



# Core Java<sup>®</sup> SE 9 for the Impatient

Second Edition

Cay S. Horstmann



FREE SAMPLE CHAPTER

SHARE WITH OTHERS



# **Core Java<sup>®</sup> SE 9 for the Impatient**

**Second Edition**

*This page intentionally left blank*

# Core Java<sup>®</sup> SE 9 for the Impatient

**Second Edition**

**Cay S. Horstmann**

◆ Addison-Wesley

Boston • Columbus • Indianapolis • New York • San Francisco • Amsterdam • Cape Town  
Dubai • London • Madrid • Milan • Munich • Paris • Montreal • Toronto • Delhi • Mexico City  
São Paulo • Sydney • Hong Kong • Seoul • Singapore • Taipei • Tokyo

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and the publisher was aware of a trademark claim, the designations have been printed with initial capital letters or in all capitals.

The author and publisher have taken care in the preparation of this book, but make no expressed or implied warranty of any kind and assume no responsibility for errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of the use of the information or programs contained herein.

For information about buying this title in bulk quantities, or for special sales opportunities (which may include electronic versions; custom cover designs; and content particular to your business, training goals, marketing focus, or branding interests), please contact our corporate sales department at [corpsales@pearsoned.com](mailto:corpsales@pearsoned.com) or (800) 382-3419.

For government sales inquiries, please contact [governmentsales@pearsoned.com](mailto:governmentsales@pearsoned.com).

For questions about sales outside the United States, please contact [intlcs@pearson.com](mailto:intlcs@pearson.com).

Visit us on the Web: [informit.com/aw](http://informit.com/aw)

*Library of Congress Control Number:* 2017947587

Copyright © 2018 Pearson Education, Inc.

Screenshots of Eclipse. Published by The Eclipse Foundation.

Screenshots of Java. Published by Oracle.

All rights reserved. Printed in the United States of America. This publication is protected by copyright, and permission must be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or likewise. For information regarding permissions, request forms and the appropriate contacts within the Pearson Education Global Rights & Permissions Department, please visit [www.pearsoned.com/permissions/](http://www.pearsoned.com/permissions/).

ISBN-13: 978-0-13-469472-6

ISBN-10: 0-13-469472-4

*To Chi—the most patient person in my life.*

*This page intentionally left blank*

---

# Contents

Preface	xxi
Acknowledgments	xxiii
About the Author	xxv

I	FUNDAMENTAL PROGRAMMING STRUCTURES	1
1.1	Our First Program	2
1.1.1	Dissecting the “Hello, World” Program	2
1.1.2	Compiling and Running a Java Program	3
1.1.3	Method Calls	6
1.1.4	JShell	7
1.2	Primitive Types	10
1.2.1	Signed Integer Types	10
1.2.2	Floating-Point Types	12
1.2.3	The <code>char</code> Type	13
1.2.4	The <code>boolean</code> Type	14
1.3	Variables	14
1.3.1	Variable Declarations	14
1.3.2	Names	14



- 1.3.3 Initialization 15
- 1.3.4 Constants 15
- 1.4 Arithmetic Operations 17
  - 1.4.1 Assignment 18
  - 1.4.2 Basic Arithmetic 18
  - 1.4.3 Mathematical Methods 19
  - 1.4.4 Number Type Conversions 20
  - 1.4.5 Relational and Logical Operators 22
  - 1.4.6 Big Numbers 23
- 1.5 Strings 24
  - 1.5.1 Concatenation 24
  - 1.5.2 Substrings 25
  - 1.5.3 String Comparison 25
  - 1.5.4 Converting Between Numbers and Strings 27
  - 1.5.5 The String API 28
  - 1.5.6 Code Points and Code Units 30
- 1.6 Input and Output 32
  - 1.6.1 Reading Input 32
  - 1.6.2 Formatted Output 33
- 1.7 Control Flow 36
  - 1.7.1 Branches 36
  - 1.7.2 Loops 38
  - 1.7.3 Breaking and Continuing 39
  - 1.7.4 Local Variable Scope 41
- 1.8 Arrays and Array Lists 43
  - 1.8.1 Working with Arrays 43
  - 1.8.2 Array Construction 44
  - 1.8.3 Array Lists 45
  - 1.8.4 Wrapper Classes for Primitive Types 46
  - 1.8.5 The Enhanced for Loop 47
  - 1.8.6 Copying Arrays and Array Lists 47
  - 1.8.7 Array Algorithms 49
  - 1.8.8 Command-Line Arguments 49
  - 1.8.9 Multidimensional Arrays 50

1.9	Functional Decomposition	52
1.9.1	Declaring and Calling Static Methods	53
1.9.2	Array Parameters and Return Values	53
1.9.3	Variable Arguments	53
	Exercises	54

## 2 OBJECT-ORIENTED PROGRAMMING 59

2.1	Working with Objects	60
2.1.1	Accessor and Mutator Methods	62
2.1.2	Object References	63
2.2	Implementing Classes	65
2.2.1	Instance Variables	65
2.2.2	Method Headers	65
2.2.3	Method Bodies	66
2.2.4	Instance Method Invocations	66
2.2.5	The <code>this</code> Reference	67
2.2.6	Call by Value	68
2.3	Object Construction	69
2.3.1	Implementing Constructors	69
2.3.2	Overloading	70
2.3.3	Calling One Constructor from Another	71
2.3.4	Default Initialization	71
2.3.5	Instance Variable Initialization	72
2.3.6	Final Instance Variables	73
2.3.7	The Constructor with No Arguments	73
2.4	Static Variables and Methods	74
2.4.1	Static Variables	74
2.4.2	Static Constants	75
2.4.3	Static Initialization Blocks	76
2.4.4	Static Methods	77
2.4.5	Factory Methods	78
2.5	Packages	78
2.5.1	Package Declarations	79
2.5.2	The <code>jar</code> Command	80

2.5.3	The Class Path	81
2.5.4	Package Access	83
2.5.5	Importing Classes	83
2.5.6	Static Imports	85
2.6	Nested Classes	85
2.6.1	Static Nested Classes	85
2.6.2	Inner Classes	87
2.6.3	Special Syntax Rules for Inner Classes	89
2.7	Documentation Comments	90
2.7.1	Comment Insertion	90
2.7.2	Class Comments	91
2.7.3	Method Comments	92
2.7.4	Variable Comments	92
2.7.5	General Comments	92
2.7.6	Links	93
2.7.7	Package, Module, and Overview Comments	94
2.7.8	Comment Extraction	94
	Exercises	95

### 3 INTERFACES AND LAMBDA EXPRESSIONS 99

3.1	Interfaces	100
3.1.1	Declaring an Interface	100
3.1.2	Implementing an Interface	101
3.1.3	Converting to an Interface Type	103
3.1.4	Casts and the <code>instanceof</code> Operator	103
3.1.5	Extending Interfaces	104
3.1.6	Implementing Multiple Interfaces	105
3.1.7	Constants	105
3.2	Static, Default, and Private Methods	105
3.2.1	Static Methods	105
3.2.2	Default Methods	106
3.2.3	Resolving Default Method Conflicts	107
3.2.4	Private Methods	109

---

3.3	Examples of Interfaces	109
3.3.1	The Comparable Interface	109
3.3.2	The Comparator Interface	111
3.3.3	The Runnable Interface	112
3.3.4	User Interface Callbacks	112
3.4	Lambda Expressions	113
3.4.1	The Syntax of Lambda Expressions	114
3.4.2	Functional Interfaces	115
3.5	Method and Constructor References	116
3.5.1	Method References	117
3.5.2	Constructor References	118
3.6	Processing Lambda Expressions	119
3.6.1	Implementing Deferred Execution	119
3.6.2	Choosing a Functional Interface	120
3.6.3	Implementing Your Own Functional Interfaces	123
3.7	Lambda Expressions and Variable Scope	124
3.7.1	Scope of a Lambda Expression	124
3.7.2	Accessing Variables from the Enclosing Scope	124
3.8	Higher-Order Functions	127
3.8.1	Methods that Return Functions	127
3.8.2	Methods That Modify Functions	128
3.8.3	Comparator Methods	128
3.9	Local and Anonymous Classes	129
3.9.1	Local Classes	129
3.9.2	Anonymous Classes	130
	Exercises	131
<b>4</b>	<b>INHERITANCE AND REFLECTION</b>	<b>135</b>
4.1	Extending a Class	136
4.1.1	Super- and Subclasses	136
4.1.2	Defining and Inheriting Subclass Methods	137
4.1.3	Method Overriding	137
4.1.4	Subclass Construction	139

4.1.5	Superclass Assignments	139
4.1.6	Casts	140
4.1.7	Final Methods and Classes	141
4.1.8	Abstract Methods and Classes	141
4.1.9	Protected Access	142
4.1.10	Anonymous Subclasses	143
4.1.11	Inheritance and Default Methods	144
4.1.12	Method Expressions with <code>super</code>	145
4.2	Object: The Cosmic Superclass	145
4.2.1	The <code>toString</code> Method	146
4.2.2	The <code>equals</code> Method	148
4.2.3	The <code>hashCode</code> Method	150
4.2.4	Cloning Objects	151
4.3	Enumerations	154
4.3.1	Methods of Enumerations	155
4.3.2	Constructors, Methods, and Fields	156
4.3.3	Bodies of Instances	157
4.3.4	Static Members	157
4.3.5	Switching on an Enumeration	158
4.4	Runtime Type Information and Resources	159
4.4.1	The Class <code>Class</code>	159
4.4.2	Loading Resources	162
4.4.3	Class Loaders	163
4.4.4	The Context Class Loader	164
4.4.5	Service Loaders	166
4.5	Reflection	168
4.5.1	Enumerating Class Members	168
4.5.2	Inspecting Objects	169
4.5.3	Invoking Methods	171
4.5.4	Constructing Objects	171
4.5.5	JavaBeans	172
4.5.6	Working with Arrays	174
4.5.7	Proxies	175
	Exercises	177

---

5	EXCEPTIONS, ASSERTIONS, AND LOGGING	181
5.1	Exception Handling	182
5.1.1	Throwing Exceptions	182
5.1.2	The Exception Hierarchy	183
5.1.3	Declaring Checked Exceptions	185
5.1.4	Catching Exceptions	186
5.1.5	The Try-with-Resources Statement	187
5.1.6	The finally Clause	189
5.1.7	Rethrowing and Chaining Exceptions	190
5.1.8	Uncaught Exceptions and the Stack Trace	192
5.1.9	The <code>Objects.requireNonNull</code> Method	193
5.2	Assertions	193
5.2.1	Using Assertions	194
5.2.2	Enabling and Disabling Assertions	194
5.3	Logging	195
5.3.1	Using Loggers	195
5.3.2	Loggers	196
5.3.3	Logging Levels	197
5.3.4	Other Logging Methods	197
5.3.5	Logging Configuration	199
5.3.6	Log Handlers	200
5.3.7	Filters and Formatters	202
	Exercises	203
6	GENERIC PROGRAMMING	207
6.1	Generic Classes	208
6.2	Generic Methods	209
6.3	Type Bounds	210
6.4	Type Variance and Wildcards	211
6.4.1	Subtype Wildcards	212
6.4.2	Supertype Wildcards	213
6.4.3	Wildcards with Type Variables	214
6.4.4	Unbounded Wildcards	215
6.4.5	Wildcard Capture	216

- 6.5 Generics in the Java Virtual Machine 216
  - 6.5.1 Type Erasure 217
  - 6.5.2 Cast Insertion 217
  - 6.5.3 Bridge Methods 218
- 6.6 Restrictions on Generics 220
  - 6.6.1 No Primitive Type Arguments 220
  - 6.6.2 At Runtime, All Types Are Raw 220
  - 6.6.3 You Cannot Instantiate Type Variables 221
  - 6.6.4 You Cannot Construct Arrays of Parameterized Types 223
  - 6.6.5 Class Type Variables Are Not Valid in Static Contexts 224
  - 6.6.6 Methods May Not Clash after Erasure 224
  - 6.6.7 Exceptions and Generics 225
- 6.7 Reflection and Generics 226
  - 6.7.1 The `Class<T>` Class 227
  - 6.7.2 Generic Type Information in the Virtual Machine 227

Exercises 229

## 7 COLLECTIONS 235

- 7.1 An Overview of the Collections Framework 236
- 7.2 Iterators 240
- 7.3 Sets 242
- 7.4 Maps 243
- 7.5 Other Collections 247
  - 7.5.1 Properties 247
  - 7.5.2 Bit Sets 248
  - 7.5.3 Enumeration Sets and Maps 250
  - 7.5.4 Stacks, Queues, Deques, and Priority Queues 250
  - 7.5.5 Weak Hash Maps 251
- 7.6 Views 252
  - 7.6.1 Small Collections 252
  - 7.6.2 Ranges 253

---

7.6.3	Unmodifiable Views	254
Exercises		255
<b>8</b>	<b>STREAMS</b>	<b>259</b>
8.1	From Iterating to Stream Operations	260
8.2	Stream Creation	261
8.3	The <code>filter</code> , <code>map</code> , and <code>flatMap</code> Methods	263
8.4	Extracting Substreams and Combining Streams	264
8.5	Other Stream Transformations	265
8.6	Simple Reductions	266
8.7	The Optional Type	267
8.7.1	How to Work with Optional Values	267
8.7.2	How Not to Work with Optional Values	269
8.7.3	Creating Optional Values	269
8.7.4	Composing Optional Value Functions with <code>flatMap</code>	269
8.7.5	Turning an Optional Into a Stream	270
8.8	Collecting Results	271
8.9	Collecting into Maps	273
8.10	Grouping and Partitioning	274
8.11	Downstream Collectors	275
8.12	Reduction Operations	277
8.13	Primitive Type Streams	279
8.14	Parallel Streams	280
Exercises		283
<b>9</b>	<b>PROCESSING INPUT AND OUTPUT</b>	<b>287</b>
9.1	Input/Output Streams, Readers, and Writers	288
9.1.1	Obtaining Streams	288
9.1.2	Reading Bytes	289
9.1.3	Writing Bytes	290
9.1.4	Character Encodings	290
9.1.5	Text Input	293
9.1.6	Text Output	294
9.1.7	Reading and Writing Binary Data	295



9.1.8	Random-Access Files	296
9.1.9	Memory-Mapped Files	297
9.1.10	File Locking	297
9.2	Paths, Files, and Directories	298
9.2.1	Paths	298
9.2.2	Creating Files and Directories	300
9.2.3	Copying, Moving, and Deleting Files	301
9.2.4	Visiting Directory Entries	302
9.2.5	ZIP File Systems	305
9.3	HTTP Connections	306
9.3.1	The <code>URLConnection</code> and <code>HttpURLConnection</code> Classes	306
9.3.2	The HTTP Client API	307
9.4	Regular Expressions	310
9.4.1	The Regular Expression Syntax	310
9.4.2	Finding One Match	314
9.4.3	Finding All Matches	315
9.4.4	Groups	316
9.4.5	Splitting along Delimiters	317
9.4.6	Replacing Matches	317
9.4.7	Flags	318
9.5	Serialization	319
9.5.1	The <code>Serializable</code> Interface	319
9.5.2	Transient Instance Variables	321
9.5.3	The <code>readObject</code> and <code>writeObject</code> Methods	321
9.5.4	The <code>readResolve</code> and <code>writeReplace</code> Methods	322
9.5.5	Versioning	324
	Exercises	325

## I0 CONCURRENT PROGRAMMING 329

10.1	Concurrent Tasks	330
10.1.1	Running Tasks	330
10.1.2	Futures	333
10.2	Asynchronous Computations	335
10.2.1	Completable Futures	335

---

10.2.2	Composing Completable Futures	337
10.2.3	Long-Running Tasks in User-Interface Callbacks	340
10.3	Thread Safety	341
10.3.1	Visibility	342
10.3.2	Race Conditions	344
10.3.3	Strategies for Safe Concurrency	346
10.3.4	Immutable Classes	347
10.4	Parallel Algorithms	348
10.4.1	Parallel Streams	348
10.4.2	Parallel Array Operations	349
10.5	Threadsafe Data Structures	350
10.5.1	Concurrent Hash Maps	350
10.5.2	Blocking Queues	352
10.5.3	Other Threadsafe Data Structures	354
10.6	Atomic Counters and Accumulators	354
10.7	Locks and Conditions	357
10.7.1	Locks	357
10.7.2	The <code>synchronized</code> Keyword	358
10.7.3	Waiting on Conditions	360
10.8	Threads	362
10.8.1	Starting a Thread	363
10.8.2	Thread Interruption	364
10.8.3	Thread-Local Variables	365
10.8.4	Miscellaneous Thread Properties	366
10.9	Processes	366
10.9.1	Building a Process	367
10.9.2	Running a Process	368
10.9.3	Process Handles	370
	Exercises	371
II	ANNOTATIONS	377
11.1	Using Annotations	378
11.1.1	Annotation Elements	378
11.1.2	Multiple and Repeated Annotations	380

11.1.3	Annotating Declarations	380
11.1.4	Annotating Type Uses	381
11.1.5	Making Receivers Explicit	382
11.2	Defining Annotations	383
11.3	Standard Annotations	386
11.3.1	Annotations for Compilation	387
11.3.2	Annotations for Managing Resources	388
11.3.3	Meta-Annotations	389
11.4	Processing Annotations at Runtime	391
11.5	Source-Level Annotation Processing	394
11.5.1	Annotation Processors	394
11.5.2	The Language Model API	395
11.5.3	Using Annotations to Generate Source Code	395
	Exercises	398
<b>I2</b>	<b>THE DATE AND TIME API</b>	<b>401</b>
12.1	The Time Line	402
12.2	Local Dates	404
12.3	Date Adjusters	407
12.4	Local Time	409
12.5	Zoned Time	410
12.6	Formatting and Parsing	413
12.7	Interoperating with Legacy Code	416
	Exercises	417
<b>I3</b>	<b>INTERNATIONALIZATION</b>	<b>421</b>
13.1	Locales	422
13.1.1	Specifying a Locale	423
13.1.2	The Default Locale	426
13.1.3	Display Names	426
13.2	Number Formats	427
13.3	Currencies	428
13.4	Date and Time Formatting	429
13.5	Collation and Normalization	431

- 13.6 Message Formatting 433
- 13.7 Resource Bundles 435
  - 13.7.1 Organizing Resource Bundles 435
  - 13.7.2 Bundle Classes 437
- 13.8 Character Encodings 438
- 13.9 Preferences 439
- Exercises 441

## I4 COMPILING AND SCRIPTING 443

- 14.1 The Compiler API 444
  - 14.1.1 Invoking the Compiler 444
  - 14.1.2 Launching a Compilation Task 444
  - 14.1.3 Reading Source Files from Memory 445
  - 14.1.4 Writing Byte Codes to Memory 446
  - 14.1.5 Capturing Diagnostics 447
- 14.2 The Scripting API 448
  - 14.2.1 Getting a Scripting Engine 448
  - 14.2.2 Bindings 449
  - 14.2.3 Redirecting Input and Output 449
  - 14.2.4 Calling Scripting Functions and Methods 450
  - 14.2.5 Compiling a Script 452
- 14.3 The Nashorn Scripting Engine 452
  - 14.3.1 Running Nashorn from the Command Line 452
  - 14.3.2 Invoking Getters, Setters, and Overloaded Methods 453
  - 14.3.3 Constructing Java Objects 454
  - 14.3.4 Strings in JavaScript and Java 455
  - 14.3.5 Numbers 456
  - 14.3.6 Working with Arrays 457
  - 14.3.7 Lists and Maps 458
  - 14.3.8 Lambdas 458
  - 14.3.9 Extending Java Classes and Implementing Java Interfaces 459
  - 14.3.10 Exceptions 461

14.4	Shell Scripting with Nashorn	461
14.4.1	Executing Shell Commands	462
14.4.2	String Interpolation	462
14.4.3	Script Inputs	463
	Exercises	464
<b>I5</b>	<b>THE JAVA PLATFORM MODULE SYSTEM</b>	<b>469</b>
15.1	The Module Concept	470
15.2	Naming Modules	472
15.3	The Modular “Hello, World!” Program	472
15.4	Requiring Modules	474
15.5	Exporting Packages	476
15.6	Modules and Reflective Access	479
15.7	Modular JARs	482
15.8	Automatic Modules and the Unnamed Module	484
15.9	Command-Line Flags for Migration	485
15.10	Transitive and Static Requirements	487
15.11	Qualified Exporting and Opening	489
15.12	Service Loading	490
15.13	Tools for Working with Modules	491
	Exercises	494
	Index	497

---

# Preface

Java is now over twenty years old, and the classic book, *Core Java*, covers, in meticulous detail, not just the language but all core libraries and a multitude of changes between versions, spanning two volumes and well over 2,000 pages. However, if you just want to be productive with modern Java, there is a much faster, easier pathway for learning the language and core libraries. In this book, I don't retrace history and don't dwell on features of past versions. I show you the good parts of Java as it exists today, with Java 9, so you can put your knowledge to work quickly.

