. *See* streams, I/O
 - IOException, 312, 402
 - IOException, 313–23
 - is prefix, 758
 - isAfter method, 771
 - isAnnotation method, 211
 - isBefore method, 771
 - isEmpty method, 428–39, 434, 447–48, 451, 786
 - isInterface method, 211
 - isInterrupted method, 524
 - isLetter method, 289
 - isLowerCase method, 289
 - ISO-86013. *See* International Organization for Standardization (ISO) calendar system
 - IsoFields class, 775
 - isUpperCase method, 289
 - isWhitespace method, 289, 346
 - Iterator class, 428–34, 438–39, 440–42, 453, 465, 468, 474, 488, 490, 494, 497, 499, 501, 512
 - iterator method, 125, 244–45, 369, 397, 431, 434, 438, 441, 501
 - Iterator object, 431
 - iterators, 428–34
 - aggregate operations vs., 474
 - fail-fast, 490
- ## J
- JApplet class, 653, 665–69, 671–73, 677, 678, 680–81, 698, 712
 - JApplet getCodeBase method, 678
 - JApplet getDocumentBase method, 678
 - JAR tool, 616, 618–23, 628, 630
 - setting entry points, 630
 - JarClassLoader class, 643–48
 - JarRunner example, 643–46
 - jarsigner tool, 722
 - JarURLConnection class, 642–45
 - Java 2D, 4
 - Java Application Programming Interface (API), 3–5, 34, 40–41, 793. *See also* APIs (Application Programming Interfaces)
 - hierarchy of packages, 265
 - legacy, 224–25
 - raw types and, 224–25
 - runtime exceptions and, 312, 326, 330
 - Java Archive (JAR) files, 615–48. *See also* security
 - adding classes class path, 630–31
 - applets packaged in, 626
 - as applications, 626–27

- benefits of, 615–16
 - creating, 616–20
 - extracting contents of, 622–23
 - manifest files, 627–35, 654, 674, 686, 724
 - paths in, 621
 - running JAR packaged software, 625–27
 - sealing, 634
 - signing, 639–41, 654, 722, 725–26
 - time stamping and, 654, 675, 725–26
 - uncompressed, 619
 - updating, 623–25
 - using, 616–27
 - using JAR-related APIs, 642–48
 - verifying, 635–42
 - viewing contents of, 620–22
- Java Archive Tool. *See* JAR tool
- Java Cache Viewer, 660–61
- Java Collections Framework. *See* collections
- Java Database Connectivity (JDBC) API, 4
- Java HotSpot virtual machine, 2
- Java Interactive Data Language (IDL) API, 4
- java launcher tool, 2, 4, 626
- Java Naming and Directory Interface (JNDI) API, 4
- Java Network Launching Protocol. *See* JNLP files
- Java platform, 2–4, 595–14
- API specification. *See* Java Application Programming Interface (API)
 - command-line arguments, 600–601
 - configuration utilities, 595–603
 - environment variables, 601–3
 - language, 2–4
 - properties, 596–600, 604–7
 - supported encodings on. *See* Unicode encoding system utilities, 603–9
- Java Plug-In software, 670, 693, 700–702, 734, 739, 749, 750
- Java Programming Language Certification, 795–805
- Java SE 8 Upgrade Exam, 801–5
 - Programmer Level I Exam, 795–801
 - Programmer Level II Exam, 801–5
- Java Remote Invocation (RMI), 4
- Java Remote Method Invocation over Internet Inter-ORB Protocol (Java RMI-IIOP), 4
- Java SE Development Kit 8. *See* JDK 8 (Java SE Development Kit 8)
- Java SE Runtime Environment. *See* JRE (Java SE Runtime Environment)
- Java Virtual Machine (Java VM), 2–3, 268–70
- Java Web Start applications, 650–56
- changing the launch button of, 737
 - common problems, 662–63
 - deploying, 653–56, 735–38
 - deploying without codebase attribute, 737–38
 - developing, 650–53
 - displaying customized loading progress indicator, 656–60
 - Java Cache Viewer, 660–61
 - retrieving resources, 653
 - running, 660–61
 - security and, 661–62
 - separating core functionality from final deployment mechanism, 652–53
 - setting up web servers for, 656
 - signed, 31, 654
- java.awt packages, 262, 265, 657, 668, 693–94, 714
- JavaBeans, 5
- javac compiler, 2, 4, 7
- case sensitivity in, 12
- javadoc tool, 24
- JavaFX, xxiv, 4, 134, 793–94
- HelloWorld.java example, 146
 - Scene Builder, 793
- java.io package, 274, 339, 386, 389, 421
- java.lang.Character API, 288
- JavaScript
- applets and, 670, 673–89
 - Deployment Toolkit scripts, 653, 673–74
 - interpreter, 670, 689, 731
- java.time, 757. *See* Date-Time package
- java.time.chrono package, 757
- java.time.format package, 757
- java.time.temporal package, 757–58, 774
- java.time.zone package, 758
- java.util.Arrays class, 56, 552
- java.util.concurrent.atomic package, 553–54
- java.util.concurrent.locks package, 544
- java.util.function, 141
- java.util.jar package, 642–43, 645
- java.util.regex package, 551, 557–58, 581–88, 590, 592
- javax.jnlp package, 650, 657, 716–17, 719
- javax.swing.JApplet class, 666, 671–73, 677, 680, 712
- JButton, 651, 672, 700
- JDialog, 667
- JDK 8 (Java SE Development Kit 8), xxiii–xxiv, 4, 6
- adding to platform list, 9
 - aggregate operations. *See* aggregate operations
 - concurrency in, 552
 - concurrent random numbers, 554–55
 - default manifest, 627
 - default methods. *See* default methods