As with my previous "Impatient" books, I quickly cut to the chase, showing you what you need to know to solve a programming problem without lecturing about the superiority of one paradigm over another. I also present the information in small chunks, organized so that you can quickly retrieve it when needed.

Assuming you are proficient in some other programming language, such as C++, JavaScript, Objective C, PHP, or Ruby, with this book you will learn how to become a competent Java programmer. I cover all aspects of Java that a developer needs to know, including the powerful concepts of lambda expressions and streams. I tell you where to find out more about old-fashioned concepts that you might still see in legacy code, but I don't dwell on them.

A key reason to use Java is to tackle concurrent programming. With parallel algorithms and threadsafe data structures readily available in the Java library,

the way application programmers should handle concurrent programming has completely changed. I provide fresh coverage, showing you how to use the powerful library features instead of error-prone low-level constructs.

Traditionally, books on Java have focused on user interface programming—but nowadays, few developers produce user interfaces on desktop computers. If you intend to use Java for server-side programming or Android programming, you will be able to use this book effectively without being distracted by desktop GUI code.

Finally, this book is written for application programmers, not for a college course and not for systems wizards. The book covers issues that application programmers need to wrestle with, such as logging and working with files—but you won't learn how to implement a linked list by hand or how to write a web server.

I hope you enjoy this rapid-fire introduction into modern Java, and I hope it will make your work with Java productive and enjoyable.

If you find errors or have suggestions for improvement, please visit <http://horstmann.com/javaimpatient> and leave a comment. On that page, you will also find a link to an archive file containing all code examples from the book.

---

# Acknowledgments

My thanks go, as always, to my editor Greg Doench, who enthusiastically supported the vision of a short book that gives a fresh introduction to Java SE 9. Dmitry Kirsanov and Alina Kirsanova once again turned an XHTML manuscript into an attractive book with amazing speed and attention to detail. My special gratitude goes to the excellent team of reviewers for both editions who spotted many errors and gave thoughtful suggestions for improvement. They are: Andres Almiray, Gail Anderson, Paul Anderson, Marcus Biel, Brian Goetz, Marty Hall, Mark Lawrence, Doug Lea, Simon Ritter, Yoshiki Shibata, and Christian Ullenboom.

*Cay Horstmann  
San Francisco  
July 2017*



*This page intentionally left blank*

---

# About the Author

**Cay S. Horstmann** is the author of *Java SE 8 for the Really Impatient* and *Scala for the Impatient* (both from Addison-Wesley), is principal author of *Core Java™, Volumes I and II, Tenth Edition* (Prentice Hall, 2016), and has written a dozen other books for professional programmers and computer science students. He is a professor of computer science at San Jose State University and is a Java Champion.

---

# Interfaces and Lambda Expressions

## Topics in This Chapter

- 3.1 Interfaces — page 100
- 3.2 Static, Default, and Private Methods — page 105
- 3.3 Examples of Interfaces — page 109
- 3.4 Lambda Expressions — page 113
- 3.5 Method and Constructor References — page 116
- 3.6 Processing Lambda Expressions — page 119
- 3.7 Lambda Expressions and Variable Scope — page 124
- 3.8 Higher-Order Functions — page 127
- 3.9 Local and Anonymous Classes — page 129
- Exercises — page 131

---

# Chapter

# 3

Java was designed as an object-oriented programming language in the 1990s when object-oriented programming was the principal paradigm for software development. Interfaces are a key feature of object-oriented programming: They let you specify what should be done, without having to provide an implementation.

Long before there was object-oriented programming, there were functional programming languages, such as Lisp, in which functions and not objects are the primary structuring mechanism. Recently, functional programming has risen in importance because it is well suited for concurrent and event-driven (or “reactive”) programming. Java supports function expressions that provide a convenient bridge between object-oriented and functional programming. In this chapter, you will learn about interfaces and lambda expressions.

The key points of this chapter are:

1. An interface specifies a set of methods that an implementing class must provide.
2. An interface is a supertype of any class that implements it. Therefore, one can assign instances of the class to variables of the interface type.
3. An interface can contain static methods. All variables of an interface are automatically public, static, and final.

4. An interface can contain default methods that an implementing class can inherit or override.
5. An interface can contain private methods that cannot be called or overridden by implementing classes.
6. The `Comparable` and `Comparator` interfaces are used for comparing objects.
7. A functional interface is an interface with a single abstract method.
8. A lambda expression denotes a block of code that can be executed at a later point in time.
9. Lambda expressions are converted to functional interfaces.
10. Method and constructor references refer to methods or constructors without invoking them.
11. Lambda expressions and local classes can access effectively final variables from the enclosing scope.

## 3.1 Interfaces

An *interface* is a mechanism for spelling out a contract between two parties: the supplier of a service and the classes that want their objects to be usable with the service. In the following sections, you will see how to define and use interfaces in Java.

### 3.1.1 Declaring an Interface

Consider a service that works on sequences of integers, reporting the average of the first  $n$  values:

```
public static double average(IntSequence seq, int n)
```

Such sequences can take many forms. Here are some examples:

- A sequence of integers supplied by a user
- A sequence of random integers
- The sequence of prime numbers
- The sequence of elements in an integer array
- The sequence of code points in a string
- The sequence of digits in a number

We want to implement a *single mechanism* for dealing with all these kinds of sequences.

First, let us spell out what is common between integer sequences. At a minimum, one needs two methods for working with a sequence:

- Test whether there is a next element
- Get the next element

To declare an interface, you provide the method headers, like this:

```
public interface IntSequence {
    boolean hasNext();
    int next();
}
```

You need not implement these methods, but you can provide default implementations if you like—see Section 3.2.2, “Default Methods” (page 106). If no implementation is provided, we say that the method is *abstract*.



---

**NOTE:** All methods of an interface are automatically `public`. Therefore, it is not necessary to declare `hasNext` and `next` as `public`. Some programmers do it anyway for greater clarity.

---

The methods in the interface suffice to implement the average method:

```
public static double average(IntSequence seq, int n) {
    int count = 0;
    double sum = 0;
    while (seq.hasNext() && count < n) {
        count++;
        sum += seq.next();
    }
    return count == 0 ? 0 : sum / count;
}
```

### 3.1.2 Implementing an Interface

Now let’s look at the other side of the coin: the classes that want to be usable with the average method. They need to *implement* the `IntSequence` interface. Here is such a class:

```
public class SquareSequence implements IntSequence {
    private int i;

    public boolean hasNext() {
        return true;
    }
}
```

```
        public int next() {
            i++;
            return i * i;
        }
    }
```

There are infinitely many squares, and an object of this class delivers them all, one at a time. (To keep the example simple, we ignore integer overflow—see Exercise 6.)

The `implements` keyword indicates that the `SquareSequence` class intends to conform to the `IntSequence` interface.



**CAUTION:** The implementing class must declare the methods of the interface as `public`. Otherwise, they would default to package access. Since the interface requires public access, the compiler would report an error.

---

This code gets the average of the first 100 squares:

```
SquareSequence squares = new SquareSequence();
double avg = average(squares, 100);
```

There are many classes that can implement the `IntSequence` interface. For example, this class yields a finite sequence, namely the digits of a positive integer starting with the least significant one:

```
public class DigitSequence implements IntSequence {
    private int number;

    public DigitSequence(int n) {
        number = n;
    }

    public boolean hasNext() {
        return number != 0;
    }

    public int next() {
        int result = number % 10;
        number /= 10;
        return result;
    }

    public int rest() {
        return number;
    }
}
```

An object `new DigitSequence(1729)` delivers the digits 9 2 7 1 before `hasNext` returns `false`.



**NOTE:** The `SquareSequence` and `DigitSequence` classes implement all methods of the `IntSequence` interface. If a class only implements some of the methods, then it must be declared with the abstract modifier. See Chapter 4 for more information on abstract classes.

### 3.1.3 Converting to an Interface Type

This code fragment computes the average of the digit sequence values:

```
IntSequence digits = new DigitSequence(1729);
double avg = average(digits, 100);
// Will only look at the first four sequence values
```

Look at the `digits` variable. Its type is `IntSequence`, not `DigitSequence`. A variable of type `IntSequence` refers to an object of some class that implements the `IntSequence` interface. You can always assign an object to a variable whose type is an implemented interface, or pass it to a method expecting such an interface.

Here is a bit of useful terminology. A type  $s$  is a *supertype* of the type  $\tau$  (the *subtype*) when any value of the subtype can be assigned to a variable of the supertype without a conversion. For example, the `IntSequence` interface is a supertype of the `DigitSequence` class.



**NOTE:** Even though it is possible to declare variables of an interface type, you can never have an object whose type is an interface. All objects are instances of classes.

### 3.1.4 Casts and the instanceof Operator

Occasionally, you need the opposite conversion—from a supertype to a subtype. Then you use a *cast*. For example, if you happen to know that the object stored in an `IntSequence` is actually a `DigitSequence`, you can convert the type like this:

```
IntSequence sequence = ...;
DigitSequence digits = (DigitSequence) sequence;
System.out.println(digits.rest());
```

In this scenario, the cast was necessary because `rest` is a method of `DigitSequence` but not `IntSequence`.



See Exercise 2 for a more compelling example.

You can only cast an object to its actual class or one of its supertypes. If you are wrong, a compile-time error or class cast exception will occur:

```
String digitString = (String) sequence;
    // Cannot possibly work—IntSequence is not a supertype of String
RandomSequence randoms = (RandomSequence) sequence;
    // Could work, throws a class cast exception if not
```

To avoid the exception, you can first test whether the object is of the desired type, using the `instanceof` operator. The expression

```
object instanceof Type
```

returns true if *object* is an instance of a class that has *Type* as a supertype. It is a good idea to make this check before using a cast.

```
if (sequence instanceof DigitSequence) {
    DigitSequence digits = (DigitSequence) sequence;
    ...
}
```



**NOTE:** The `instanceof` operator is null-safe: The expression `obj instanceof Type` is false if `obj` is null. After all, null cannot possibly be a reference to an object of any given type.

---

### 3.1.5 Extending Interfaces

An interface can *extend* another, requiring or providing additional methods on top of the original ones. For example, `Closeable` is an interface with a single method:

```
public interface Closeable {
    void close();
}
```

As you will see in Chapter 5, this is an important interface for closing resources when an exception occurs.

The `Channel` interface extends this interface:

```
public interface Channel extends Closeable {
    boolean isOpen();
}
```

A class that implements the `Channel` interface must provide both methods, and its objects can be converted to both interface types.

### 3.1.6 Implementing Multiple Interfaces

A class can implement any number of interfaces. For example, a `FileSequence` class that reads integers from a file can implement the `Closeable` interface in addition to `IntSequence`:

```
public class FileSequence implements IntSequence, Closeable {
    ...
}
```

Then the `FileSequence` class has both `IntSequence` and `Closeable` as supertypes.

### 3.1.7 Constants

Any variable defined in an interface is automatically `public static final`.

For example, the `SwingConstants` interface defines constants for compass directions:

```
public interface SwingConstants {
    int NORTH = 1;
    int NORTH_EAST = 2;
    int EAST = 3;
    ...
}
```

You can refer to them by their qualified name, `SwingConstants.NORTH`. If your class chooses to implement the `SwingConstants` interface, you can drop the `SwingConstants` qualifier and simply write `NORTH`. However, this is not a common idiom. It is far better to use enumerations for a set of constants; see Chapter 4.



**NOTE:** You cannot have instance variables in an interface. An interface specifies behavior, not object state.

---

## 3.2 Static, Default, and Private Methods

In earlier versions of Java, all methods of an interface had to be abstract—that is, without a body. Nowadays you can add three kinds of methods with a concrete implementation: static, default, and private methods. The following sections describe these methods.

### 3.2.1 Static Methods

There was never a technical reason why an interface could not have static methods, but they did not fit into the view of interfaces as abstract

specifications. That thinking has now evolved. In particular, factory methods make a lot of sense in interfaces. For example, the `IntSequence` interface can have a static method `digitsOf` that generates a sequence of digits of a given integer:

```
IntSequence digits = IntSequence.digitsOf(1729);
```

The method yields an instance of some class implementing the `IntSequence` interface, but the caller need not care which one it is.

```
public interface IntSequence {  
    ...  
    static IntSequence digitsOf(int n) {  
        return new DigitSequence(n);  
    }  
}
```



**NOTE:** In the past, it had been common to place static methods in a companion class. You find pairs of interfaces and utility classes, such as `Collection/Collections` or `Path/Paths`, in the Java API. This split is no longer necessary.

---

### 3.2.2 Default Methods

You can supply a *default* implementation for any interface method. You must tag such a method with the default modifier.

```
public interface IntSequence {  
    default boolean hasNext() { return true; }  
    // By default, sequences are infinite  
    int next();  
}
```

A class implementing this interface can choose to override the `hasNext` method or to inherit the default implementation.



**NOTE:** Default methods put an end to the classic pattern of providing an interface and a companion class that implements most or all of its methods, such as `Collection/AbstractCollection` or `WindowListener/WindowAdapter` in the Java API. Nowadays you should just implement the methods in the interface.

---

An important use for default methods is *interface evolution*. Consider for example the `Collection` interface that has been a part of Java for many years. Suppose that way back when, you provided a class

```
public class Bag implements Collection
```

Later, in Java 8, a `stream` method was added to the interface.

Suppose the `stream` method was not a default method. Then the `Bag` class no longer compiles since it doesn't implement the new method. Adding a nondefault method to an interface is not *source-compatible*.

But suppose you don't recompile the class and simply use an old JAR file containing it. The class will still load, even with the missing method. Programs can still construct `Bag` instances, and nothing bad will happen. (Adding a method to an interface is *binary-compatible*.) However, if a program calls the `stream` method on a `Bag` instance, an `AbstractMethodError` occurs.

Making the method a default method solves both problems. The `Bag` class will again compile. And if the class is loaded without being recompiled and the `stream` method is invoked on a `Bag` instance, the `Collection.stream` method is called.

### 3.2.3 Resolving Default Method Conflicts

If a class implements two interfaces, one of which has a default method and the other a method (default or not) with the same name and parameter types, then you must resolve the conflict. This doesn't happen very often, and it is usually easy to deal with the situation.

Let's look at an example. Suppose we have an interface `Person` with a `getId` method:

```
public interface Person {
    String getName();
    default int getId() { return 0; }
}
```

And suppose there is an interface `Identified`, also with such a method.

```
public interface Identified {
    default int getId() { return Math.abs(hashCode()); }
}
```

You will see what the `hashCode` method does in Chapter 4. For now, all that matters is that it returns some integer that is derived from the object.

What happens if you form a class that implements both of them?

```
public class Employee implements Person, Identified {
    ...
}
```

The class inherits two `getId` methods provided by the `Person` and `Identified` interfaces. There is no way for the Java compiler to choose one over the other. The compiler reports an error and leaves it up to you to resolve the ambiguity.

Provide a `getId` method in the `Employee` class and either implement your own ID scheme, or delegate to one of the conflicting methods, like this:

```
public class Employee implements Person, Identified {  
    public int getId() { return Identified.super.getId(); }  
    ...  
}
```



**NOTE:** The `super` keyword lets you call a supertype method. In this case, we need to specify which supertype we want. The syntax may seem a bit odd, but it is consistent with the syntax for invoking a superclass method that you will see in Chapter 4.

---

Now assume that the `Identified` interface does not provide a default implementation for `getId`:

```
interface Identified {  
    int getId();  
}
```

Can the `Employee` class inherit the default method from the `Person` interface? At first glance, this might seem reasonable. But how does the compiler know whether the `Person.getId` method actually does what `Identified.getId` is expected to do? After all, it might return the level of the person's Freudian id, not an ID number.

The Java designers decided in favor of safety and uniformity. It doesn't matter how two interfaces conflict; if at least one interface provides an implementation, the compiler reports an error, and it is up to the programmer to resolve the ambiguity.



**NOTE:** If neither interface provides a default for a shared method, then there is no conflict. An implementing class has two choices: implement the method, or leave it unimplemented and declare the class as `abstract`.

---



**NOTE:** If a class extends a superclass (see Chapter 4) and implements an interface, inheriting the same method from both, the rules are easier. In that case, only the superclass method matters, and any default method from the interface is simply ignored. This is actually a more common case than conflicting interfaces. See Chapter 4 for the details.

---

### 3.2.4 Private Methods

As of Java 9, methods in an interface can be private. A private method can be static or an instance method, but it cannot be a default method since that can be overridden. As private methods can only be used in the methods of the interface itself, their use is limited to being helper methods for the other methods of the interface.

For example, suppose the `IntSequence` class provides methods

```
static of(int a)
static of(int a, int b)
static of(int a, int b, int c)
```

Then each of these methods could call a helper method

```
private static IntSequence makeFiniteSequence(int... values) { ... }
```

## 3.3 Examples of Interfaces

At first glance, interfaces don't seem to do very much. An interface is just a set of methods that a class promises to implement. To make the importance of interfaces more tangible, the following sections show you four examples of commonly used interfaces from the Java API.

### 3.3.1 The Comparable Interface

Suppose you want to sort an array of objects. A sorting algorithm repeatedly compares elements and rearranges them if they are out of order. Of course, the rules for doing the comparison are different for each class, and the sorting algorithm should just call a method supplied by the class. As long as all classes can agree on what that method is called, the sorting algorithm can do its job. That is where interfaces come in.

If a class wants to enable sorting for its objects, it should implement the `Comparable` interface. There is a technical point about this interface. We want to compare strings against strings, employees against employees, and so on. For that reason, the `Comparable` interface has a type parameter.

```
public interface Comparable<T> {
    int compareTo(T other);
}
```

For example, the `String` class implements `Comparable<String>` so that its `compareTo` method has the signature

```
int compareTo(String other)
```



---

**NOTE:** A type with a type parameter such as `Comparable` or `ArrayList` is a *generic* type. You will learn all about generic types in Chapter 6.

---

When calling `x.compareTo(y)`, the `compareTo` method returns an integer value to indicate whether `x` or `y` should come first. A positive return value (not necessarily 1) indicates that `x` should come after `y`. A negative integer (not necessarily -1) is returned when `x` should come before `y`. If `x` and `y` are considered equal, the returned value is 0.

Note that the return value can be any integer. That flexibility is useful because it allows you to return a difference of integers. That is handy, provided the difference cannot produce integer overflow.

```
public class Employee implements Comparable<Employee> {
    ...
    public int compareTo(Employee other) {
        return getId() - other.getId(); // Ok if IDs always ≥ 0
    }
}
```



---

**CAUTION:** Returning a difference of integers does not always work. The difference can overflow for large operands of opposite sign. In that case, use the `Integer.compare` method that works correctly for all integers. However, if you know that the integers are non-negative, or their absolute value is less than `Integer.MAX_VALUE / 2`, then the difference works fine.

---

When comparing floating-point values, you cannot just return the difference. Instead, use the static `Double.compare` method. It does the right thing, even for  $\pm\infty$  and NaN.

Here is how the `Employee` class can implement the `Comparable` interface, ordering employees by salary:

```
public class Employee implements Comparable<Employee> {
    ...
    public int compareTo(Employee other) {
        return Double.compare(salary, other.salary);
    }
}
```



---

**NOTE:** It is perfectly legal for the `compare` method to access `other.salary`. In Java, a method can access private features of *any* object of its class.

---

The `String` class, as well as over a hundred other classes in the Java library, implements the `Comparable` interface. You can use the `Arrays.sort` method to sort an array of `Comparable` objects:

```
String[] friends = { "Peter", "Paul", "Mary" };
Arrays.sort(friends); // friends is now ["Mary", "Paul", "Peter"]
```



**NOTE:** Strangely, the `Arrays.sort` method does not check at compile time whether the argument is an array of `Comparable` objects. Instead, it throws an exception if it encounters an element of a class that doesn't implement the `Comparable` interface.

### 3.3.2 The Comparator Interface

Now suppose we want to sort strings by increasing length, not in dictionary order. We can't have the `String` class implement the `compareTo` method in two ways—and at any rate, the `String` class isn't ours to modify.

To deal with this situation, there is a second version of the `Arrays.sort` method whose parameters are an array and a *comparator*—an instance of a class that implements the `Comparator` interface.

```
public interface Comparator<T> {
    int compare(T first, T second);
}
```

To compare strings by length, define a class that implements `Comparator<String>`:

```
class LengthComparator implements Comparator<String> {
    public int compare(String first, String second) {
        return first.length() - second.length();
    }
}
```

To actually do the comparison, you need to make an instance:

```
Comparator<String> comp = new LengthComparator();
if (comp.compare(words[i], words[j]) > 0) ...
```

Contrast this call with `words[i].compareTo(words[j])`. The `compare` method is called on the comparator object, not the string itself.



**NOTE:** Even though the `LengthComparator` object has no state, you still need to make an instance of it. You need the instance to call the `compare` method—it is not a static method.



To sort an array, pass a `LengthComparator` object to the `Arrays.sort` method:

```
String[] friends = { "Peter", "Paul", "Mary" };
Arrays.sort(friends, new LengthComparator());
```

Now the array is either `["Paul", "Mary", "Peter"]` or `["Mary", "Paul", "Peter"]`.

You will see in Section 3.4.2, “Functional Interfaces” (page 115) how to use a `Comparator` much more easily, using a lambda expression.

### 3.3.3 The Runnable Interface

At a time when just about every processor has multiple cores, you want to keep those cores busy. You may want to run certain tasks in a separate thread, or give them to a thread pool for execution. To define the task, you implement the `Runnable` interface. This interface has just one method.

```
class HelloTask implements Runnable {
    public void run() {
        for (int i = 0; i < 1000; i++) {
            System.out.println("Hello, World!");
        }
    }
}
```

If you want to execute this task in a new thread, create the thread from the `Runnable` and start it.

```
Runnable task = new HelloTask();
Thread thread = new Thread(task);
thread.start();
```

Now the `run` method executes in a separate thread, and the current thread can proceed with other work.



**NOTE:** In Chapter 10, you will see other ways of executing a `Runnable`.

---



**NOTE:** There is also a `Callable<T>` interface for tasks that return a result of type `T`.

---

### 3.3.4 User Interface Callbacks

In a graphical user interface, you have to specify actions to be carried out when the user clicks a button, selects a menu option, drags a slider, and so on. These actions are often called *callbacks* because some code gets called back when a user action occurs.

In Java-based GUI libraries, interfaces are used for callbacks. For example, in JavaFX, the following interface is used for reporting events:

```
public interface EventHandler<T> {  
    void handle(T event);  
}
```

This too is a generic interface where  $T$  is the type of event that is being reported, such as an `ActionEvent` for a button click.

To specify the action, implement the interface:

```
class CancelAction implements EventHandler<ActionEvent> {  
    public void handle(ActionEvent event) {  
        System.out.println("Oh noes!");  
    }  
}
```

Then, make an object of that class and add it to the button:

```
Button cancelButton = new Button("Cancel");  
cancelButton.setOnAction(new CancelAction());
```



**NOTE:** Since Oracle positions JavaFX as the successor to the Swing GUI toolkit, I use JavaFX in these examples. (Don't worry—you need not know any more about JavaFX than the couple of statements you just saw.) The details don't matter; in every user interface toolkit, be it Swing, JavaFX, or Android, you give a button some code that you want to run when the button is clicked.

---

Of course, this way of defining a button action is rather tedious. In other languages, you just give the button a function to execute, without going through the detour of making a class and instantiating it. The next section shows how you can do the same in Java.

## 3.4 Lambda Expressions

A *lambda expression* is a block of code that you can pass around so it can be executed later, once or multiple times. In the preceding sections, you have seen many situations where it is useful to specify such a block of code:

- To pass a comparison method to `Arrays.sort`
- To run a task in a separate thread
- To specify an action that should happen when a button is clicked

However, Java is an object-oriented language where (just about) everything is an object. There are no function types in Java. Instead, functions are expressed as objects, instances of classes that implement a particular interface. Lambda expressions give you a convenient syntax for creating such instances.

### 3.4.1 The Syntax of Lambda Expressions

Consider again the sorting example from Section 3.3.2, “The Comparator Interface” (page 111). We pass code that checks whether one string is shorter than another. We compute

```
first.length() - second.length()
```

What are `first` and `second`? They are both strings. Java is a strongly typed language, and we must specify that as well:

```
(String first, String second) -> first.length() - second.length()
```

You have just seen your first *lambda expression*. Such an expression is simply a block of code, together with the specification of any variables that must be passed to the code.

Why the name? Many years ago, before there were any computers, the logician Alonzo Church wanted to formalize what it means for a mathematical function to be effectively computable. (Curiously, there are functions that are known to exist, but nobody knows how to compute their values.) He used the Greek letter lambda ( $\lambda$ ) to mark parameters, somewhat like

```
 $\lambda$ first.  $\lambda$ second. first.length() - second.length()
```



**NOTE:** Why the letter  $\lambda$ ? Did Church run out of letters of the alphabet? Actually, the venerable *Principia Mathematica* (see <http://plato.stanford.edu/entries/principia-mathematica>) used the  $\wedge$  accent to denote function parameters, which inspired Church to use an uppercase lambda  $\Lambda$ . But in the end, he switched to the lowercase version. Ever since, an expression with parameter variables has been called a lambda expression.

---

If the body of a lambda expression carries out a computation that doesn't fit in a single expression, write it exactly like you would have written a method: enclosed in `{}` and with explicit `return` statements. For example,

```
(String first, String second) -> {  
    int difference = first.length() < second.length();  
    if (difference < 0) return -1;  
    else if (difference > 0) return 1;  
    else return 0;  
}
```

If a lambda expression has no parameters, supply empty parentheses, just as with a parameterless method:

```
Runnable task = () -> { for (int i = 0; i < 1000; i++) doWork(); }
```

If the parameter types of a lambda expression can be inferred, you can omit them. For example,

```
Comparator<String> comp  
    = (first, second) -> first.length() - second.length();  
    // Same as (String first, String second)
```

Here, the compiler can deduce that `first` and `second` must be strings because the lambda expression is assigned to a string comparator. (We will have a closer look at this assignment in the next section.)

If a method has a single parameter with inferred type, you can even omit the parentheses:

```
EventHandler<ActionEvent> listener = event ->  
    System.out.println("Oh noes!");  
    // Instead of (event) -> or (ActionEvent event) ->
```

You never specify the result type of a lambda expression. However, the compiler infers it from the body and checks that it matches the expected type. For example, the expression

```
(String first, String second) -> first.length() - second.length()
```

can be used in a context where a result of type `int` is expected (or a compatible type such as `Integer`, `long`, or `double`).

## 3.4.2 Functional Interfaces

As you already saw, there are many interfaces in Java that express actions, such as `Runnable` or `Comparator`. Lambda expressions are compatible with these interfaces.

You can supply a lambda expression whenever an object of an interface with a *single abstract method* is expected. Such an interface is called a *functional interface*.

To demonstrate the conversion to a functional interface, consider the `Arrays.sort` method. Its second parameter requires an instance of `Comparator`, an interface with a single method. Simply supply a lambda:

```
Arrays.sort(words,
    (first, second) -> first.length() - second.length());
```

Behind the scenes, the second parameter variable of the `Arrays.sort` method receives an object of some class that implements `Comparator<String>`. Invoking the `compare` method on that object executes the body of the lambda expression. The management of these objects and classes is completely implementation-dependent and highly optimized.

In most programming languages that support function literals, you can declare function types such as `(String, String) -> int`, declare variables of those types, put functions into those variables, and invoke them. In Java, there is *only one thing* you can do with a lambda expression: put it in a variable whose type is a functional interface, so that it is converted to an instance of that interface.



**NOTE:** You cannot assign a lambda expression to a variable of type `Object`, the common supertype of all classes in Java (see Chapter 4). `Object` is a class, not a functional interface.

---

The Java API provides a large number of functional interfaces (see Section 3.6.2, “Choosing a Functional Interface,” page 120). One of them is

```
public interface Predicate<T> {
    boolean test(T t);
    // Additional default and static methods
}
```

The `ArrayList` class has a `removeIf` method whose parameter is a `Predicate`. It is specifically designed for receiving a lambda expression. For example, the following statement removes all `null` values from an array list:

```
list.removeIf(e -> e == null);
```

## 3.5 Method and Constructor References

Sometimes, there is already a method that carries out exactly the action that you’d like to pass on to some other code. There is special syntax for a *method reference* that is even shorter than a lambda expression calling the method. A similar shortcut exists for constructors. You will see both in the following sections.

### 3.5.1 Method References

Suppose you want to sort strings regardless of letter case. You could call

```
Arrays.sort(strings, (x, y) -> x.compareToIgnoreCase(y));
```

Instead, you can pass this method expression:

```
Arrays.sort(strings, String::compareToIgnoreCase);
```

The expression `String::compareToIgnoreCase` is a *method reference* that is equivalent to the lambda expression `(x, y) -> x.compareToIgnoreCase(y)`.

Here is another example. The `Objects` class defines a method `isNull`. The call `Objects.isNull(x)` simply returns the value of `x == null`. It seems hardly worth having a method for this case, but it was designed to be passed as a method expression. The call

```
list.removeIf(Objects::isNull);
```

removes all `null` values from a list.

As another example, suppose you want to print all elements of a list. The `ArrayList` class has a method `forEach` that applies a function to each element. You could call

```
list.forEach(x -> System.out.println(x));
```

It would be nicer, however, if you could just pass the `println` method to the `forEach` method. Here is how to do that:

```
list.forEach(System.out::println);
```

As you can see from these examples, the `::` operator separates the method name from the name of a class or object. There are three variations:

1. *Class::instanceMethod*
2. *Class::staticMethod*
3. *object::instanceMethod*

In the first case, the first parameter becomes the receiver of the method, and any other parameters are passed to the method. For example, `String::compareToIgnoreCase` is the same as `(x, y) -> x.compareToIgnoreCase(y)`.

In the second case, all parameters are passed to the static method. The method expression `Objects::isNull` is equivalent to `x -> Objects.isNull(x)`.

In the third case, the method is invoked on the given object, and the parameters are passed to the instance method. Therefore, `System.out::println` is equivalent to `x -> System.out.println(x)`.



**NOTE:** When there are multiple overloaded methods with the same name, the compiler will try to find from the context which one you mean. For example, there are multiple versions of the `println` method. When passed to the `forEach` method of an `ArrayList<String>`, the `println(String)` method is picked.

You can capture the `this` parameter in a method reference. For example, `this::equals` is the same as `x -> this.equals(x)`.



**NOTE:** In an inner class, you can capture the `this` reference of an enclosing class as `EnclosingClass.this::method`. You can also capture `super`—see Chapter 4.

### 3.5.2 Constructor References

Constructor references are just like method references, except that the name of the method is `new`. For example, `Employee::new` is a reference to an `Employee` constructor. If the class has more than one constructor, then it depends on the context which constructor is chosen.

Here is an example for using such a constructor reference. Suppose you have a list of strings

```
List<String> names = ...;
```

You want a list of employees, one for each name. As you will see in Chapter 8, you can use streams to do this without a loop: Turn the list into a stream, and then call the `map` method. It applies a function and collects all results.

```
Stream<Employee> stream = names.stream().map(Employee::new);
```

Since `names.stream()` contains `String` objects, the compiler knows that `Employee::new` refers to the constructor `Employee(String)`.

You can form constructor references with array types. For example, `int[]::new` is a constructor reference with one parameter: the length of the array. It is equivalent to the lambda expression `n -> new int[n]`.

Array constructor references are useful to overcome a limitation of Java: It is not possible to construct an array of a generic type. (See Chapter 6 for details.) For that reason, methods such as `Stream.toArray` return an `Object` array, not an array of the element type:

```
Object[] employees = stream.toArray();
```

But that is unsatisfactory. The user wants an array of employees, not objects. To solve this problem, another version of `toArray` accepts a constructor reference:

```
Employee[] buttons = stream.toArray(Employee[]::new);
```

The `toArray` method invokes this constructor to obtain an array of the correct type. Then it fills and returns the array.

## 3.6 Processing Lambda Expressions

Up to now, you have seen how to produce lambda expressions and pass them to a method that expects a functional interface. In the following sections, you will see how to write your own methods that can consume lambda expressions.

### 3.6.1 Implementing Deferred Execution

The point of using lambdas is *deferred execution*. After all, if you wanted to execute some code right now, you'd do that, without wrapping it inside a lambda. There are many reasons for executing code later, such as:

- Running the code in a separate thread
- Running the code multiple times
- Running the code at the right point in an algorithm (for example, the comparison operation in sorting)
- Running the code when something happens (a button was clicked, data has arrived, and so on)
- Running the code only when necessary

Let's look at a simple example. Suppose you want to repeat an action `n` times. The action and the count are passed to a `repeat` method:

```
repeat(10, () -> System.out.println("Hello, World!"));
```

To accept the lambda, we need to pick (or, in rare cases, provide) a functional interface. In this case, we can just use `Runnable`:

```
public static void repeat(int n, Runnable action) {  
    for (int i = 0; i < n; i++) action.run();  
}
```

Note that the body of the lambda expression is executed when `action.run()` is called.



Now let's make this example a bit more sophisticated. We want to tell the action in which iteration it occurs. For that, we need to pick a functional interface that has a method with an `int` parameter and a `void` return. Instead of rolling your own, I strongly recommend that you use one of the standard ones described in the next section. The standard interface for processing `int` values is

```
public interface IntConsumer {
    void accept(int value);
}
```

Here is the improved version of the `repeat` method:

```
public static void repeat(int n, IntConsumer action) {
    for (int i = 0; i < n; i++) action.accept(i);
}
```

And here is how you call it:

```
repeat(10, i -> System.out.println("Countdown: " + (9 - i)));
```

### 3.6.2 Choosing a Functional Interface

In most functional programming languages, function types are *structural*. To specify a function that maps two strings to an integer, you use a type that looks something like `Function2<String, String, Integer>` or `(String, String) -> int`. In Java, you instead declare the intent of the function using a functional interface such as `Comparator<String>`. In the theory of programming languages this is called *nominal* typing.

Of course, there are many situations where you want to accept “any function” without particular semantics. There are a number of generic function types for that purpose (see Table 3-1), and it's a very good idea to use one of them when you can.

For example, suppose you write a method to process files that match a certain criterion. Should you use the descriptive `java.io.FileFilter` class or a `Predicate<File>`? I strongly recommend that you use the standard `Predicate<File>`. The only reason not to do so would be if you already have many useful methods producing `FileFilter` instances.

**Table 3-1** Common Functional Interfaces

Functional Interface	Parameter types	Return type	Abstract method name	Description	Other methods
Runnable	none	void	run	Runs an action without arguments or return value	
Supplier<T>	none	T	get	Supplies a value of type T	
Consumer<T>	T	void	accept	Consumes a value of type T	andThen
BiConsumer<T, U>	T, U	void	accept	Consumes values of types T and U	andThen
Function<T, R>	T	R	apply	A function with argument of type T	compose, andThen, identity
BiFunction<T, U, R>	T, U	R	apply	A function with arguments of types T and U	andThen
UnaryOperator<T>	T	T	apply	A unary operator on the type T	compose, andThen, identity
BinaryOperator<T>	T, T	T	apply	A binary operator on the type T	andThen, maxBy, minBy
Predicate<T>	T	boolean	test	A boolean-valued function	and, or, negate, isEqual
BiPredicate<T, U>	T, U	boolean	test	A boolean-valued function with two arguments	and, or, negate



**NOTE:** Most of the standard functional interfaces have nonabstract methods for producing or combining functions. For example, `Predicate.isEqual(a)` is the same as `a::equals`, but it also works if `a` is `null`. There are default methods `and`, `or`, `negate` for combining predicates. For example,

```
Predicate.isEqual(a).or(Predicate.isEqual(b))
```

is the same as

```
x -> a.equals(x) || b.equals(x)
```

Table 3-2 lists the 34 available specializations for primitive types `int`, `long`, and `double`. It is a good idea to use these specializations to reduce autoboxing. For that reason, I used an `IntConsumer` instead of a `Consumer<Integer>` in the example of the preceding section.