JDK 8 (Java SE Development Kit 8) (*continued*)
 directory structure, 609–13
 generics and, 224
 high-level concurrency objects and, 543
 JAR tool in, 616
 lambda expressions. *See* lambda expressions
 local classes. *See* local classes
 repeating annotations and, 165. *See also*
 annotations; type annotations
 target typing and, 236
 ThreadLocalRandom, 543, 555
 TransferQueue implementation, 498
 JFrame class, 651
 JNLP files, 739–48
 API, 650, 706, 711, 714–17, 739
 common errors, 662–63
 commonly used elements and attributes,
 741–47
 deployment options with `jnlp_href`, 733
 embedding in Applet tag, 734–35
 encoding, 740
 rich Internet applications (RIAs) and, 714–19
 security and, 634
 signed, 725
 structure of, 740–47
 join method, 525
 JPanel class, 651–52, 671–72
 JProgressBar object, 657, 658, 694, 695
 JRE (Java SE Runtime Environment), 604
 checking client version of, 738–39
 ensuring the presence of, 751–53
 JSR 310 Date and Time API. *See* Date-Time
 package

K

keys method, 599
 keySet method, 453–56
 keywords, 90. *See also* by individual type

L

lambda expressions, xxiii, 136–55
 aggregate operations that accept, 145–46
 as anonymous methods, 147
 as arguments, 190
 classification function, 479
 errors, 149
 example use, 137
 generic types and, 141–42, 144–45
 GUI applications and, 146–47
 interference and, 484–85
 in pipelines and streams, 478
 shadowing and, 148

specifying search criteria code in, 141
 stateful, 486–87
 stream operations and, 486
 syntax of, 147
 using throughout an application, 142–44, 155–56
 last method, 605, 646
 lastIndexOf method, 296–99, 438–39
 lastIndexOfSubList method, 446
 laziness, 485–86
 length method, 290, 302
 line feed, 50, 344
 line terminators, 344, 364, 567, 578
 link awareness, 374
 LinkedBlockingDeque class, 499
 LinkedBlockingQueue class, 497
 LinkedHashMap implementation, 450, 451, 491,
 495
 LinkedHashMap implementation, 433–34, 450,
 491, 492, 493
 LinkedList implementation, 498
 links
 hard, 359, 399
 symbolic, 361, 364, 367, 374–77, 379, 381,
 399–405, 408, 419, 422
 Linux. *See* Solaris/Linux
 List interface, 468–46
 algorithms, 445–46
 collection operations, 375, 386, 394, 553
 implementations, 493–94
 iterators, 440–43
 method, 513–14
 positional access and search operations,
 439–40
 range view operations, 443–45
 listIterator method, 438, 440–42, 512
 ListOfNumbers example, 313–14, 320, 322,
 323, 337
 listRoots method, 421
 lists, 138
 cursor positions in, 441–42
 iterating backward, 441
 literals, 43, 48–51, 291, 557, 560–61, 566
 character and string, 50
 class, 50
 floating point, 49
 integer, 48–49
 using underscore characters, 50–51
 LiveConnect Specification, 683–84, 686
 local classes, 127–31
 specifying search criteria code in, 139–40
 when to use, 155
 LocalDate class, 763