**Table 3-2** Functional Interfaces for Primitive Types

*p, q* is `int`, `long`, `double`; *P, Q* is `Int`, `Long`, `Double`

Functional Interface	Parameter types	Return type	Abstract method name
<code>BooleanSupplier</code>	none	<code>boolean</code>	<code>getAsBoolean</code>
<code>PSupplier</code>	none	<i>p</i>	<code>getAsP</code>
<code>PConsumer</code>	<i>p</i>	<code>void</code>	<code>accept</code>
<code>ObjPConsumer&lt;T&gt;</code>	<i>T, p</i>	<code>void</code>	<code>accept</code>
<code>PFunction&lt;T&gt;</code>	<i>p</i>	<i>T</i>	<code>apply</code>
<code>PToQFunction</code>	<i>p</i>	<i>q</i>	<code>applyAsQ</code>
<code>ToPFunction&lt;T&gt;</code>	<i>T</i>	<i>p</i>	<code>applyAsP</code>
<code>ToPBiFunction&lt;T, U&gt;</code>	<i>T, U</i>	<i>p</i>	<code>applyAsP</code>
<code>PUnaryOperator</code>	<i>p</i>	<i>p</i>	<code>applyAsP</code>
<code>PBinaryOperator</code>	<i>p, p</i>	<i>p</i>	<code>applyAsP</code>
<code>PPredicate</code>	<i>p</i>	<code>boolean</code>	<code>test</code>

### 3.6.3 Implementing Your Own Functional Interfaces

Ever so often, you will be in a situation where none of the standard functional interfaces work for you. Then you need to roll your own.

Suppose you want to fill an image with color patterns, where the user supplies a function yielding the color for each pixel. There is no standard type for a mapping `(int, int) -> Color`. You could use `BiFunction<Integer, Integer, Color>`, but that involves autoboxing.

In this case, it makes sense to define a new interface

```
@FunctionalInterface
public interface PixelFunction {
    Color apply(int x, int y);
}
```



**NOTE:** It is a good idea to tag functional interfaces with the `@FunctionalInterface` annotation. This has two advantages. First, the compiler checks that the annotated entity is an interface with a single abstract method. Second, the javadoc page includes a statement that your interface is a functional interface.

Now you are ready to implement a method:

```
BufferedImage createImage(int width, int height, PixelFunction f) {
    BufferedImage image = new BufferedImage(width, height,
        BufferedImage.TYPE_INT_RGB);

    for (int x = 0; x < width; x++)
        for (int y = 0; y < height; y++) {
            Color color = f.apply(x, y);
            image.setRGB(x, y, color.getRGB());
        }
    return image;
}
```

To call it, supply a lambda expression that yields a color value for two integers:

```
BufferedImage frenchFlag = createImage(150, 100,
    (x, y) -> x < 50 ? Color.BLUE : x < 100 ? Color.WHITE : Color.RED);
```

## 3.7 Lambda Expressions and Variable Scope

In the following sections, you will learn how variables work inside lambda expressions. This information is somewhat technical but essential for working with lambda expressions.

### 3.7.1 Scope of a Lambda Expression

The body of a lambda expression has *the same scope as a nested block*. The same rules for name conflicts and shadowing apply. It is illegal to declare a parameter or a local variable in the lambda that has the same name as a local variable.

```
int first = 0;
Comparator<String> comp = (first, second) -> first.length() - second.length();
// Error: Variable first already defined
```

Inside a method, you can't have two local variables with the same name, therefore you can't introduce such variables in a lambda expression either.

As another consequence of the "same scope" rule, the `this` keyword in a lambda expression denotes the `this` parameter of the method that creates the lambda. For example, consider

```
public class Application() {
    public void doWork() {
        Runnable runner = () -> { ...; System.out.println(this.toString()); ... };
        ...
    }
}
```

The expression `this.toString()` calls the `toString` method of the `Application` object, *not* the `Runnable` instance. There is nothing special about the use of `this` in a lambda expression. The scope of the lambda expression is nested inside the `doWork` method, and `this` has the same meaning anywhere in that method.

### 3.7.2 Accessing Variables from the Enclosing Scope

Often, you want to access variables from an enclosing method or class in a lambda expression. Consider this example:

```
public static void repeatMessage(String text, int count) {
    Runnable r = () -> {
        for (int i = 0; i < count; i++) {
            System.out.println(text);
        }
    };
    new Thread(r).start();
}
```

Note that the lambda expression accesses the parameter variables defined in the enclosing scope, not in the lambda expression itself.

Consider a call

```
repeatMessage("Hello", 1000); // Prints Hello 1000 times in a separate thread
```

Now look at the variables `count` and `text` inside the lambda expression. If you think about it, something nonobvious is going on here. The code of the lambda expression may run long after the call to `repeatMessage` has returned and the parameter variables are gone. How do the `text` and `count` variables stay around when the lambda expression is ready to execute?

To understand what is happening, we need to refine our understanding of a lambda expression. A lambda expression has three ingredients:

1. A block of code
2. Parameters
3. Values for the *free* variables—that is, the variables that are not parameters and not defined inside the code

In our example, the lambda expression has two free variables, `text` and `count`. The data structure representing the lambda expression must store the values for these variables—in our case, "Hello" and 1000. We say that these values have been *captured* by the lambda expression. (It's an implementation detail how that is done. For example, one can translate a lambda expression into an object with a single method, so that the values of the free variables are copied into instance variables of that object.)



---

**NOTE:** The technical term for a block of code together with the values of free variables is a *closure*. In Java, lambda expressions are closures.

---

As you have seen, a lambda expression can capture the value of a variable in the enclosing scope. To ensure that the captured value is well defined, there is an important restriction. In a lambda expression, you can only reference variables whose value doesn't change. This is sometimes described by saying that lambda expressions capture values, not variables. For example, the following is a compile-time error:

```
for (int i = 0; i < n; i++) {
    new Thread(() -> System.out.println(i)).start();
    // Error—cannot capture i
}
```

The lambda expression tries to capture `i`, but this is not legal because `i` changes. There is no single value to capture. The rule is that a lambda

expression can only access local variables from an enclosing scope that are *effectively final*. An effectively final variable is never modified—it either is or could be declared as `final`.



**NOTE:** The same rule applies to variables captured by local classes (see Section 3.9, “Local and Anonymous Classes,” page 129). In the past, the rule was more draconian and required captured variables to actually be declared `final`. This is no longer the case.



**NOTE:** The variable of an enhanced `for` loop is effectively final since its scope is a single iteration. The following is perfectly legal:

```
for (String arg : args) {
    new Thread(() -> System.out.println(arg)).start();
    // OK to capture arg
}
```

A new variable `arg` is created in each iteration and assigned the next value from the `args` array. In contrast, the scope of the variable `i` in the preceding example was the entire loop.

As a consequence of the “effectively final” rule, a lambda expression cannot mutate any captured variables. For example,

```
public static void repeatMessage(String text, int count, int threads) {
    Runnable r = () -> {
        while (count > 0) {
            count--; // Error: Can't mutate captured variable
            System.out.println(text);
        }
    };
    for (int i = 0; i < threads; i++) new Thread(r).start();
}
```

This is actually a good thing. As you will see in Chapter 10, if two threads update `count` at the same time, its value is undefined.



**NOTE:** Don’t count on the compiler to catch all concurrent access errors. The prohibition against mutation only holds for local variables. If `count` is an instance variable or static variable of an enclosing class, then no error is reported even though the result is just as undefined.



**CAUTION:** One can circumvent the check for inappropriate mutations by using an array of length 1:

```
int[] counter = new int[1];
button.setOnAction(event -> counter[0]++);
```

The counter variable is effectively final—it is never changed since it always refers to the same array, so you can access it in the lambda expression.

Of course, code like this is not threadsafe. Except possibly for a callback in a single-threaded UI, this is a terrible idea. You will see how to implement a threadsafe shared counter in Chapter 10.

## 3.8 Higher-Order Functions

In a functional programming language, functions are first-class citizens. Just like you can pass numbers to methods and have methods that produce numbers, you can have arguments and return values that are functions. Functions that process or return functions are called *higher-order functions*. This sounds abstract, but it is very useful in practice. Java is not quite a functional language because it uses functional interfaces, but the principle is the same. In the following sections, we will look at some examples and examine the higher-order functions in the `Comparator` interface.

### 3.8.1 Methods that Return Functions

Suppose sometimes we want to sort an array of strings in ascending order and other times in descending order. We can make a method that produces the correct comparator:

```
public static Comparator<String> compareInDirection(int direction) {
    return (x, y) -> direction * x.compareTo(y);
}
```

The call `compareInDirection(1)` yields an ascending comparator, and the call `compareInDirection(-1)` a descending comparator.

The result can be passed to another method (such as `Arrays.sort`) that expects such an interface.

```
Arrays.sort(friends, compareInDirection(-1));
```

In general, don't be shy to write methods that produce functions (or, technically, instances of classes that implement a functional interface). This is useful to generate custom functions that you pass to methods with functional interfaces.



### 3.8.2 Methods That Modify Functions

In the preceding section, you saw a method that yields an increasing or decreasing string comparator. We can generalize this idea by reversing any comparator:

```
public static Comparator<String> reverse(Comparator<String> comp) {  
    return (x, y) -> comp.compare(y, x);  
}
```

This method operates on functions. It receives a function and returns a modified function. To get case-insensitive descending order, use

```
reverse(String::compareToIgnoreCase)
```



**NOTE:** The `Comparator` interface has a default method `reversed` that produces the reverse of a given comparator in just this way.

---

### 3.8.3 Comparator Methods

The `Comparator` interface has a number of useful static methods that are higher-order functions generating comparators.

The `comparing` method takes a “key extractor” function that maps a type `T` to a comparable type (such as `String`). The function is applied to the objects to be compared, and the comparison is then made on the returned keys. For example, suppose a `Person` class has a method `getLastName`. Then you can sort an array of `Person` objects by last name like this:

```
Arrays.sort(people, Comparator.comparing(Person::getLastName));
```

You can chain comparators with the `thenComparing` method to break ties. For example, sort an array of people by last name, then use the first name for people with the same last name:

```
Arrays.sort(people, Comparator  
    .comparing(Person::getLastName)  
    .thenComparing(Person::getFirstName));
```

There are a few variations of these methods. You can specify a comparator to be used for the keys that the `comparing` and `thenComparing` methods extract. For example, here we sort people by the length of their names:

```
Arrays.sort(people, Comparator.comparing(Person::getLastName,  
    (s, t) -> s.length() - t.length()));
```

Moreover, both the `comparing` and `thenComparing` methods have variants that avoid boxing of `int`, `long`, or `double` values. An easier way of sorting by name length would be

```
Arrays.sort(people, Comparator.comparingInt(p -> p.getLastName().length()));
```

If your key function can return `null`, you will like the `nullsFirst` and `nullsLast` adapters. These static methods take an existing comparator and modify it so that it doesn't throw an exception when encountering `null` values but ranks them as smaller or larger than regular values. For example, suppose `getMiddleName` returns a `null` when a person has no middle name. Then you can use `Comparator.comparing(Person::getMiddleName(), Comparator.nullsFirst(...))`.

The `nullsFirst` method needs a comparator—in this case, one that compares two strings. The `naturalOrder` method makes a comparator for any class implementing `Comparable`. Here is the complete call for sorting by potentially null middle names. I use a static import of `java.util.Comparator.*` to make the expression more legible. Note that the type for `naturalOrder` is inferred.

```
Arrays.sort(people, comparing(Person::getMiddleName,  
    nullsFirst(naturalOrder())));
```

The static `reverseOrder` method gives the reverse of the natural order.

## 3.9 Local and Anonymous Classes

Long before there were lambda expressions, Java had a mechanism for concisely defining classes that implement an interface (functional or not). For functional interfaces, you should definitely use lambda expressions, but once in a while, you may want a concise form for an interface that isn't functional. You will also encounter the classic constructs in legacy code.

### 3.9.1 Local Classes

You can define a class inside a method. Such a class is called a *local class*. You would do this for classes that are just tactical. This occurs often when a class implements an interface and the caller of the method only cares about the interface, not the class.

For example, consider a method

```
public static IntSequence randomInts(int low, int high)
```

that generates an infinite sequence of random integers with the given bounds.

Since `IntSequence` is an interface, the method must return an object of some class implementing that interface. The caller doesn't care about the class, so it can be declared inside the method:

```
private static Random generator = new Random();

public static IntSequence randomInts(int low, int high) {
    class RandomSequence implements IntSequence {
        public int next() { return low + generator.nextInt(high - low + 1); }
        public boolean hasNext() { return true; }
    }

    return new RandomSequence();
}
```



**NOTE:** A local class is not declared as `public` or `private` since it is never accessible outside the method.

---

There are two advantages of making a class local. First, its name is hidden in the scope of the method. Second, the methods of the class can access variables from the enclosing scope, just like the variables of a lambda expression.

In our example, the `next` method captures three variables: `low`, `high`, and `generator`. If you turned `RandomInt` into a nested class, you would have to provide an explicit constructor that receives these values and stores them in instance variables (see Exercise 16).

### 3.9.2 Anonymous Classes

In the example of the preceding section, the name `RandomSequence` was used exactly once: to construct the return value. In this case, you can make the class *anonymous*:

```
public static IntSequence randomInts(int low, int high) {
    return new IntSequence() {
        public int next() { return low + generator.nextInt(high - low + 1); }
        public boolean hasNext() { return true; }
    }
}
```

The expression

```
new Interface() { methods }
```

means: Define a class implementing the interface that has the given methods, and construct one object of that class.



**NOTE:** As always, the `()` in the `new` expression indicate the construction arguments. A default constructor of the anonymous class is invoked.

---

Before Java had lambda expressions, anonymous inner classes were the most concise syntax available for providing runnables, comparators, and other functional objects. You will often see them in legacy code.

Nowadays, they are only necessary when you need to provide two or more methods, as in the preceding example. If the `IntSequence` interface has a default `hasNext` method, as in Exercise 16, you can simply use a lambda expression:

```
public static IntSequence randomInts(int low, int high) {
    return () -> low + generator.nextInt(high - low + 1);
}
```

## Exercises

1. Provide an interface `Measurable` with a method `double getMeasure()` that measures an object in some way. Make `Employee` implement `Measurable`. Provide a method `double average(Measurable[] objects)` that computes the average measure. Use it to compute the average salary of an array of employees.
2. Continue with the preceding exercise and provide a method `Measurable largest(Measurable[] objects)`. Use it to find the name of the employee with the largest salary. Why do you need a cast?
3. What are all the supertypes of `String`? Of `Scanner`? Of `ImageOutputStream`? Note that each type is its own supertype. A class or interface without declared supertype has supertype `Object`.
4. Implement a static `of` method of the `IntSequence` class that yields a sequence with the arguments. For example, `IntSequence.of(3, 1, 4, 1, 5, 9)` yields a sequence with six values. Extra credit if you return an instance of an anonymous inner class.
5. Add a static method with the name `constant` of the `IntSequence` class that yields an infinite constant sequence. For example, `IntSequence.constant(1)` yields values `1 1 1...`, ad infinitum. Extra credit if you do this with a lambda expression.
6. The `SquareSequence` class doesn't actually deliver an infinite sequence of squares due to integer overflow. Specifically, how does it behave? Fix the problem by defining a `Sequence<T>` interface and a `SquareSequence` class that implements `Sequence<BigInteger>`.
7. In this exercise, you will try out what happens when a method is added to an interface. In Java 7, implement a class `DigitSequence` that implements `Iterator<Integer>`, not `IntSequence`. Provide methods `hasNext`, `next`, and a `do-nothing` `remove`. Write a program that prints the elements of an instance.

In Java 8, the `Iterator` class gained another method, `forEachRemaining`. Does your code still compile when you switch to Java 8? If you put your Java 7 class in a JAR file and don't recompile, does it work in Java 8? What if you call the `forEachRemaining` method? Also, the `remove` method has become a default method in Java 8, throwing an `UnsupportedOperationException`. What happens when `remove` is called on an instance of your class?

8. Implement the method `void luckySort(ArrayList<String> strings, Comparator<String> comp)` that keeps calling `Collections.shuffle` on the array list until the elements are in increasing order, as determined by the comparator.
9. Implement a class `Greeter` that implements `Runnable` and whose `run` method prints `n` copies of "Hello, " + `target`, where `n` and `target` are set in the constructor. Construct two instances with different messages and execute them concurrently in two threads.

10. Implement methods

```
public static void runTogether(Runnable... tasks)
public static void runInOrder(Runnable... tasks)
```

The first method should run each task in a separate thread and then return. The second method should run all methods in the current thread and return when the last one has completed.

11. Using the `listFiles(FileFilter)` and `isDirectory` methods of the `java.io.File` class, write a method that returns all subdirectories of a given directory. Use a lambda expression instead of a `FileFilter` object. Repeat with a method expression and an anonymous inner class.
12. Using the `list(FileNameFilter)` method of the `java.io.File` class, write a method that returns all files in a given directory with a given extension. Use a lambda expression, not a `FileNameFilter`. Which variable from the enclosing scope does it capture?
13. Given an array of `File` objects, sort it so that directories come before files, and within each group, elements are sorted by path name. Use a lambda expression to specify the `Comparator`.
14. Write a method that takes an array of `Runnable` instances and returns a `Runnable` whose `run` method executes them in order. Return a lambda expression.
15. Write a call to `Arrays.sort` that sorts employees by salary, breaking ties by name. Use `Comparator.thenComparing`. Then do this in reverse order.
16. Implement the `RandomSequence` in Section 3.9.1, "Local Classes" (page 129) as a nested class, outside the `randomInts` method.