- LocalDateTime class, 765–66
 - locales, 342, 347–48
 - LocalTime class, 764–65
 - lockInterruptibly method, 544
 - locks, 531–32, 544
 - deadlocks, 491, 533–35, 544
 - intrinsic, 531, 536
 - livelocks, 527, 533, 535
 - starvation, 527, 533, 535
 - synchronization and, 531–32
 - logarithms, 178, 279, 281, 286
 - logical operators, 58–68
 - Long class, 273, 286, 292–93, 459
 - long data type, 47
 - default value of, 48
 - longValue method, 273
 - lookingAt method, 584, 586–87
 - loops, 80–84, 798
 - infinite, 79–81, 86, 411
 - nested, 84
 - test harness, 559–60, 570
 - ls command, 22, 23, 238, 254, 407
- M**
- main method, 24–26
 - manifest files, 616, 619, 627–35
 - default, 627
 - digest entries, 637–638
 - fetching attributes, 645
 - modifying, 628–629
 - setting application entry point, 629–630
 - setting package version information, 631–633
 - signature block files, 638, 641
 - signature files, 637–38
 - Map interface, 214, 449–58, 469, 482, 486, 491, 496, 504, 507, 803
 - basic operations, 451–52
 - bulk operations, 452
 - implementations of, 495–96
 - viewing as a Collection, 452–54
 - mapper element, 480
 - Matcher class, 557–58, 583, 585, 587–88
 - MatcherDemo example, 585–86
 - MatchesLooking example, 586–87
 - Math class, 266, 279, 281–82, 286
 - MAX_VALUE constant, 286, 404
 - members, 45
 - controlling access to, 110–11, 799
 - memory
 - allocating sufficient, 101
 - consistency errors, 528–29
 - error-handling, 331–32
 - garbage collection, 106–7
 - leaks, 5
 - locations, 12
 - saving in large arrays, 46–47
 - metadata, 378–86
 - method references, 152–55
 - to a constructor, 154–55
 - to an instance method of a particular object, 154
 - to an instance method of an arbitrary object of a particular type, 154
 - in pipelines and streams, 478
 - to a static method, 154
 - method signatures, 92
 - in interface declarations, 177–78
 - in method declarations, 92
 - overloaded methods and, 92
 - type erasure and, 248–49
 - methods, 34–36. *See also* by individual type
 - abstract, 184–86, 212–16
 - access modifiers and, 90, 95, 213, 798
 - accessor, 290, 295–96, 381–82, 467
 - applet milestone, 667–68
 - atomic, 496
 - bridge, 245–49
 - chaining, 372
 - class, 114, 118, 122, 273, 286, 292, 294
 - default, 182–92
 - defining, 92–94
 - final, 212
 - generic, 226–27
 - hiding, 199–203
 - instance, 199, 200–201
 - interface, 200–201
 - naming, 93, 758
 - overloaded, 93–94
 - overriding, 199–203
 - package-private, 111
 - qualified names, 119
 - returning a class or interface, 108–9
 - returning values from, 107–8
 - static, 186–87
 - synchronized, 529–31
 - wildcards, 240–43
 - Microsoft Windows
 - access control list (ACL), 380
 - CLASSPATH in, 612
 - common errors, 27–28
 - environment variables on, 602
 - file name separators on, 267
 - HelloWorld, 15–19
 - log files, 698

Microsoft Windows (*continued*)

- PATH in, 362–70
- path separators on, 296
- root directories on, 359–60
- system file stores, 417–18

MIME types, 380, 385, 417, 422, 656, 663

minus prefix, 758, 771

MIN_VALUE constant, 272, 286, 463

modifiers. *See* access modifiers

modularity, 36

monitor locks. *See* locks, intrinsic

Month enum, 760, 762

MonthDay class, 764

Mozilla Firefox add-ons, 732, 736

MultiDimArrayDemo example, 54, 55

multimaps, 456

multiple inheritance, 198–99

multisets, 510

N

NameSort example, 461

nanoTime method, 609

nCopies method, 502–3

NegativeArraySizeException, 326

nested classes, 121–57

- controlling access and, 196
- importing, 264–65
- inheritance and, 195
- inner. *See* inner classes
- nonstatic, 121–22, 156
- static, 122–23, 156
- when to use, 156