---

# Index

## Symbols and Numbers

- (minus sign)
  - flag (for output), 35
  - in dates, 414
  - in regular expressions, 310
  - operator, 17–18
- - in command-line options, 81
  - in shell scripts, 463
  - operator, 17, 19
- >, in lambda expressions, 114, 117
- ∞, in string templates, 434
- \_ (underscore)
  - in number literals, 12
  - in variable names, 14, 67
- , (comma)
  - flag (for output), 35
  - in numbers, 422, 428, 433
  - normalizing, 317
  - trailing, in arrays, 44
- ;(semicolon)
  - in Java vs. JavaScript, 450
  - path separator (Windows), 81, 248
- : (colon)
  - in assertions, 194
  - in dates, 414
  - in switch statement, 37
  - path separator (Unix), 81, 248
- :: operator, 117, 145
- ! (exclamation sign)
  - comments, in property files, 247
  - operator, 17, 22
- != operator, 17, 22
  - for wrapper classes, 47
- ? (quotation mark)
  - in regular expressions, 310–311, 313
  - replacement character, 295, 438
  - wildcard, for types, 212–216, 227
- ? : operator, 17, 22
- / (slash)
  - file separator (Unix), 248, 298
  - in javac path segments, 5
  - operator, 17–18
  - root component, 298
- //, /\*...\*/ comments, 3
- /\*\*...\*/ comments, 90–91
- /= operator, 17

- . (period)
  - in method calls, 6
  - in numbers, 422, 428, 433
  - in package names, 5, 79
  - in regular expressions, 310–311, 319
  - operator, 17
- .., parent directory, 299
- ... (ellipsis), for varargs, 54
- `...` (back quotes), in shell scripts, 462
- ^ (caret)
  - for function parameters, 114
  - in regular expressions, 310–313, 318
  - operator, 17, 23
- ^= operator, 17
- ~ (tilde), operator, 17, 23
- '...' (single quotes)
  - for character literals, 13–14
  - in JavaScript, 450
  - in string templates, 434
- "..." (double quotes)
  - for strings, 6
  - in javadoc hyperlinks, 94
  - in shell scripts, 462
- "" (empty string), 26–27, 147
- ( (left parenthesis), in formatted output, 35
- (...) (parentheses)
  - empty, for anonymous classes, 130
  - for anonymous functions (JavaScript), 458
  - for casts, 21, 103
  - in regular expressions, 310–313, 316–317
  - operator, 17
- [...] (square brackets)
  - for arrays, 43–44, 50
  - in JavaScript, 454, 457–458
  - in regular expressions, 310–312
  - operator, 17
- {...} (curly braces)
  - in annotation elements, 379
  - in lambda expressions, 114
  - in regular expressions, 310–313, 318
  - in string templates, 433
  - with arrays, 44
- {{...}}, double brace initialization, 144
- @ (at)
  - in java command, 487
  - in javadoc comments, 91
- \$ (dollar sign)
  - currency symbol, 433
  - flag (for output), 36
  - in JavaScript function calls, 455, 460
  - in regular expressions, 310–311, 313, 318
  - in variable names, 14
- \${...}, in shell scripts, 462–463
- € currency symbol, 428, 433
- \* (asterisk)
  - for annotation processors, 394
  - in documentation comments, 92
  - in regular expressions, 310–313, 317
  - operator, 17–18
  - wildcard:
    - in class path, 81
    - in imported classes, 83–84
- \*= operator, 17
- \ (backslash)
  - character literal, 14
  - file separator (Windows), 248, 298
  - in option files, 487
  - in regular expressions, 310–311, 318
- & (ampersand), operator, 17, 23
- && (double ampersand)
  - in regular expressions, 312
  - operator, 17, 22
- &= operator, 17
- # (number sign)
  - comments, in property files, 247
  - flag (for output), 35
  - in javadoc hyperlinks, 93
  - in option files, 487
  - in string templates, 434
- #!, in shell scripts, 464
- % (percent sign)
  - conversion character, 34–35
  - operator, 17–18
- % pattern variable, 202
- %= operator, 17
- + (plus sign)
  - flag (for output), 35
  - in regular expressions, 310–313

- operator, 17–18
  - for strings, 24–25, 27, 147
- ++ operator, 17, 19
- += operator, 17
- < (left angle bracket)
  - flag (for output), 36
  - in shell syntax, 33
  - in string templates, 434
  - operator, 22, 456
- << operator, 17, 23
- <= operator, 17
- << operator, 17, 22
- <%...%>, <%=...%> delimiters (JSP), 464
- ≤, in string templates, 434
- <> (diamond syntax)
  - for array lists, 45
  - for constructors of generic classes, 209
- <...> (angle brackets)
  - for type parameters, 109, 208
  - in javadoc hyperlinks, 93
  - in regular expressions, 313
- =, -= operators, 17–18
- = operator, 17, 22, 149
  - for class objects, 160
  - for enumerations, 155
  - for strings, 26
  - for wrapper classes, 47
- =>, in JavaScript, 459
- > (right angle bracket)
  - in shell syntax, 33
  - operator, 22
- >=, >>, >>> operators, 17, 22–23
- >>=, >>>= operators, 17
- | (vertical bar)
  - in regular expressions, 310–312
  - in string templates, 434
  - operator, 17, 23
- |= operator, 17
- || operator, 17, 22
- 0 (zero)
  - as default value, 71, 74
  - flag (for output), 35
  - formatting symbol (date/time), 416
  - prefix, for octal literals, 11
- \0, in regular expressions, 311
- 0b prefix, 11

- 0x prefix, 11, 35
- 0xFF byte order mark, 291

## A

- a formatting symbol (date/time), 416
- a, A conversion characters, 34
- \a, \A, in regular expressions, 311, 314
- abstract classes, 141–142
- abstract methods, of an interface, 115
- abstract modifier, 103, 141–142
- AbstractCollection class, 106
- AbstractMethodError, 107
- AbstractProcessor class, 394
- accept methods (Consumer, XxxConsumer), 121–122
- acceptEither method (CompletableFuture), 339–340
- AccessibleObject class, 172
  - setAccessible method, 170, 172
  - trySetAccessible method, 170
- accessors, 62
- accumulate method (LongAccumulator), 356
- accumulateAndGet method (AtomicXxx), 355
- accumulator functions, 278
- add method
  - of ArrayDeque, 250
  - of ArrayList, 46, 62
  - of BlockingQueue, 353
  - of Collection, 236
  - of List, 238
  - of ListIterator, 241
  - of LongAdder, 356
- addAll method
  - of Collection, 214, 236
  - of Collections, 239
  - of List, 238
- addExact method (Math), 20
- addHandler method (Logger), 200
- addition, 18
  - identity for, 278
- addSuppressed method (IOException), 189
- aggregators, 488
- allMatch method (Stream), 267
- allOf method
  - of CompletableFuture, 339–340
  - of EnumSet, 250



- allProcesses method (ProcessHandle), 370
- and, andNot methods (BitSet), 249
- and, andThen methods (functional interfaces), 121
- Android, 341
- AnnotatedConstruct interface, 395
- AnnotatedElement interface, 392–393
- annotation interfaces, 383–386
- annotation processors, 394
- annotations
  - accessing, 384
    - from a different module, 489
  - and modifiers, 382
  - container, 389, 392
  - declaration, 380–381
  - documented, 389
  - generating source code with, 395–398
  - inherited, 389, 392
  - key/value pairs in. *See* elements
  - meta, 384–390
  - multiple, 380
  - processing:
    - at runtime, 391–393
    - source-level, 394–398
  - repeatable, 380, 389, 392
  - standard, 386–390
  - type use, 381–382
- anonymous classes, 130–131
- anyMatch method (Stream), 267
- anyOf method (CompletableFuture), 339–340
- Apache Commons CSV, 484
- API documentation, 28–30
  - generating, 90
- Applet class, 163
- applications. *See* programs
- apply, applyAsXxx methods (functional interfaces), 121–122
- applyToEither method (CompletableFuture), 339–340
- \$ARG, in shell scripts, 463
- arguments array (jjs), 463
- arithmetic operations, 17–24
- Array class, 174–175
- array list variables, 45
- array lists, 45–46
  - anonymous, 144
  - checking for nulls, 215
  - constructing, 45–46
  - converting between, 212
  - copying, 48
  - filling, 49
  - instantiating with type variables, 222
  - size of, 46
  - sorting, 49
  - visiting all elements of, 47
  - working with elements of, 46–47
- array variables
  - assigning values to, 45
  - copying, 47
  - declaring, 43–44
  - initializing, 43
- ArrayBlockingQueue class, 353
- ArrayDeque class, 250
- ArrayIndexOutOfBoundsException, 43
- ArrayList class, 45–46, 237
  - add method, 46, 62
  - clone method, 154
  - forEach method, 117
  - get, remove, set, size methods, 46
  - removeIf method, 116
- arrays, 43–45
  - accessing nonexistent elements in, 43
  - allocating, 222
  - annotating, 381
  - casting, 174
  - checking, 174
  - comparing, 149
  - computing values of, 349
  - constructing, 43–44
  - constructor references with, 118
  - converting:
    - to a reference of type Object, 146
    - to/from streams, 271, 281, 350
  - copying, 48
  - covariant, 212
  - filling, 44, 49
  - generating Class objects for, 160
  - growing, 174–175
  - hash codes of, 151
  - in JavaScript, 457–458
  - length of, 43, 45, 127

- multidimensional, 50–52, 147
  - of bytes, 288–289
  - of generic types, 118, 223
  - of objects, 44, 349
  - of primitive types, 349
  - of strings, 317
  - passing into methods, 53
  - printing, 49, 52, 147
  - serializable, 319
  - sorting, 49, 109–111, 349–350
  - superclass assignment in, 140
  - using class literals with, 160
- Array class
- asList method, 253
  - copyOf method, 48
  - deepToString method, 147
  - equals method, 149
  - fill method, 49
  - hashCode method, 151
  - parallelXxx methods, 49, 349
  - sort method, 49, 111–112, 116–117
  - stream method, 262, 279
  - toString method, 49, 147
- ArrayStoreException, 140, 212, 223
- ASCII, 30, 290
- for property files, 437
  - for source files, 438
- ASM tool, 398
- assert statement, 194
- AssertionError, 194
- assertions, 193–195
- checking, 381
  - enabling/disabling, 194–195
- assignment operators, 18
- associative operations, 278
- asString method (HttpResponse), 308
- asSubclass method (Class), 227
- asynchronous computations, 335–341
- AsyncTask class (Android), 341
- atomic operations, 346, 351, 354–357, 360
- and performance, 355
- AtomicXxx classes, 355
- atZone method (LocalDateTime), 410
- @author tag (javadoc), 91, 95
- autoboxing, 46, 123
- AutoCloseable interface, 187, 210
- close method, 188
- availableCharsets method (Charset), 292
- availableProcessors method (Runtime), 331
- average method (XxxStream), 280
- ## B
- b, B conversion characters, 35
- \b (backspace), 14
- \b, \B, in regular expressions, 314
- bash scripts (Unix), 461
- BasicFileAttributes class, 303
- batch files (Windows), 461
- BeanInfo class, 173
- between method (Duration), 403
- BiConsumer interface, 121
- BiFunction interface, 121, 123
- BigDecimal class, 13, 23–24
- big-endian format, 291, 296–297
- BigInteger class, 11, 23–24
- binary data, reading/writing, 296
- binary numbers, 11, 13
- binary trees, 242
- BinaryOperator interface, 121
- binarySearch method (Collections), 240
- Bindings interface, 449
- BiPredicate interface, 121
- BitSet class, 248–249
- collecting streams into, 279
  - methods of, 249
- bitwise operators, 23
- block statement, labeled, 41
- blocking queues, 352–353
- BlockingQueue interface, 353
- Boolean class, 46
- boolean type, 14
- default value of, 71, 74
  - formatting for output, 35
  - reading/writing, 296
  - streams of, 279
- BooleanSupplier interface, 122
- bootstrap class loader, 163
- boxed method (XxxStream), 280
- branches, 36–38
- break statement, 37, 39–41

- bridge methods, 218–219
  - clashes of, 225
- BufferedReader class, 294
- build method (HttpClient), 308
- bulk operations, 352
- Byte class, 46
  - MIN\_VALUE, MAX\_VALUE constants, 11
  - toUnsignedInt method, 12
- byte codes, 4
  - writing to memory, 446–447
- byte order mark, 291
- byte type, 10–12, 289
  - streams of, 279
  - type conversions of, 21
- ByteArrayClass class, 446
- ByteArrayClassLoader class, 447
- ByteArrayXxxStream classes, 288–289
- ByteBuffer class, 297
- bytes
  - arrays of, 288–289
  - converting to strings, 292
  - reading, 289
  - writing, 290
- C**
- c, C conversion characters, 34
- C:\ root component, 298
- C/C++ programming languages
  - #include directive in, 84
  - allocating memory in, 346
  - integer types in, 11
  - pointers in, 63
- C# programming language, type parameters in, 215
- \c, in regular expressions, 311
- CachedRowSetImpl class, 486
- calculators, 157
- Calendar class, 401
  - getFirstDayOfWeek method, 431
  - weekends in, 407
- calendars, 60
- call method (CompilationTask), 445
- call by reference, 69
- Callable interface, 112
  - call method, 333
  - extending, 445
- callbacks, 112–113, 337
  - registering, 335
- camel case, 15
- cancel method
  - of CompletableFuture, 337
  - of Future, 333
- cancellation requests, 364
- CancellationException, 337
- cardinality method (BitSet), 249
- carriage return, character literal for, 14
- case label, 37
- cast method (Class), 227
- casts, 21, 103–104, 140
  - and generic types, 220
  - annotating, 382
  - inserting, 217–218
- catch statement, 186–187
  - annotating parameters of, 380
  - in JavaScript, 461
  - in try-with-resources, 189
  - no type variables in, 225
- ceiling method (NavigableSet), 243
- Channel interface, 104
- channels, 297
- char type, 13–14
  - streams of, 279
  - type conversions of, 21
- Character class, 46
- character classes, 310
- character encodings, 290–293
  - detecting, 292
  - localizing, 438
  - partial, 292, 295
  - platform, 292, 438
- character literals, 13–14
- characters, 288
  - combined, 432
  - formatting for output, 34
  - normalized, 432–433
  - reading/writing, 296
- charAt method (String), 31
- CharSequence interface, 28
  - chars, codePoints methods, 279
  - splitting by regular expressions, 263

- Charset class
  - availableCharsets method, 292
  - defaultCharset method, 292, 438
  - displayName method, 438
  - forName method, 292
- checked exceptions, 183–186
  - and generic types, 226
  - and no-argument constructors, 171
  - combining in a superclass, 185
  - declaring, 185–186
  - documenting, 186
  - in lambda expressions, 186
  - not allowed in a method, 191
  - rethrowing, 190
- checked views, 221, 254
- checkedXxx methods (Collections), 240, 254
- Checker Framework, 381
- childrenNames method (Preferences), 440
- choice indicator, in string templates, 434
- Church, Alonzo, 114, 404
- Class class, 159–162, 228
  - asSubclass, cast methods, 227
  - comparing objects of, 160
  - forName method, 160–161, 164–165, 184, 192, 447
  - generic, 227
  - getCanonicalName method, 160–161
  - getClassLoader method, 161
  - getComponentType method, 161, 174
  - getConstructor(s) methods, 162, 168, 171, 227
  - getDeclaredConstructor(s) methods, 162, 168, 227
  - getDeclaredField(s) methods, 162
  - getDeclaredMethod(s) methods, 162, 171
  - getDeclaringClass method, 161
  - getEnclosingXxx methods, 161
  - getEnumConstants method, 227
  - getField(s) methods, 162, 168
  - getInterfaces method, 161
  - getMethod(s) methods, 162, 168, 171
  - getModifiers method, 161
  - getName method, 159–161
  - getPackage, getPackageName methods, 161
  - getResource method, 163, 435
  - getResourceAsStream method, 161–162
  - getSimpleName method, 161
  - getSuperclass method, 161, 227
  - getTypeName method, 161
  - getTypeParameters method, 228
  - isXxx methods, 161, 174
  - newInstance method, 171, 227
  - toString, toGenericString methods, 161
- class declarations
  - annotations in, 380, 389
  - initialization blocks in, 72–73
- class files, 4, 163
  - paths of, 79
  - processing annotations in, 398
- class literals, 160
  - no annotations for, 382
  - no type variables in, 221
- class loaders, 163–164
- class objects, 160
- class path, 80–81
  - problems with, 471
- .class suffix, 160
- ClassCastException, 104, 221
- classes, 2, 60
  - abstract, 103, 108, 141–142
  - accessing from a different module, 489
  - adding functionality to, 77
  - adding to packages, 83
  - anonymous, 130–131
  - companion, 106
  - compiling on the fly, 446
  - constructing objects of, 14
  - deprecated, 93
  - documentation comments for, 90–92
  - encapsulation of, 469–470
  - enumerating members of, 158, 168–169
  - evolving, 324
  - extending, 136–145
    - in JavaScript, 459–460
  - fields of, 135
  - final, 141
  - generic, 45
  - immutable, 28, 347
  - implementing, 65–69, 153
  - importing, 83–84
  - inner, 87–89

- classes (*cont.*)
  - instances of, 6, 65, 78
  - loading, 169
  - local, 129–130
  - members of, 135
  - naming, 14–15, 78, 159
  - nested, 85–90, 382
  - not known at compile time, 160, 175
  - protected, 142–143
  - public, 83, 476
  - static initialization of, 164
  - system, 195
  - testing, 83
  - utility, 83, 165
  - wrapper, 46–47
- classes win rule, 151
- classifier functions, 274
- ClassLoader class
  - defineClass method, 486
  - extending, 447
  - findClass, loadClass methods, 164
  - setXxxAssertionStatus methods, 195
- classloader inversion, 165
- ClassNotFoundException, 184
- CLASSPATH environment variable, 82
- clear method
  - of BitSet, 249
  - of Collection, 236
  - of Map, 246
- clone method
  - of ArrayList, 154
  - of Enum, 156
  - of Message, 153–154
  - of Object, 143, 146, 151–154, 171
  - protected, 152
- Cloneable interface, 153
- CloneNotSupportedException, 153–154, 156
- cloning, 151–154
- close method
  - of AutoCloseable, 188
  - of PrintWriter, 187–188
  - throwing exceptions, 188
- Closeable interface, 104
  - close method, 188
- closures, 125
- code element (HTML), in documentation
  - comments, 91
- code generator tools, 388
- code points, 31, 290
  - turning a string into, 263
- code units, 13, 31, 279
  - in regular expressions, 311
- codePoints method (CharSequence), 279
- codePoints, codePointXxx methods (String), 31–32
- Collator class, 27
  - methods of, 432
- collect method (Stream), 271–272, 279
- Collection interface, 106, 236
  - add method, 236
  - addAll method, 214, 236
  - clear method, 236
  - contains, containsAll, isEmpty methods, 237
  - iterator, spliterator methods, 237
  - parallelStream method, 237, 260–261, 280, 348
  - remove, removeXxx, retainAll methods, 236
  - size method, 237
  - stream method, 237, 260–261
  - toArray method, 237
- collections, 235–254
  - generic, 254
  - iterating over elements of, 260–261
  - mutable, 253
  - processing, 239
  - serializable, 319
  - threadsafe, 354
  - unmodifiable views of, 253–254
  - vs. streams, 261
  - with given elements, 252
- Collections class, 106, 239
  - addAll method, 239
  - binarySearch method, 240
  - copy method, 239
  - disjoint method, 239
  - fill method, 49, 239
  - frequency method, 239
  - indexOfSubList, lastIndexOfSubList methods, 240
  - nCopies method, 237, 239

- replaceAll method, 239
  - reverse, shuffle methods, 49, 240
  - rotate, swap methods, 240
  - sort method, 49, 215, 240
  - synchronizedXxx, unmodifiableXxx methods, 240
- Collector interface, 272
- Collectors class, 85
- counting method, 275
  - filtering method, 277
  - flatMap method, 276
  - groupBy method, 274–277
  - groupByConcurrent method, 275, 282
  - joining method, 272
  - mapping method, 276
  - maxBy, minBy methods, 276
  - partitioningBy method, 275, 277
  - reducing method, 277
  - summarizingXxx methods, 272, 276
  - summingXxx methods, 276
  - toCollection, toList methods, 272
  - toConcurrentMap method, 274
  - toMap method, 273–274
  - toSet method, 272, 275
- com global object (JavaScript), 454
- command-line arguments, 49–50
- comments, 3
- documentation, 90–95
- commonPool method (ForkJoinPool), 335
- companion classes, 106
- Comparable interface, 109–111, 155, 215, 242
- compareTo method, 109
  - streams of, 265
  - with priority queues, 251
- Comparator interface, 85, 111–112, 127–129, 242
- comparing, comparingXxx methods, 128–129
  - naturalOrder method, 129
  - nullsFirst, nullsLast methods, 129
  - reversed method, 128
  - reverseOrder method, 129
  - streams of, 265
  - thenComparing method, 128–129
  - with priority queues, 251
- compare method (Integer, Double), 110
- compareTo method
- of Enum, 156
  - of Instant, 403
  - of String, 26–27, 109, 431
- compareToIgnoreCase method (String), 117
- compareUnsigned method (Integer, Long), 20
- compatibility, drawbacks of, 216
- Compilable interface, 452
- compilation, 4
- CompilationTask interface, 444
- call method, 445
- compile method (Pattern), 315, 318
- compiler
- instruction reordering in, 343
  - invoking, 444
- compile-time errors, 15
- completable futures, 335–340
- combining, 340
  - composing, 337–340
  - interrupting, 337
- CompletableFuture class, 335–340
- acceptEither, applyToEither methods, 339–340
  - allOf, anyOf methods, 339–340
  - cancel method, 337
  - complete, completeExceptionally methods, 336
  - exceptionally method, 338–339
  - handle method, 339
  - isDone method, 336
  - runAfterXxx methods, 339–340
  - supplyAsync method, 335–337
  - thenAccept method, 335, 339
  - thenAcceptBoth, thenCombine methods, 339–340
  - thenApply, thenApplyAsync, thenCompose methods, 337–339
  - thenRun method, 339
  - whenComplete method, 336, 338–339
- CompletionStage interface, 339
- compose method (functional interfaces), 121
- computations
- asynchronous, 335–341
  - mutator, 62
  - reproducible floating-point, 20

- computations (*cont.*)
    - with arbitrary precision, 13
  - compute, computeIfXXX methods (Map), 245
  - concat method (Stream), 265
  - concatenation, 24–25
    - objects with strings, 147
  - concurrent access errors, 126
  - concurrent programming, 329–369
    - for scripts, 449
    - strategies for, 346
  - ConcurrentHashMap class, 350–352, 362
    - compute method, 350–352
    - computeIfXXX, forEachXXX, merge, putIfAbsent, reduceXXX, searchXXX methods, 351
    - keySet, newKeySet methods, 354
    - no null values in, 244
  - ConcurrentModificationException, 241, 350
  - ConcurrentSkipListXXX classes, 354
  - conditional operator, 22
  - configuration files, 439–441
    - editing, 199–200
    - locating, 162
    - resolving paths for, 299
  - confinement, 346
  - connect method (URLConnection), 306
  - Console class, 33
  - console, displaying fonts on, 438
  - ConsoleHandler class, 200, 203
  - constants, 15–16, 105
    - naming, 15
    - static, 75–76
    - using in another class, 16
  - Constructor interface, 168–169
    - getModifiers, getName methods, 168
    - newInstance method, 171–172
  - constructor references, 118–119
    - annotating, 382
  - constructors, 69–74
    - annotating, 224, 380–381
    - documentation comments for, 90
    - executing, 70
    - for subclasses, 139
    - implementing, 69–70
    - in abstract classes, 142
    - invoking another constructor from, 71
    - no-argument, 73, 139, 171
    - overloading, 70–71
    - public, 70, 168
    - references in, 348
  - Consumer interface, 121
  - contains method (String), 28
  - contains, containsAll methods (Collection), 237
  - containsXXX methods (Map), 246
  - Content-Type header, 292
  - context class loaders, 164–166
  - continue statement, 40–41
  - control flow, 36–43
  - conversion characters, 34–35
  - cooperative cancellation, 364
  - copy method
    - of Collections, 239
    - of Files, 290, 301–302, 305
  - copyOf method (Arrays), 48
  - CopyOnWriteArrayXXX classes, 354
  - CORBA (Common Object Request Broker Architecture), 470
  - count method (Stream), 261, 266
  - counters
    - atomic, 354–357
    - de/incrementing, 189
  - counting method (Collectors), 275
  - country codes, 275, 424
  - covariance, 211
  - createBindings method (ScriptEngine), 449
  - createInstance method (Util), 165
  - createTempXXX methods (Files), 301
  - createXXX methods (Files), 300
  - critical sections, 346, 357, 363
  - Crockford, Douglas, 451
  - currencies, 428–429
    - formatting, 433
  - Currency class, 428
  - current method (ProcessHandle), 370
- ## D
- d
    - conversion character, 34
    - formatting symbol (date/time), 416
  - D suffix, 12
  - \d, \D, in regular expressions, 312
  - daemon threads, 366

- databases, 377
  - annotating access to, 388
  - persisting objects in, 479
- DataInput/Output interfaces, 295–296
  - read/writeXxx methods, 296–297, 322
- DataXxxStream classes, 296
- Date class, 401, 416–417
- DateFormat class, 429
- dates
  - computing, 407–408
  - formatting, 413–416, 422, 429–431, 433
  - local, 404–407
  - nonexistent, 407, 412, 430
  - parsing, 415
- datesUntil method (LocalDate), 406–407
- DateTimeFormat class, 429–431
- DateTimeFormatter class, 413–416
  - and legacy classes, 417
  - format method, 413, 430
  - ofLocalizedXxx methods, 413, 430
  - ofPattern method, 415
  - parse method, 415
  - toFormat method, 415
  - withLocale method, 413, 430
- DateTimeParseException, 430
- daylight savings time, 410–413
- DayOfWeek enumeration, 61, 406–407, 411
  - getDisplayName method, 415, 430
- dayOfWeekInMonth method (TemporalAdjusters), 408
- deadlocks, 346, 358, 362–363
- debugging
  - messages for, 183
  - overriding methods for, 141
  - primary arrays for, 49
  - streams, 266
  - threads, 366
  - using anonymous subclasses for, 143–144
  - with assertions, 194
- DecimalFormat class, 78
  - number format patterns of, 433
- declaration-site variance, 215
- decomposition (for classes), 52–54
- decomposition modes (for characters), 432
- decrement operator, 19
- decrementExact method (Math), 20
- deep copies, 153
- deepToString method (Arrays), 147
- default label (in switch), 37, 159
- default methods, 106–108
  - conflicts of, 107–108, 144–145
  - in interfaces, 151
- default modifier, 106, 385
- defaultCharset method (Charset), 292, 438
- defaultXxxObject methods (ObjectXxxStream), 322
- defensive programming, 193
- deferred execution, 119–120
- defineClass method (ClassLoader), 486
- delete, deleteIfExists methods (Files), 301
- delimiters, for scanners, 294
- @Deprecated annotation, 93, 386–387
- @deprecated tag (javadoc), 93, 387
- Deque interface, 238, 250
- destroy, destroyForcibly methods
  - of Process, 369
  - of ProcessHandle, 370
- DiagnosticCollector class, 447
- DiagnosticListener interface, 447
- diamond syntax (<>)
  - for array lists, 45
  - for constructors of generic classes, 209
- directories, 298
  - checking for existence, 300, 302
  - creating, 300–302
  - deleting, 301, 304–305
  - moving, 301
  - temporary, 301
  - user, 299
  - visiting, 302–305
  - working, 367
- directory method (ProcessBuilder), 367
- disjoint method (Collections), 239
- displayName method (Charset), 438
- distinct method (Stream), 265, 282
- dividedBy method (Duration), 404
- divideUnsigned method (Integer, Long), 20
- division, 18



- do statement, 38
  - doc-files directory, 91
  - documentation comments, 90–95
  - @Documented annotation, 387, 389
  - domain names
    - for modules, 472
    - for packages, 79
  - dot notation, 6, 16
  - double brace initialization, 144
  - Double class, 46
    - compare method, 110
    - equals method, 149
    - isFinite, isInfinite methods, 13
    - NaN, NEGATIVE\_INFINITY, POSITIVE\_INFINITY values, 13
    - parseDouble method, 27
    - toString method, 27
  - double type, 12–13
    - atomic operations on, 357
    - functional interfaces for, 122
    - streams of, 279
    - type conversions of, 20–22
  - DoubleAccumulator, DoubleAdder classes, 357
  - DoubleConsumer, DoubleXxxOperator, DoublePredicate, DoubleSupplier, DoubleToXxxFunction interfaces, 122
  - DoubleFunction interface, 122, 220
  - doubles method (Random), 280
  - DoubleStream class, 279–280
  - DoubleSummaryStatistics class, 272, 280
  - doubleValue method (Number), 428
  - downstream collectors, 275–277, 282
  - Driver.parentLogger method, 488
  - dropWhile method (Stream), 265
  - Duration class
    - between method, 403
    - dividedBy, isZero, isNegative, minus, minusXxx, multipliedBy, negated, plus, plusXxx methods, 404
    - immutability of, 347, 404
    - ofXxx methods, 403, 405, 413
    - toXxx methods, 403
  - dynamic method lookup, 139–140, 218–219
  - dynamically typed languages, 456
- ## E
- E constant (Math), 20
  - e, E
    - conversion characters, 34
    - formatting symbols (date/time), 416
  - \e, \E, in regular expressions, 311
  - Eclipse, 5
  - ECMAScript standard, 452, 459
  - edu global object (JavaScript), 454
  - effectively final variables, 126
  - efficiency, and final modifier, 141
  - Element interface, 395
  - element method (BlockingQueue), 353
  - elements (in annotations), 378–379, 385
  - else statement, 36
  - em element (HTML), in documentation comments, 91
  - Emacs text editor, 453
  - empty method
    - of Optional, 269
    - of Stream, 262
  - empty string, 26, 147
    - concatenating, 27
  - encapsulation, 60, 469–471, 479
  - encodings. *See* character encodings
  - end method (Matcher, MatchResult), 315–316
  - <<END, in shell scripts, 463
  - endsWith method (String), 28
  - engine scope, 449
  - enhanced for loop, 47, 52, 126
    - for collections, 241
    - for enumerations, 155
    - for iterators, 167
    - for paths, 300
  - entering, exiting methods (Logger), 197
  - Entry class, 217
  - entrySet method (Map), 246
  - Enum class, 155–156
  - enum instances
    - adding methods to, 157
    - construction, 156
    - referred by name, 159
  - enum keyword, 16, 154
  - enumeration sets, 250
  - enumerations, 154–159
    - annotating, 380

- comparing, 155
  - constructing, 156
  - defining, 16
  - nested inside classes, 158
  - serialization of, 323
  - static members of, 157–158
  - traversing instances of, 155
  - using in switch, 158
- EnumMap, EnumSet classes, 250
- \$ENV, in shell scripts, 463
- environment variables, modifying, 368
- epoch, definition of, 402
- equality, testing for, 22
- equals method
  - final, 150
  - for subclasses, 149
  - for values from different classes, 149
  - null-safe, 149
  - of Arrays, 149
  - of Double, 149
  - of Instant, 403
  - of Object, 146, 148–150
  - of Objects, 149
  - of String, 25–26
  - of wrapper classes, 47
  - overriding, 148–150
  - symmetric, 150
- equalsIgnoreCase method (String), 26
- \$ERR, in shell scripts, 462
- Error class, 183
- error messages, for generic methods, 210
- eval method (ScriptEngine), 449–451
- even numbers, 18
- EventHandler interface, 113
- Exception class, 183
- exceptionally method (CompletableFuture), 338–339
- exceptions, 182–193
  - and generic types, 225–226
  - annotating, 382
  - catching, 186–190
    - in JavaScript, 461
  - chaining, 190–191
  - checked, 171, 183–186
  - combining in a superclass, 185
  - creating, 184
  - documenting, 186
  - hierarchy of, 183–185
  - logging, 198
  - rethrowing, 189–191
  - suppressed, 189
  - throwing, 182–183
  - uncaught, 192
  - unchecked, 183
- exec method (Runtime), 367
- Executable class
  - getModifiers method, 172
  - getParameters method, 169
- ExecutableElement interface, 395
- ExecutionException, 333
- Executor interface, 338
- executor services, 331
  - default, 335
- ExecutorCompletionService class, 334
- Executors class, 331
- ExecutorService interface, 445
  - execute method, 331
  - invokeAll, invokeAny methods, 334
- exists method (Files), 300, 302
- exit function (shell scripts), 464
- \$EXIT, in shell scripts, 462
- exitValue method (Process), 369
- exports keyword, 473, 476–479
  - qualified, 489
- exportSubtree method (Preferences), 440
- extends keyword, 104, 136, 210–214
- Externalizable interface, 322
- ## F
- f conversion character, 34
- F suffix, 12
- \f, in regular expressions, 311
- factory methods, 70, 78
- failures, logging, 190
- falling through, 37
- false value (boolean), 14
  - as default value, 71, 74
- Field interface, 168–169
  - get, getXxx, set, setXxx methods, 170, 172
  - getModifiers, getName method, 168, 172
  - getType method, 168

- fields (instance and static variables), 135
  - enumerating, 168–169
  - final, 344
  - provided, 143
  - public, 168
  - retrieving values of, 169–171
  - setting, 170
  - transient, 321
- File class, 300
- file attributes
  - copying, 301
  - filtering paths by, 303
- file handlers
  - configuring, 201–202
  - default, 200
- file managers, 446
- file pointers, 296
- file.encoding system property, 292
- file.separator system property, 248
- FileChannel class
  - get, getXXX, open, put, putXXX methods, 297
  - lock, tryLock methods, 298
- FileFilter class, 120
- FileHandler class, 200–203
- FileNotFoundException, 183
- files
  - archiving, 305
  - channels to, 297
  - checking for existence, 183, 300–302
  - closing, 187
  - copying/moving, 301–302
  - creating, 299–302
  - deleting, 301
  - empty, 300
  - encoding of, 290–291
  - locking, 297–298
  - memory-mapped, 297
  - missing, 447
  - random-access, 296–297
  - reading from/writing to, 33, 183, 289
  - temporary, 301
- Files class
  - copy method, 290, 301–302, 305
  - createTempXXX methods, 301
  - createXXX methods, 300
  - delete, deleteIfExists methods, 301
  - exists method, 300, 302
  - find method, 302–303
  - isXXX methods, 300, 302
  - lines method, 263, 293
  - list method, 302–303
  - move method, 301–302
  - newBufferedReader method, 294, 448
  - newBufferedWriter method, 294, 302
  - newXXXStream methods, 288, 302, 320
  - read, readNBytes methods, 289
  - readAllBytes method, 289, 293
  - readAllLines method, 293
  - walk method, 302–305
  - walkFileTree method, 302, 304
  - write method, 295, 302
- FileSystem, FileSystems classes, 305
- FileTime class, 417
- FileVisitor interface, 304
- fill method
  - of Arrays, 49
  - of Collections, 49, 239
- filter method (Stream), 261–263, 267
- Filter interface, 202
- filtering method (Collectors), 277
- final fields, 344
- final methods, 347
- final modifier, 15, 73, 141
- final variables, 343, 347
- finalize method
  - of Enum, 156
  - of Object, 146
- finally statement, 189–190
  - for locks, 358
- financial calculations, 13
- find method (Files), 302–303
- findAll method (Scanner), 316
- findAny method (Stream), 267
- findClass method (ClassLoader), 164
- findFirst method (Stream), 168, 267
- fine method (Logger), 197
- first method (SortedSet), 243
- first day of week, 431
- firstDayOfXXX methods (TemporalAdjusters), 408
- flag bits, sequences of, 248

- flatMap method
  - general concept of, 264
  - of Optional, 269–271
  - of Stream, 264
- flatMapMapping method (Collectors), 276
- flip method (BitSet), 249
- Float class, 46
- float type, 12–13
  - streams of, 279
  - type conversions of, 20–22
- floating-point types, 12–13
  - and binary number system, 13
  - comparing, 110
  - division of, 18
  - formatting for output, 34
  - in hexadecimal notation, 13
  - type conversions of, 20–22
- floor method (NavigableSet), 243
- floorMod method (Math), 19
- fonts, missing, 438
- for statement, 39
  - declaring variables for, 42
  - enhanced, 47, 52, 126, 155, 241, 300
  - multiple variables in, 39
- for each loop (JavaScript), 458
- forEach method
  - of ArrayList, 117
  - of Map, 246
- forEach, forEachOrdered methods (Stream), 271
- forEachXxx methods (ConcurrentHashMap), 352
- ForkJoinPool class, 338
  - commonPool method, 335
- forLanguageTag method (Locale), 426
- format method
  - of DateTimeFormatter, 413, 430
  - of MessageFormat, 433–435
  - of String, 427
- Format class, 417
- format specifiers, 34
- formatted output, 33–36
- Formatter class, 203
- formatters, for date/time values, 414–415
- forms, posting data from, 307–309

- forName method
  - of Charset, 292
  - of Class, 160–161, 164–165, 184, 192, 447
- frequency method (Collections), 239
- from method (Instant, ZonedDateTime), 416
- full indicator, in string templates, 433
- Function interface, 121, 273
- function keyword (JavaScript), 458
- function types, 114
  - structural, 120
- functional interfaces, 115–116
  - as method parameters, 213–214
  - common, 121
  - contravariant in parameter types, 214
  - for primitive types, 122
  - implementing, 123
- @FunctionalInterface annotation, 123, 386, 388–389
- functions, 60
  - higher-order, 127–129
- Future interface, 334
  - cancel, isCancelled, isDone methods, 333
  - get method, 333, 335
- futures, 333–335
  - completable, 335–340

## G

- G formatting symbol (date/time), 416
- g, G conversion characters, 34
- \G, in regular expressions, 314
- %g pattern variable, 202
- garbage collector, 251
- generate method (Stream), 262, 279
- @Generated annotation, 387–388
- generators, converting to streams, 281
- generic classes, 45, 208–209
  - constructing objects of, 209
  - information available at runtime, 227
  - instantiating, 209
- generic collections, 254
- generic constructors, 228
- generic methods, 209–210
  - calling, 210
  - declaring, 210
  - information available at runtime, 227