NetBeans IDE, 1, 5–10, 14–15, 31, 410, 663, 796

 HelloWorld application, 6–15

new keyword, 48, 101, 132, 222, 289

newCachedThreadPool method, 549

newFixedThreadPool method, 548

newline. *See* line terminators

newSingleThreadExecutor method, 549

next method, 431

nextIndex method, 441–42

NIO.2, 339–422

NonNull module, 171

NoSuchElementException, 446–47, 474

NoSuchMethodError, 30–31

Notepad demo, 656, 660, 736–38

Notepad text editor, 16–17

notifyAll method, 208, 536–38

now method, 758, 783

null parameter, 756–57

null value, 50, 342, 413

NullPointerException, 78, 171, 312, 330, 442, 459–60, 756, 800

Number class, 271, 273, 286, 601

number systems, 48–49

 converting between, 273

 decimal, 47, 49

 hexidecimal, 49, 211, 273–74, 286, 351, 591

 octal, 273–74

NumberFormatException, 526, 601

numbers, 271–87

 converting between strings and, 292–95

 formatting, 274–78

 random, 283

O

Object class, 175, 208–16, 237, 243

 as a superclass, 208–12

object ordering, 458–64

object references, 59, 87, 105–7, 113–14, 122, 209–10, 248, 342, 358, 688, 796, 799

ObjectInput interface, 357

ObjectInputStream class, 357

object-oriented programming, 33–41, 203

ObjectOutput interface, 357

ObjectOutputStream class, 357

objects, 34–36, 99–107, 118–19

 calling methods, 105–6

 casting, 197–98

 creating, 100–104

 declaring variables to refer to, 101

 hash codes of, 208, 211, 460

 immutable, 539–43

 initializing, 102–4

 lock, 544–46

 referencing fields, 104–5

ObjectStreams example, 357

octal number system, 273–74

of prefix, 758

offer method, 446

offerFirst method, 448–49

offerLast method, 448–49

OffsetDateTime class, 767, 769–70

operation element, 480

operators, 58–68. *See also* by individual type

 assignment, 59

 precedence of, 59, 69, 797

 prefix/postfix, 59, 62

OutputStream class, 340–41, 343–45, 718

OutputStreamWriter class, 344, 718

@Override annotation class, 168, 199

P

package members, 263

 package importing, 264

- package referring to, 263–64
 - package using, 263–67
 - package-private, 111
 - package statements, 261–62, 264, 269, 679
 - packages, 4, 33, 34, 40, 259–70, 796
 - apparent hierarchies of, 265
 - creating, 261–62
 - importing, 264–65
 - name ambiguities, 265–66
 - naming, 262–63
 - qualified names, 262–67
 - using package members, 263–67
 - pages. *See* web pages
 - Panel class, 651
 - parallelism, 480–81
 - parallelSort method, 57, 552
 - parameterized types, 224
 - assigning raw types, 224–25
 - backward compatibility and, 224
 - bounded, 227–28
 - casting, 254
 - generic, 252
 - heap pollution and, 250, 251
 - primitive, 252–53
 - restrictions, 252–56
 - type erasure and, 244–45
 - type inference and, 233–34
 - varargs methods and, 249–50
 - parameters, 45
 - naming, 97
 - types, 96
 - parentheses. *See* ()
 - parse methods, 758, 772
 - parseXXX methods, 294, 601
 - PassPrimitiveByValue class, 98
 - Password example, 353–54
 - passwords, 353, 603, 639–40, 641
 - Path class, 362–70
 - PATH variable, 27, 29, 610–13
 - Pattern class, 557–59, 575, 578–79, 581. *See also* regular expressions
 - PatternSyntaxException, 589–91
 - peek method, 447, 449
 - percent sign. *See* %
 - Period class, 780
 - Perl, 557, 558, 578, 591
 - permissions
 - Permissions attribute, 31, 634, 724
 - sandbox, 654, 674
 - PI constant, 266
 - pipelines, 145, 472–74. *See also* streams
 - collections vs., 473
 - components of, 473
 - downstream collectors, 479
 - ordering, 483–84
 - parallel execution of, 481
 - terminal operations, 473, 475. *See also* reduction operations
 - Planet class, 159–60
 - pluggable type systems, xxiii, 170–71. *See also* type annotations
 - plus method, 758, 771
 - poll method, 410, 416, 446–47
 - polymorphism, 203–6, 245, 249, 799
 - pound sign. *See* #
 - pow method, 95, 281
 - precision query, 778
 - Predicate interface, 141–42
 - Preferences API, 603
 - PrePostDemo example, 62, 68
 - primitive data types, 46–51. *See also by individual type*; numbers
 - print method, 349–50
 - printf method, 97, 274–76
 - println method, 349–50
 - PriorityBlockingQueue class, 497
 - PriorityQueue implementation, 490, 497
 - problems. *See* errors
 - ProcessBuilder object, 520, 602
 - processElements method, 145–46
 - processes, 520
 - lightweight. *See* threads
 - Producer example, 538
 - ProducerConsumerExample example, 539
 - programs. *See* applications
 - properties
 - managing, 597
 - saving, 599–600
 - setting, 599–600
 - system, 605–7, 713–14
 - PropertiesTest example, 606
 - propertyName method, 599
 - protected modifier, 111
 - public modifier, 91, 111, 178, 185, 187
 - put method, 512
 - putAll method, 449, 452, 454
 - pwd command, 22, 30
- Q**
- qualified names
 - in applets, 659, 697
 - for fields, 97
 - for instance variables, 118
 - for methods, 118
 - for packages, 262–63
 - quantifiers, 573

question mark. *See* ?

Queue implementations, 427, 446–47, 490, 496–97

Queue interface, 446–48, 469, 491, 494, 497, 504

queues, 446–48

bounded, 446

priority, 427

QuoteClientApplet applet, 704–5

quoteReplacement method, 585

QuoteServer applet, 704–5

R

radians, 282–83

random access files, 339, 390, 393–95

random method, 283

random numbers, 283, 286, 543, 554–55

RandomAccessFile class, 337, 420

raw types, 224–25, 234, 248, 249, 250

readDouble method, 355–56

readInt method, 355–56

readObject method, 357–59

readPassword method, 353–54

readUTF method, 355–56

Receiver applet, 702–3

reduction operations, 474–80

concurrent, 481–82

multilevel reduction in streams, 479

mutable, 484

RegexTestHarness example, 559, 579–80

RegexTestHarness2 example, 589–90

regionMatches method, 300–301

RegionMatchesDemo example, 300

regular expressions, 557–93

backreferences in, 574–75

boundary matchers in, 576–77

capturing groups in, 572–76

character classes in, 557–58, 562–67

greedy quantifiers, 569, 573–74

intersections, 558–65

Matcher class, 583–89

metacharacters in, 561–62

negation, 563

Pattern class, 578–83

PatternsyntaxException class, 589–91

possessive quantifiers, 573

quantifiers in, 568–74

ranges, 563–64

reluctant quantifiers, 573

string literals, 560–62

subtraction, 565–66

test harness, 559–60

Unicode support, 591–92

zero-length matches in, 569–72

Relatable interface, 178–80

relational operators. *See* comparisons

remove method, 429, 431, 434, 469, 502

removeAll method, 430, 432–37, 454–56, 503

removeDups method, 434

removeEldestEntry method, 495

removeFirst method, 448, 494, 498

removeFirstOccurrence method, 449

removeLast method, 449, 498

removeLastOccurrence method, 449 [*]