- generic type declarations, 228–229
- generic types, 110
  - and exceptions, 225–226
  - and lambda expressions, 213
  - and reflection, 226–229
  - annotating, 381
  - arrays of, 118
  - casting, 220
  - in JVM, 216–219
  - invariant, 212–213
  - restrictions on, 220–226
- GenericArrayType interface, 228
- get method
  - of Array, 174
  - of ArrayList, 46
  - of BitSet, 249
  - of Field, 170, 172
  - of FileChannel, 297
  - of Future, 333, 335
  - of List, 238
  - of LongAccumulator, 356
  - of Map, 243, 245
  - of Optional, 269–271
  - of Path, 298–300
  - of Preferences, 440
  - of ServiceLoader.Provider, 167
  - of Supplier, 121
  - of ThreadLocal, 365
- GET requests, 308
- getAndXxx methods (AtomicXxx), 355
- getAnnotation, getAnnotationsByType methods (AnnotatedConstruct), 395
- getAnnotationXxx methods (AnnotatedElement), 392–393
- getAsXxx methods
  - of OptionalXxx, 280
  - of XxxSupplier, 122
- getAudioClip method (Applet), 163
- getAvailableCurrencies method (Currency), 428
- getAvailableIds method (ZoneId), 410
- getAvailableLocales method (Locale), 425
- getAverage method (XxxSummaryStatistics), 272
- getBundle method (ResourceBundle), 436–438
- getCanonicalName method (Class), 160–161
- getClass method (Object), 141, 146, 149, 159, 221, 227
- getClassLoader method (Class), 161
- getComponentType method (Class), 161, 174
- getConstructor(s) methods (Class), 162, 168, 171, 227
- getContents method (ListResourceBundle), 437
- getContextClassLoader method (Thread), 165
- getCountry method (Locale), 274
- getCurrencyInstance method (NumberFormat), 427
- getDayOfXxx methods
  - of LocalDate, 61, 406–407
  - of LocalTime, 409
  - of ZonedDateTime, 411
- getDeclaredAnnotationXxx methods (AnnotatedElement), 392–393
- getDeclaredConstructor(s) methods (Class), 162, 168, 227
- getDeclaredField(s) methods (Class), 162
- getDeclaredMethod(s) methods (Class), 162, 171
- getDeclaringClass method
  - of Class, 161
  - of Enum, 156
- getDefault method (Locale), 426, 436
- getDisplayName method
  - of Currency, 429
  - of DayOfWeek, Month, 415, 430
  - of Locale, 426
- getElementsAnnotatedWith method (RoundEnvironment), 395
- getEnclosedElements method (TypeElement), 395
- getEnclosingXxx methods (Class), 161
- getEngineXxx methods (ScriptEngineManager), 448
- getEnumConstants method (Class), 227
- getErrorStream method (Process), 368
- getField(s) methods (Class), 162, 168
- getFileName method (Path), 300
- getFilePointer method (RandomAccessFile), 297
- getFirstDayOfWeek method (Calendar), 431

- getGlobal method (Logger), 195
- getHead method (Formatter), 203
- getHeaderFields method (URLConnection), 307
- getInputStream method
  - of URL, 306
  - of URLConnection, 307
- getInstance method
  - of Collator, 432
  - of Currency, 428
- getInterfaces method (Class), 161
- getISOxxx methods (Locale), 425
- getLength method (Array), 174
- getLogger method (Logger), 196
- getMax method (xxxSummaryStatistics), 272
- getMethod(s) methods (Class), 162, 168, 171
- getMethodCallSyntax method (ScriptEngineFactory), 451
- getModifiers method
  - of Class, 161
  - of Constructor, 168
  - of Executable, 172
  - of Field, 168, 172
  - of Method, 168
- getMonthxxx methods
  - of LocalDate, 61, 406
  - of LocalTime, 409
  - of ZonedDateTime, 412
- getName method
  - of Class, 159–161
  - of Constructor, 168
  - of Field, 168, 172
  - of Method, 168
  - of Parameter, 172
  - of Path, 300
  - of PropertyDescriptor, 173
- getNumberInstance method (NumberFormat), 427
- getObject method (ResourceBundle), 437
- getOrDefault method (Map), 244–245
- getOutputStream method (URLConnection), 306
- getPackage, getPackageName methods (Class), 161
- getParameters method (Executable), 169
- getParent method (Path), 300
- getPath method (FileSystem), 305
- getPercentInstance method (NumberFormat), 427
- getProperties method (System), 248
- getProperty method (System), 163
- getPropertyDescriptors method (BeanInfo), 173
- getPropertyType, getReadMethod methods (PropertyDescriptor), 173
- getQualifiedName method (TypeElement), 395
- getResource method (Class), 163, 435
- getResourceAsStream method
  - of Class, 161–162
  - of Module, 481
- getRoot method (Path), 300
- getSimpleName method
  - of Class, 161
  - of Element, 395
- getString method (ResourceBundle), 436
- getSuperclass method (Class), 161, 227
- getSuppressed method (IOException), 189
- getSymbol method (Currency), 429
- getSystemJavaCompiler method (ToolProvider), 444
- getTail method (Formatter), 203
- getTask method (JavaCompiler), 444–445
- getType method (Field), 168
- getTypeName method (Class), 161
- getTypeParameters method (Class), 228
- getURLs method (URLClassLoader), 163
- getValue method (LocalDate), 61
- getWriteMethod method (PropertyDescriptor), 173
- getxxx methods (Array), 174
- getxxx methods (Field), 170, 172
- getxxx methods (FileChannel), 297
- getxxx methods (Preferences), 440
- getxxxInstance methods (NumberFormat), 78
- getxxxStream methods (Process), 367
- getYear method
  - of LocalDate, 406
  - of LocalTime, 409
  - of ZonedDateTime, 412
- GlassFish administration tool, 463
- Goetz, Brian, 329
- Gregorian calendar reform, 406

GregorianCalendar class, 416–417  
group method (Matcher, MatchResult), 315, 317  
grouping, 274–275  
    classifier functions of, 274  
    reducing to numbers, 275  
groupingBy method (Collectors), 274–277  
groupingByConcurrent method (Collectors), 275, 282  
GUI (graphical user interface)  
    callbacks in, 112–113  
    long-running tasks in, 340–341  
    missing fonts in, 438

## H

H formatting symbol (date/time), 416  
h, H conversion characters, 35  
\h, \H, in regular expressions, 312  
\h pattern variable, 202  
handle method (CompletableFuture), 339  
Handler class, 203  
Hansen, Per Brinch, 360  
hash method (Object), 151  
hash codes, 150–151  
    computing in String class, 150  
    formatting for output, 35  
hash functions, 150–151, 242  
hash maps  
    concurrent, 350–352  
    weak, 251  
hash tables, 242  
hashCode method  
    of Arrays, 151  
    of Enum, 156  
    of Object, 146, 148, 150–151  
HashMap class, 243  
    null values in, 244  
HashSet class, 242  
Hashtable class, 360  
hasNext method (Iterator), 240  
hasNext, hasNextXxx methods (Scanner), 33, 293  
headMap method (SortedMap), 253  
headSet method  
    of NavigableSet, 243  
    of SortedSet, 243, 253

heap pollution, 221, 254  
Hello, World! program, 2  
    modular, 472–474  
helper methods, 216  
here documents, 463  
hexadecimal numbers, 11, 13  
    formatting for output, 34  
higher method (NavigableSet), 243  
higher-order functions, 127–129  
hn, hr elements (HTML), in  
    documentation comments, 91  
Hoare, Tony, 360  
HTML documentation, generating, 398  
HTTP connections, 306–309  
HttpClient class, 306–309, 335  
    enabling logging for, 309  
HttpHeaders class, 309  
HttpResponse class, 308–309  
URLConnection class, 306–307  
hyperlinks  
    in documentation comments, 93–94  
    regular expressions for, 310

## I

[I prefix, 147, 160  
IANA (Internet Assigned Numbers Authority), 410  
IDE (integrated development environment), 3, 5  
identity method  
    of Function, 121, 273  
    of UnaryOperator, 121  
identity values, 278  
if statement, 36  
ifPresent, ifPresentOrElse methods (Optional), 268  
IllegalArgumentException, 194  
IllegalStateException, 273, 353  
ImageIcon class, 163  
images, locating, 162  
img element (HTML), in documentation comments, 91  
immutability, 346  
immutable classes, 347  
implements keyword, 101–102

- import statement, 7, 83–84
  - no annotations for, 382
  - static, 85
- import static statement, 159
- importPreferences method (Preferences), 441
- InaccessibleObjectException, 170, 481
- increment method (LongAdder), 356
- increment operator, 19
- incrementAndGet method (AtomicXxx), 355
- incrementExact method (Math), 20
- indexOf method
  - of List, 238
  - of String, 28
- indexOfSubList method (Collections), 240
- info method
  - of Logger, 195
  - of ProcessHandle, 370
- inheritance, 136–154
  - and default methods, 144–145
  - classes win rule, 145, 151
- @Inherited annotation, 387, 389
- initCause method (Throwable), 191
- initialization blocks, 72–73
  - static, 76
- inlining, 141
- inner classes, 87–89
  - anonymous, 130–131
  - capturing this references in, 118
  - invoking methods of outer classes, 88
  - local, 126, 129–131
  - syntax for, 89
- input
  - reading, 32–33, 293–294
  - redirecting, 449
  - setting locales for, 427
  - splitting along delimiters, 317
- input prompts, 33
- input streams, 288
  - copying, 290
  - obtaining, 288
  - reading from, 289
- InputStream class, 289
  - transferTo method, 290
- InputStreamReader class, 293
- INSTANCE instance (enum types), 323
- instance methods, 6, 66–67
- instance variables, 65, 67–68
  - annotating, 380
  - comparing, 149
  - default values of, 71–72
  - final, 73
  - in abstract classes, 142
  - in JavaScript, 460
  - initializing, 72–73, 139
  - not accessible from static methods, 77
  - of deserialized objects, 322–324
  - protected, 143
  - setting, 70
  - transient, 321
  - vs. local, 72
- instanceof operator, 104, 140, 149
  - annotating, 382
- instances, 6
- Instant class, 402
  - and legacy classes, 417
  - compareTo, equals methods, 403
  - from method, 416
  - immutability of, 347, 404
  - minus, minusXxx, plus, plusXxx methods, 404
  - now method, 403
- instruction reordering, 343
- int type, 10–12
  - functional interfaces for, 122
  - processing values of, 120
  - random number generator for, 6, 38
  - streams of, 279
  - type conversions of, 20–22
  - using class literals with, 160
- IntBinaryOperator interface, 122
- IntConsumer interface, 120, 122
- Integer class, 46
  - compare method, 110
  - MIN\_VALUE, MAX\_VALUE constants, 11
  - parseInt method, 27, 184
  - toString method, 27
  - unsigned division in, 12
  - xxxUnsigned methods, 20
- integer indicator, in string templates, 433
- integer types, 10–12
  - comparing, 110
  - computing, 18, 20



- integer types (*cont.*)
  - formatting for output, 34
  - in hexadecimal notation, 11
  - reading/writing, 296–297
  - type conversions of, 20–22
  - values of:
    - even/odd, 18
    - signed, 12
- @interface declaration, 384–385
- interface keyword, 101
- interface methods, 106–108
- interfaces, 100–105
  - annotating, 380–381
  - compatibility of, 107
  - declarations of, 100–101
  - defining variables in, 105
  - documentation comments for, 90
  - evolution of, 106
  - extending, 104
  - functional, 115–116
  - implementing, 101–103
    - in JavaScript, 459–460
    - in scripting engines, 451
  - multiple, 105
  - methods of, 101–102
  - nested, enumerating, 168–169
  - no instance variables in, 105
  - no redefining methods of the `Object` class in, 151
  - views of, 252
- Internet Engineering Task Force, 423
- interrupted method (`Thread`), 364
- interrupted status, 364
- `InterruptedException`, 363–364
- `intersects` method (`BitSet`), 249
- `IntFunction` interface, 122, 220
- `IntPredicate` interface, 122
- intrinsic locks, 358–360
- `ints` method (`Random`), 280
- `IntSequence` interface, 129
- `IntStream` class, 279–280
  - parallel method, 280
- `IntSummaryStatistics` class, 272, 280
- `IntSupplier`, `IntToXxxFunction`,
  - `IntUnaryOperator` interfaces, 122
- `InvalidClassException`, 324
- `InvalidPathException`, 298
- Invocable interface, 450
- `InvocationHandler` interface, 175
- invoke method (`Method`), 171–172
- invokeXxx methods (`ExecutorService`), 334
- `IOException`, 183, 293
  - `addSuppressed`, `getSuppressed` methods, 189
- `isAfter`, `isBefore` methods
  - of `LocalDate`, 406
  - of `LocalTime`, 409
  - of `ZonedDateTime`, 412
- `isAlive` method
  - of `Process`, 369
  - of `ProcessHandle`, 370
- `isCancelled` method (`Future`), 333
- `isDone` method
  - of `CompletableFuture`, 336
  - of `Future`, 333
- `isEmpty` method
  - of `BitSet`, 249
  - of `Collection`, 237
  - of `Map`, 246
- `isEqual` method (`Predicate`), 121–122
- `isFinite`, `isInfinite` methods (`Double`), 13
- `isInterrupted` method (`Thread`), 364
- `isLoggable` method (`Filter`), 202
- `isNamePresent` method (`Parameter`), 172
- `isNull` method (`Objects`), 117
- ISO 8601 format, 388
- ISO 8859-1 encoding, 292, 295
- `isPresent` method (`Optional`), 269–271
- `isXxx` methods (`Class`), 161, 174
- `isXxx` methods (`Files`), 300, 302
- `isXxx` methods (`Modifier`), 162, 168
- `isZero`, `isNegative` methods (`Duration`), 404
- Iterable interface, 240–241, 300, 458
  - iterator method, 240
- iterate method (`Stream`), 262, 266, 279, 349
- iterator method
  - of `Collection`, 237
  - of `ServiceLoader`, 167
  - of `Stream`, 271
- Iterator interface
  - `next`, `hasNext` methods, 240
  - `remove`, `removeIf` methods, 241

iterators, 240–241, 271  
  converting to streams, 281  
  for random numbers, 459  
  invalid, 241  
  traversing, 167  
  weakly consistent, 350

## J

JAR files, 80–81  
  dependencies in, 491  
  for split packages, 483  
  manifest for, 484–485  
  modular, 482–484  
  processing order of, 82  
  resources in, 163, 435  
  scanning for deprecated elements, 387  
jar program, 80–81  
  -C option, 482–483  
  -d option, 482–483  
  --module-version option, 483  
Java EE platform, 335, 486–487  
Java Persistence Architecture, 377  
Java Platform Module System, 469–493  
  layers in, 483  
  migration to, 484–486  
  no support for versioning in, 471, 474, 483  
  service loading in, 490–491  
java program, 4  
  --add-exports, --add-opens options, 486  
  --add-module option, 484, 487  
  -cp (--class-path, -classpath) option, 81–82  
  -disableassertions (-da) option, 195  
  -enableassertions (-ea) option, 194  
  -enablesystemassertions (-esa) option, 195  
  --illegal-access option, 486  
  -jar option, 81  
  -m, -p (--module, --module-path) options, 473, 483  
  option files for, 487  
  specifying locales in, 426  
Java programming language  
  compatibility with older versions of, 145, 216  
  online API documentation on, 28–30

  portability of, 19  
  strongly typed, 14  
  Unicode support in, 30–32  
  uniformity of, 3, 108  
java, javax, javafx global objects  
  (JavaScript), 454  
java.activation module, 486–487  
java.awt package, 83, 471  
java.base module, 475  
java.class.path, java.home, java.io.tmpdir  
  system properties, 248  
java.corba module, 486–487  
java.desktop module, 474  
Java.extend function (JavaScript), 459  
Java.from function (JavaScript), 457  
java.lang, java.lang.annotation packages,  
  386  
java.lang.reflect package, 168  
java.logging module, 488  
java.sql package, 417  
Java.super function (JavaScript), 460  
java.time package, 401–417  
Java.to function (JavaScript), 457  
java.transaction module, 486–487  
Java.type function (JavaScript), 454–455  
java.util package, 7, 350  
java.util.concurrent package, 350, 353  
java.util.concurrent.atomic package, 355  
java.util.logging package, 196  
java.version system property, 248  
java.xml.bind, java.xml.ws,  
  java.xml.ws.annotation modules,  
  486–487  
JavaBeans, 172–173  
javac program, 4  
  -author option, 95  
  -cp (--class-path, -classpath) option, 81  
  -d option, 80, 94  
  -encoding option, 438  
  -link, -linksource options, 95  
  -parameters option, 169  
  -processor option, 394  
  -version option, 95  
  -Xlint option, 37  
  -XprintRounds option, 398  
JavaCompiler.getTask method, 444–445

- javadoc program, 90–95
    - including annotations in, 389
  - JavaFileObject interface, 445
  - JavaFX platform, 112–113
    - and threads, 341
    - distributed over multiple modules, 489
  - javafx.base, javafx.controls modules, 487–488
  - java.n.log files, 200
  - JavaScript programming language
    - accessing classes of, from Java, 451
    - anonymous functions in, 458
    - anonymous subclasses in, 459
    - arrays in, 457–458
    - arrow function syntax, 459
    - bracket notation in, 454, 457–458
    - calling static methods in, 455
    - catching Java exceptions in, 461
    - constructing Java objects in, 454–455
    - delimiters in, 450
    - extending Java classes in, 459–460
    - implementing Java interfaces in, 459–460
    - inner classes in, 455
    - instance variables in, 460
    - lists and maps in, 458
    - methods in, 453–454
    - numbers in, 456
    - objects in, 456
    - REPL for, 452–453
    - semicolons in, 450
    - strings in, 456
    - superclasses in, 460
  - JavaServer Faces framework, 246
  - javax.annotation package, 386
  - javax.swing package, 474
  - JAXB (Java Architecture for XML Binding), 479
  - jconsole program, 200
  - jdepscan program, 387
  - jdeps program, 491
  - JDK (Java Development Kit), 3
    - obsolete features in, 470
  - jdk.incubator.http package, 306
  - jjs program, 452–453
    - command-line arguments in, 463
    - executing commands in, 462
  - jlink program, 492
  - jmod program, 493
  - job scheduling, 251
  - join method
    - of String, 25
    - of Thread, 363
  - joining method (Collectors), 272
  - JPA (Java Persistence API), 479
  - JShell, 7–10
    - imported packages in, 9–10
    - loading modules into, 484
  - JSP (JavaServer Pages), 464
  - JUnit, 377–378
- ## K
- K formatting symbol (date/time), 416
  - \k, in regular expressions, 313
  - key/value pairs
    - adding new keys to, 243
    - in annotations. *See* elements
    - removed by garbage collector, 251
    - values of, 243
  - keys method (Preferences), 440
  - keySet method
    - of ConcurrentHashMap, 354
    - of Map, 246, 252
  - keywords, 15
- ## L
- L suffix, 11
  - [L prefix, 160
  - labeled statements, 40–41
  - lambda expressions, 113–116
    - and generic types, 213
    - annotating targets for, 388
    - capturing variables in, 124–127
    - executing, 119
    - for loggers, 196
    - parameters of, 115
    - processing, 119–123
    - return type of, 115
    - scope of, 124
    - this reference in, 124