renameTo method, 420

@Repeatable annotation type, 170, 172

replace method, 496

replaceAll method, 298, 445, 584, 587–89

ReplaceDemo example, 587

ReplaceDemo2 example, 587–88

REPLACE_EXISTING enum, 376–78

replaceFirst method, 298, 585, 587–89

reserved words. *See* keywords

retainAll method, 436–37, 454, 455

@Retention annotation type, 169

return statements, 85, 107, 147, 151, 464

return types, 92–94

constructors, 102

covariant, 109, 199

rich Internet applications (RIAs), xxiv, 711–27

cookies and, 719–22

customizing the loading experience in, 722

entry points, 635

local, 726

security in, 722–26

setting secure properties, 711–14

setting trusted arguments, 711–14

signing, 730–31

system properties, 713–14

testing, 724

user acceptance of, 729–31

using the JNLP API, 714–19

Root example, 349–50

Root2 example, 350

round method, 280

run method, 522, 523

runtime, 2, 26

checks at, 197

errors, 29–31

examining annotations at, 163

RuntimeException, 309, 312, 326, 329–30

S

Safelock example, 544–46

@SafeVarargs annotation type, 169

- sandbox, 635, 661–62, 722–25, 729–31, 748
 - applets, 705–7, 713–14
 - permissions, 654, 674, 677, 691, 703
- Scanner class, 346–48, 457
- scanning, 345–46
- ScanSum example, 348
- ScanXan example, 346–47
- ScheduledExecutorService interface, 546, 548, 549
- ScheduledThreadPoolExecutor class, 549
- security, xxiv
 - applets and, 596, 677–78
 - coding guidelines, 724
 - digitally signed files, 31, 637
 - JAR files, 31, 615, 635–42
 - Java Control Panel settings, 31, 730
 - Java versions and, 724, 730
 - Java Web Start applications and, 661–62
 - keystores and, 31, 639
 - legacy file I/O code and, 418–19
 - managers, 607–8, 707
 - manifest attributes and, 634–35
 - password entry and, 353
 - public and private keys, 636, 639
 - rich Internet applications (RIAs) and, 722–24
 - sandbox, 706–7
 - time stamping and, 654, 675, 725–26
 - TOCTTOU, 375
 - violations, 608
 - web browsers and, 697
- SecurityException, 172, 607, 608
- SecurityManager class, 607–8
- semicolon. *See* ;
- Sender applet, 702–3
- sequences. *See* collections, ordered
- Serializable interface, 214, 232, 357, 490
- serialization, 152, 214
- servers, 664, 678. *See* web servers
- ServiceLoader class, 603
- Set implementations, 492–93
- Set interface, 433–37, 469, 504
 - array operations of, 437
 - basic operations of, 434–35
 - bulk operations of, 436–37
- set method, 553, 757–58
- setDefaultHostnameVerifier method, 662
- setDefaultSSLSocketFactory method, 662
- setLastModified method, 420–21
- setLayout method, 379
- setLength method, 302, 303
- setProperties method, 605–7
- setProperty method, 599–600
- shadowing, 123–24
 - fields, 123–24
 - lambda expressions and, 148
 - local classes and, 129
- Short class, 74, 273, 285, 293, 459
- short data type, 46
 - default value of, 46
 - switch statement and, 74
- shortValue method, 273, 286
- ShowDocument applet, 682
- showDocument method, 682–83, 706
- showStatus method, 681
- Shuffle example, 440, 444
- signature block files, 638
- signature files, 637–38
- Signer Certificate Authority (CA) keystore, 31
- Simple applet, 668
- SimpleThreads example, 522, 525–26
- single quote. *See* '
- singleton method, 432, 455, 489, 503
- size method, 511–12
- slash. *See* /
- sleep method, 522–23
- SleepMessages example, 523–24
- Smalltalk's collection hierarchy, 425
- Socket class, 40
- sockets, 40, 520
- software. *See* applications
- Solaris/Linux
 - HelloWorld, 20–23
 - paths in, 360–67
 - updating PATH variable, 611–12
- sort method, 56, 189–90, 448, 506
- SortedMap interface, 428, 467–69, 490, 495, 500, 502, 516
 - Sorted comparison to SortedSet, 468
 - Sorted map operations, 468
 - Sorted standard conversion constructor in, 468
- SortedSet interface, 426, 428, 464–67, 468–69, 490, 492, 500
 - Sorted comparison to SortedMap, 469
 - Sorted endpoint operations in, 467
 - Sorted range-view operations, 465–67
 - Sorted set operations, 465
 - Sorted standard conversion constructors, 434
- split method, 550, 581, 583
- SplitDemo example, 581
- SplitDemo2 example, 581–82
- sqrt method, 97, 281, 349–50
- square brackets. *See* []
- square root, 266, 281, 349–50
- SSLSocketFactory class, 662

- Stack interface, 448
- stack trace, 248, 312, 327–28, 335
- StackOfInts class, 263
- standard error, 352, 698
- standard input, 352–53
- start method, 586, 667, 691, 699, 709
- startsWith method, 301, 369
- statements, 70. *See also* by individual type
 - synchronized, 529, 531–532
- static import statement, 266–67
- static initialization blocks, 117
- static keyword, 130–31, 186–87
- static modifier, 44, 57, 112, 114–15
- stop method, 667
- Stream.collect method, 476–80
- Stream.reduce method, 475–76
- streams, 145, 473
 - parallel, 481–84
 - pipelines and, 472–74
- streams, I/O, 339–59. *See also* by individual type
 - buffered, 345–46
 - byte, 340–42
 - character, 342–45
 - closing, 341–42
 - creating a file using, 389
 - data, 354–57
 - flushing, 346
 - object, 357–59
 - reading a file using, 389
 - unbuffered, 345
- string builders, 302–6
- String class, 48, 57, 74, 212, 271, 288, 289, 290, 291, 292, 295–98, 300, 302, 306–7, 588
- StringBuilder class, 271, 302–7, 800
- StringDemo example, 290, 294, 305
- StringIndexOutOfBoundsException, 299
- stringPropertyNames method, 599
- strings, 288–308
 - capacity of, 302
 - comparing portions of, 300, 301
 - concatenating, 291–92
 - converting between numbers and, 292–95
 - creating, 289
 - creating format strings, 292
 - length, 302
 - manipulating characters in, 295–300
 - replacing characters in, 296
 - searching within, 296
- StringSwitchDemo example, 77–78
- subclasses, 38–39, 88–90, 111, 118, 194, 787
 - abstract methods and, 212–16
 - access levels and, 111
 - capabilities of, 196
 - constructors, 207–8
 - creating, 38–39
 - final methods and, 117–18
 - inheritance and, 38–39
 - polymorphism in, 203–4
 - returning, 108
- subList method, 438, 443–46, 466
- submit method, 547
- subSequence method, 55, 297, 363, 575, 583–86
- subSet method, 264, 436, 464, 466, 670, 759
- substring method, 295–96, 299
- subtyping, 203–31, 239, 249
- super keyword, 202, 207, 238
- superclasses, 33, 168, 175, 198–99, 209, 216, 334
 - accessing, 206–7
 - choosing, 329
 - constructors for, 95, 207
 - declaring, 89–90
 - inheritance and, 38–39, 193–94, 216
 - Object class, 208–12
 - private members in, 196–97
- supplier argument, 477
- @SuppressWarnings annotation type, 165, 167–68, 226, 252, 416
- swap method, 439–40, 445, 508, 788
- Swing, 4, 210, 794. *See* graphical user interfaces (GUIs)
- switch block, 74–75
- switch statements, 74–79
- SwitchDemo example, 74
- SwitchDemo2 example, 76–77
- SwitchDemoFallThrough example, 75–76
- symbolic links, 361–62, 364, 374–77, 379, 381, 399–405, 408, 419, 422
- synchronization, 527–33
 - atomic access, 533
 - intrinsic locks and, 531
 - reentrant, 532
 - synchronized class example, 540–41
- synchronized keyword, 529–30
- synchronizedCollection method, 500–501
- SynchronizedCounter example, 529–30, 554
- synchronizedList method, 486–87, 494
- synchronizedMap method, 500–501
- SynchronizedRGB example, 540–42
- synchronizedSet method, 500
- synchronizedSortedMap method, 500
- synchronizedSortedSet method, 500
- SynchronousQueue class, 497
- synthetic constructs, 124–25
- System class, 26, 55–56, 597, 603–5

`System.console`, 353, 559, 590
`System.err`, 349, 352–53
`System.in`, 352–53
`System.out`, 274, 348, 352

T

`tab`, 289
`tailSet` method, 464, 467
`@Target` annotation type, 170
target typing, 150–51, 235–36
Temporal interface, 774–75
`TemporalAccessor` interface, 774–75
`TemporalAdjuster` interface, 776–80
 custom, 779–80
 predefined, 778–79
`TemporalQuery` method, 778–80
`TemporalUnit` interface, 774
ternary operators, 59, 64, 67, 797
test harness, 559–60
`TestFormat` example, 276–77
`TextField` class, 135
`this` keyword, 87, 98, 109–10, 799
`Thread` class, 522
thread pools, 411, 546–49
`ThreadLocalRandom`, 543, 554–55
`ThreadPoolExecutor` class, 549
threads, 520–21
 in applets, 670
 contention, 481
 defining, 521–22
 guarded blocks and, 535–39
 interference, 485–86, 527
 interrupts, 523–25
 joins, 525
 locks and, 534–35
 multithreaded applications, 272
 pausing, 522–23
 starting, 523–24
 synchronization of, 527–33
 thread objects, 521–27
 thread pools, 548–49
 thread safe, 306
throw statement, 324–25, 335
`Throwable` class, 255, 315, 325–26, 335
`throws` keyword, 324
`TicTacToe` example, 618–26
time. *See* Date-Time package
Time Zone Database (TZDB), 756
`to` prefix, 758
`toArray` method, 429–33, 465, 468, 497, 512, 514–15
`TOCTTOU`, 375

`toDegrees` method, 282–83
tokens, 346–47
`toLowerCase` method, 77–78, 289, 297, 306
`toRadians` method, 282–83
`toString` method, 211–12
`ToStringDemo` example, 294–95
`toUpperCase` method, 289, 297, 306
`TransferQueue` implementation, 498
`TreeMap` implementation, 450, 451, 468, 490–91, 495, 553
`TreeSet` implementation, 433–35, 450, 463, 465, 490–93
`TrigonometricDemo` example, 282
trigonometry, 272, 282–83, 286
`trim` method, 297, 470
troubleshooting. *See* errors
`Trusted-Library` attribute, 635
`Trusted-Only` attribute, 635
try blocks, 314–16, 318–22, 336, 370, 685, 800
`tryLock` method, 544–45
`try-with-resources` statement, 313, 317–20, 370, 397
type annotations, xxiii, 165. *See also* annotations
 pluggable type systems and, 170–71
type erasure, 244–52, 256
 bridge methods and, 247–49
 effects of, 247–49
type inference, 219, 223, 227, 232–34, 241, 801
type parameters, 98, 141, 221–30, 233–35, 237, 245–46, 249, 253–57
type variables, 221–22, 228
types. *See also* by individual type
 multiple inheritance of, 198–99
 nonreifiable, 227–27
 parameterized. *See* parameterized types
 raw, 224–26
 supertypes with common ancestors, 201
 type-checking, 170–71
TZDB. *See* Time Zone Database (TZDB)

U

unary operators, 59, 61–62, 66, 797
`UnaryDemo` example, 61
unboxing, 253, 271–72, 283–86, 288
underscore. *See* `_`
Unicode encoding
 character properties, 591–92
 regular expressions and, 591–92
 UTF-8, 356, 617, 628, 740
 UTF-16, 50, 740
UNIX. *See* Solaris/Linux
`unset` `CLASSPATH`, 30, 269

UnsupportedOperationException, 382, 385, 400, 426, 501–2
 URLClassLoader implementation, 642–44, 646
 useDelimiter method, 347
 UTF. *See* Unicode encoding

V

valueOf method, 286, 293, 294
 ValueOfDemo example, 287, 293–94
 values method, 159
 varargs, 96
 potential vulnerabilities of, 250–52
 preventing warnings from, 252
 variables, 44–57. *See also* by individual type;
 fields
 atomic, 553–54
 class. *See* fields, static
 constant, 130–31
 environment, 601–2, 609–13
 instance. *See* instance variables
 local, 42, 44, 133–34, 148–49
 naming conventions, 45–46, 90, 92
 referring to objects, 101
 Vector collection, 490, 494, 514
 compared to ArrayList, 494
 vertical bar. *See* |
 vi text editor, 20
 volatile keyword, 533, 553

W

wait method, 208
 warning messages, 225
 deprecation, 168
 security, 686
 suppressing, 686
 unchecked, 168
 WarningDemo example, 225
 watch keys, 413–14
 WatchService API, 410–16
 WeakHashMap implementation, 495–96
 web browsers
 displaying documents in, 682–83
 frames in, 682–83
 security in, 677–78
 web pages
 HTML frames, 682–83
 invoking applets, 674–76, 704–5
 Java applications, 654–56. *See* Java Web Start applications

web servers
 applets and, 31, 453–54
 JNLP errors in, 663
 placing applications on, 649, 656
 setting up, 656, 731–32
 testing, 31, 749–50
 while statement, 79–80, 85–86
 WhileDemo example, 79
 white space
 allowing, 577–78
 character construct for, 567
 cleaning up, 749
 disallowed, 45
 leading, 576–77
 tokens and, 308, 347–48
 trailing, 296–97
 wildcards, 236–44
 capture and, 240–43
 guidelines for using, 243–44
 helper methods and, 240–43
 lower-bounded, 238–39
 subtyping and, 239–40
 unbounded, 237–38
 upper-bounded, 236–37
 Windows. *See* Microsoft Windows
 with method, 758
 wrappers, 344, 480, 491, 500–502
 checked interface, 502
 implementations of, 489–90, 499–502
 synchronization, 480–81, 489, 491, 500–501
 unmodifiable, 502
 write method, 349, 386–88
 writeDouble method, 355–56
 writeInt method, 355–56
 writeObject method, 358–59
 writer method, 353
 writeUTF method, 355–56

Y

Year class, 764
 YearMonth class, 763–64

Z

ZIP archives, 616
 ZonedDateTime object, 767–69
 ZoneId class, 766–67
 ZoneOffset class, 766–67

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