- throwing exceptions in, 186
  - using with streams, 263
  - vs. anonymous functions (JavaScript), 458
  - with parallel streams, 348
- language codes, 275, 424
- language model API, 395
- last method (SortedSet), 243
- lastIndexOf method
  - of List, 238
  - of String, 28
- lastIndexOfSubList method (Collections), 240
- lastXxx methods (TemporalAdjusters), 408
- lazy operations, 261, 266, 283, 317
- leap seconds, 402
- leap years, 405–406
- legacy code, 416–417
- length method
  - of arrays, 43
  - of RandomAccessFile, 297
  - of String, 6, 31
- .level suffix, 199
- lib/modules file, 493
- limit method (Stream), 264, 282
- line feed
  - character literal for, 14
  - formatting for output, 35
  - in regular expressions, 314
- line.separator system property, 248
- lines method
  - of BufferedReader, 294
  - of Files, 263, 293
- @link tag (javadoc), 93–94
- linked lists, 237, 241
- LinkedBlockingQueue class, 353, 362
- LinkedHashMap class, 246
- LinkedList class, 237
- list method (Files), 302–303
- List interface, 215, 237
  - add, addAll, get, indexOf, lastIndexOf, listIterator, remove, replaceAll, set, sort methods, 238
  - of method, 46, 48, 238, 252
  - subList method, 238, 253
- ListIterator interface, 241
- ListResourceBundle class, 437
- lists
  - converting to streams, 281
  - in Nashorn, 458
  - mutable, 253
  - printing elements of, 117
  - removing null values from, 117
  - sublists of, 253
  - unmodifiable views of, 254
- little-endian format, 291
- load method (ServiceLoader), 167
- load balancing, 319
- loadClass method (ClassLoader), 164
- local classes, 129–130
- local date/time, 404–410
- local variables, 41–43
  - annotating, 380–381
  - vs. instance, 72
- LocalDate class, 61
  - and legacy classes, 417
  - datesUntil method, 406–407
  - getXxx methods, 61, 406–407
  - isXxx methods, 406
  - minus, minusXxx methods, 406–407
  - now method, 70, 77, 405–406
  - of method, 61, 70, 405–406
  - ofInstant method, 406
  - parse method, 430
  - plus, plusXxx methods, 61–62, 64, 406–407
  - toEpochSecond method, 406
  - until method, 406
  - withXxx methods, 406
- LocalDateTime class, 410
  - and legacy classes, 417
  - atZone method, 410
  - parse method, 430
- Locale class, 273
  - forLanguageTag method, 426
  - getAvailableLocales method, 425
  - getCountry method, 274
  - getDefault method, 426, 436
  - getDisplayName method, 426
  - getISOXxx methods, 425
  - setDefault method, 426
  - predefined fields, 425

- locales, 273–276, 422–427
    - date/time formatting for, 429–431
    - default, 413, 426, 429–430, 436
    - displaying names of, 426
    - first day of week in, 431
    - for template strings, 433–435
    - formatting styles for, 415, 430
    - sorting words for, 431–432
    - specifying, 423–425
    - weekdays and months in, 415
  - LocalTime class, 409–410
    - and legacy classes, 417
    - final, 141
    - getXxx, isXxx, minus, minusXxx, now, of,
      - ofInstant, plus, plusXxx, toXxx, withXxx
    - methods, 409
    - parse method, 430
  - lock method
    - of FileChannel, 298
    - of ReentrantLock, 358
  - locks, 346
    - error-prone, 347
    - intrinsic, 358–360
    - reentrant, 357–358
    - releasing, 189, 343
  - log handlers, 200–202
    - default, 197, 200
    - filtering/formatting, 202
    - installing custom, 200
    - levels of, 200
    - suppressing messages in, 197
  - Logger class, 488
    - addHandler method, 200
    - entering, exiting methods, 197
    - fine method, 197
    - getGlobal method, 195
    - getLogger method, 196
    - info method, 195
    - log method, 197–198
    - logp, logrb methods, 198
    - setFilter method, 203
    - setLevel method, 195, 197, 200
    - setUseParentHandlers method,
      - 200
    - throwing method, 198
    - warning method, 197
  - loggers
    - defining, 196
    - filtering/formatting, 202
    - hierarchy of, 196
  - logging, 195–203
    - configuring, 197–200
    - enabling/disabling, 197
    - failures, 190
    - levels of, 197–200
    - localizing, 199
    - overriding methods for, 141
    - using for unexpected exceptions, 198
  - Long class, 46
    - MIN\_VALUE, MAX\_VALUE constants, 11
    - unsigned division in, 12
    - xxxUnsigned methods, 20
  - long indicator, in string templates, 433
  - long type, 10–12
    - atomic operations on, 356–357
    - functional interfaces for, 122
    - streams of, 279
    - type conversions of, 20–22
  - LongAccumulator class, 356
    - accumulate, get methods, 356
  - LongAdder class, 356–357
    - add, increment, sum methods, 356
  - LongConsumer, LongXxxOperator, LongPredicate,
    - LongSupplier, LongToXxxFunction
  - interfaces, 122
  - LongFunction interface, 122, 220
  - longs method (Random), 280
  - LongStream class, 279–280
  - LongSummaryStatistics class, 272, 280
  - long-term persistence, 324
  - Lookup class, 482
  - lookup method (MethodHandles), 482
  - loops, 38–39
    - exiting, 39–41
    - infinite, 39
- ## M
- m, M formatting symbols (date/time), 416
  - main method, 2, 6
    - decomposing, 52–54
    - string array parameter of, 49
  - ManagedExecutorService class, 335

- Map interface, 238
  - clear method, 246
  - compute, computeIfXxx methods, 245
  - containsXxx methods, 246
  - entrySet method, 246
  - forEach method, 246
  - get, getOrDefault methods, 243, 245
  - isEmpty method, 246
  - keySet method, 246, 252
  - merge method, 244–245
  - of method, 246, 252
  - ofEntries method, 252
  - put method, 243, 245
  - putAll, putIfAbsent methods, 245
  - remove, replace methods, 245
  - replaceAll method, 246
  - size method, 246
  - values method, 246, 252
- map method
  - of Optional, 268
  - of Stream, 263
- mapping method (Collectors), 276
- maps, 243–246
  - concurrent, 246, 274
  - empty, 246
  - in Nashorn, 458
  - iterating over, 244
  - of stream elements, 273–274, 282
  - order of elements in, 246
  - views of, 244
    - unmodifiable , 254
- mapToInt method (Stream), 278
- mapToXxx methods (XxxStream), 280
- marker interfaces, 153
- Matcher class, 315–317
  - quoteReplacement method, 318
  - replaceAll method, 317–318
  - replaceFirst method, 318
- matcher, matches methods (Pattern), 314
- MatchResult interface, 315–318
- Math class
  - E constant, 20
  - floorMod method, 19
  - max, min methods, 19
  - PI constant, 20, 75
  - pow method, 19, 77
  - round method, 21
  - sqrt method, 19
  - xxxExact methods, 20, 22
- max method
  - of Stream, 266
  - of XxxStream, 280
- MAX\_VALUE constant (integer classes), 11
- maxBy method
  - of BinaryOperator, 121
  - of Collectors, 276
- medium indicator, in string templates, 433
- memory
  - allocating, 346
  - caching, 342
  - concurrent access to, 343
- memory-mapped files, 297
- merge method
  - of ConcurrentHashMap, 351
  - of Map, 244–245
- Message class, 153–154
- MessageFormat class, 433–435
- meta-annotations, 384–390
- META-INF/MANIFEST.MF file, 484–485
- META-INF/services directory, 490
- Method interface, 168–169
  - getModifiers, getName methods, 168
  - invoke method, 171–172
- method calls, 6
  - receiver of, 67
- method expressions, 117, 145
- method references, 117–118, 221
  - annotating, 382
- MethodHandles.lookup method, 482
- methods, 2
  - abstract, 115, 141–142
  - accessor, 62
  - annotating, 224, 380
  - atomic, 351
  - body of, 66
  - chaining calls of, 62
  - clashes of, 224–225
  - compatible, 151
  - declarations of, 65
  - default, 106–108
  - deprecated, 93
  - documentation comments for, 90, 92

- methods (*cont.*)
    - enumerating, 168–169
    - factory, 70, 78
    - final, 141, 347
    - header of, 65
    - inlining, 141
    - instance, 66–67
    - invoking, 171
    - modifying functions, 128
    - mutator, 62, 254, 347
    - naming, 14–15
    - native, 76
    - overloading, 71, 118
    - overriding, 106, 137–139, 141, 185–186, 387
    - parameters of, 169
      - null checks for, 193
    - passing arrays into, 53
    - private, 109
    - proxied, 176
    - public, 101–102, 168
    - restricted to subclasses, 142–143
    - return value of, 2, 66
    - returning functions, 127
    - static, 53, 77–78, 85, 105–106
    - storing in variables, 6
    - symmetric, 150
    - synchronized, 359–361
    - utility, 83
    - variable number of arguments of, 53
  - Microsoft Notepad, 291
  - Microsoft Windows
    - batch files, 461
    - path separator, 81, 248
    - registry, 439
  - min method
    - of Math, 19
    - of Stream, 266
    - of XxxStream, 280
  - MIN\_VALUE constant (integer classes), 11
  - minBy method
    - of BinaryOperator, 121
    - of Collectors, 276
  - minus, minusXxx methods
    - of Instant, Duration, 404
    - of LocalDate, 406–407
    - of LocalDateTime, 409
    - of ZonedDateTime, 411
  - Modifier interface
    - isXxx methods, 162, 168
    - toString method, 162
  - modifiers, checking, 168
  - module keyword, 473
  - module path, 473, 483–485
  - Module.getResourceAsStream method, 481
  - module-info.class file, 473, 482
  - module-info.java file, 473
  - modules, 469–493
    - aggregator, 488
    - and versioning, 471, 474, 483
    - annotating, 474
    - automatic, 484–485
    - bundling up the minimal set of, 492
    - declaration of, 472–473
    - deprecated, 487
    - documentation comments for, 91, 94
    - illegal access to, 486
    - inspecting files in, 493
    - loading into JShell, 484
    - naming, 472, 484
    - open, 481
    - reflective access for, 169–170
    - required, 474–476, 487–489
    - tools for, 491–493
    - transitive, 487–489
    - unnamed, 485
  - monads, 264
  - monitors (classes), 360
  - Month enumeration, 405–406, 412
    - getDisplayName method, 415, 430
  - MonthDay class, 407
  - move method (Files), 301–302
  - multiplication, 18
  - multipliedBy method (Duration), 404
  - mutators, 62
    - and unmodifiable views, 254
- ## N
- n
- conversion character, 35
  - formatting symbol (date/time), 416

- `\n` (line feed)
  - for character literals, 14
  - in property files, 247–248
  - in regular expressions, 311–313, 318
- name method (Enum), 156
- NaN (not a number), 13
- Nashorn engine, 448, 452–461
  - anonymous subclasses in, 459
  - arrays in, 457–458
  - catching Java exceptions in, 461
  - class objects in, 455
  - extending Java classes in, 459–460
  - getters/setters in, 454
  - implementing Java interfaces in, 459–460
  - instance variables in, 460
  - lists and maps in, 458
  - methods in, 453–454
  - no standard input source in, 450
  - numbers in, 456
  - running from command line, 452
  - shell scripting in, 461–464
  - strings in, 455
  - superclasses in, 460
- native methods, 76
- naturalOrder method (Comparator), 129
- navigable maps/sets, 254
- NavigableMap interface, 354
- NavigableSet interface, 238, 242, 253
  - methods of, 243
- nCopies method (Collections), 237, 239
- negate method (Predicate, BiPredicate), 121
- negated method (Duration), 404
- negateExact method (Math), 20
- NEGATIVE\_INFINITY value (Double), 13
- negative values, 10
- nested classes, 85–90
  - annotating, 382
  - enumerating, 168–169
  - inner, 87–89
  - public, 86
  - static, 85–86
- new operator, 6, 14, 17, 70
  - as constructor reference, 118
  - for anonymous classes, 130
  - for arrays, 43–44, 50
    - in JavaScript, 455–459
  - newBufferedReader method (Files), 294, 448
  - newBufferedWriter method (Files), 294, 302
  - newBuilder, newHttpClient methods (HttpClient), 308, 335
  - newFileSystem method (FileSystems), 305
  - newInputStream method (Files), 288, 302, 320
  - newInstance method
    - of Array, 174
    - of Class, 171, 227
    - of Constructor, 171–172
  - newKeySet method (ConcurrentHashMap), 354
  - newline. *See* line feed
  - newOutputStream method (Files), 288, 302, 320
  - newProxyInstance method (Proxy), 175
  - newXxxThreadPool methods (Executors), 331
  - next method (Iterator), 240
  - next, nextOrSame methods (TemporalAdjusters), 408
  - next, nextXxx methods (Scanner), 32, 293
  - nextInt method (Random), 6, 38
  - nextXxxBit methods (BitSet), 249
- nominal typing, 120
- noneMatch method (Stream), 267
- noneOf method (EnumSet), 250
- noninterference, of stream operations, 283
- @NonNull annotation, 381
- normalize method (Path), 299
- Normalizer class, 433
- NoSuchElementException, 269, 353
- notify, notifyAll methods (Object), 146, 361–362
- NotSerializableException, 321
- now method
  - of Instant, 403
  - of LocalDate, 70, 77, 405–406
  - of LocalTime, 409
  - of ZonedDateTime, 411
- null value, 26, 64
  - as default value, 71, 74
  - checking parameters for, 193
  - comparing against, 149
  - converting to strings, 147



- NullPointerException, 26, 45, 64, 72, 184, 193, 244
  - vs. Optional, 266
- nullsFirst, nullsLast methods (Comparator), 129
- Number class, 428
- number indicator, in string templates, 433
- Number type (JavaScript), 456
- NumberFormat class
  - getXxxInstance methods, 78, 427
  - not threadsafe, 365–366
  - parse method, 428
  - setCurrency method, 429
- NumberFormatException, 184
- numbers
  - big, 23–24
  - comparing, 110
  - converting to strings, 27
  - default value of, 71, 74
  - even or odd, 18
  - formatting, 34, 422, 427, 433
  - from grouped elements, 275
  - in regular expressions, 312
  - non-negative, 194, 248
  - printing, 34
  - random, 6, 38, 262, 264, 280
  - reading/writing, 293, 296–297
  - rounding, 13, 21
  - type conversions of, 20–22
  - unsigned, 12, 20
  - with fractional parts, 12–13
- 0**
- o conversion character, 34
- Object class, 145–154
  - clone method, 143, 146, 151–154, 171
  - equals method, 146, 148–150
  - finalize method, 146
  - getClass method, 141, 146, 149, 159, 221, 227
  - hashCode method, 146, 148, 150–151
  - notify, notifyAll methods, 146, 361–362
  - toString method, 146–147
  - wait method, 146, 361–362
- object references, 63–64
  - and serialization, 320
  - attempting to change, 69
  - comparing, 148
  - default value of, 71, 74
  - null, 64
  - passed by value, 69
- ObjectInputStream class, 320–321
  - defaultReadObject method, 322
  - readFields method, 325
  - readObject method, 320–323, 325
- object-oriented programming, 59–97
  - encapsulation, 469–470
- ObjectOutputStream class, 320
  - defaultWriteObject method, 322
  - writeObject method, 320–322
- object-relational mappers, 479
- objects, 2, 60–64
  - calling methods on, 6
  - casting, 103–104
  - cloning, 151–154
  - comparing, 47, 148–150
  - constructing, 6, 69–74, 171–172
    - in JavaScript, 454–455
  - converting:
    - to strings, 146–147
    - to XML, 480
  - deep/shallow copies of, 152–154
  - deserialized, 322–324
  - externalizable, 322
  - immutable, 62
  - initializing variables with, 14
  - inspecting, 169–171
  - invoking static methods on, 77
  - mutable, 73
  - serializable, 319–321
  - sorting, 109–111
  - state of, 60
- Objects class
  - equals method, 149
  - hash method, 151
  - isNull method, 117
  - requireNonNull method, 193
- ObjXxxConsumer interfaces, 122
- octal numbers, 11
  - formatting for output, 34
- octonions, 31
- odd numbers, 18

- of method
  - of EnumSet, 250
  - of IntStream, 279
  - of List, 46, 48, 238, 252
  - of LocalDate, 61, 70, 405–406
  - of LocalTime, 409
  - of Map, 246, 252
  - of Optional, 269
  - of ProcessHandle, 370
  - of Set, 252
  - of Stream, 261–262
  - of ZonedDateTime, 410–411
- ofDateAdjuster method (TemporalAdjusters), 408
- ofDays method (Period), 413
- ofEntries method (Map), 252
- offer method (BlockingQueue), 353
- offsetByCodePoints method (String), 31
- OffsetDateTime class, 413
- ofInstant method
  - of LocalDate, 406
  - of LocalTime, 409
  - of ZonedDateTime, 411
- ofLocalizedXxx methods (DateTimeFormatter), 413, 430
- ofNullable method
  - of Optional, 269
  - of Stream, 271
- ofPattern method (DateTimeFormatter), 415
- ofXxx methods (Duration), 403, 405, 413
- onExit method
  - of Process, 369
  - of ProcessHandle, 370
- open keyword, 481
- open method (FileChannel), 297
- openConnection method (URL), 306
- opens keyword, 481
  - qualified, 489
- openStream method (URL), 288
- Operation interface, 157
- operations
  - associative, 278
  - atomic, 346, 351, 354–357, 360
  - bulk, 352
  - lazy, 261, 266, 283, 317
  - parallel, 348–350
  - performed optimistically, 355
  - stateless, 281
  - threadsafe, 350–354
- operators, 17–24
  - precedence of, 17
- option files, 487
- Optional class, 266–270
  - creating values of, 269
  - empty method, 269
  - flatMap method, 269–271
  - for empty streams, 277–278
  - for processes, 370
  - get method, 269–271
  - ifPresent, ifPresentOrElse methods, 268
  - isPresent method, 269–271
  - map method, 268
  - of, ofNullable methods, 269
  - orElse method, 266–268
  - orElseXxx methods, 267–268
  - stream method, 270–271
- OptionalXxx classes, 280
- or method
  - of BitSet, 249
  - of Predicate, BiPredicate, 121
- order method (ByteBuffer), 297
- ordinal method (Enum), 156
- org global object (JavaScript), 454
- org.omg.corba package, 470
- os.arch, os.name, os.version system properties, 248
- OSGi (Open Service Gateway Initiative), 471
- \$OUT, in shell scripts, 462
- output
  - formatted, 33–36
  - redirecting, 449
  - setting locales for, 427
  - writing, 294–295
- output streams, 288
  - closing, 290
  - obtaining, 288
  - writing to, 290
- OutputStream class, 320
  - write method, 290
- OutputStreamWriter class, 294
- @Override annotation, 138, 386–387

- overriding, 137–139
  - for logging/debugging, 141
- overview.html file, 94
- P**
- \p, \P, in regular expressions, 312
- package statement, 79
- package declarations, 79–80
- Package object (JavaScript), 454
- package-info.java file, 94, 380
- packages, 3, 78–85
  - accessing, 83, 143, 470, 477–478, 481, 484
  - adding classes to, 83
  - annotating, 380–381
  - default, 79
  - documentation comments for, 91, 94
  - exporting, 476–479, 481
  - naming, 79
  - not nesting, 79
  - split, 483
- parallel method (*xxxStream*), 280
- parallel streams, 348–349
- parallelStream method (*Collection*), 237, 260–261, 280, 348
- parallel*xxx* methods (*Arrays*), 49, 349
- @param tag (javadoc), 92
- Parameter class, 172
- parameter variables, 68
  - annotating, 380
  - scope of, 42
- ParameterizedType interface, 228
- parentLogger method (*Driver*), 488
- parse method
  - of *DateTimeFormatter*, 415
  - of *Localxxx*, *ZonedDateTime*, 430
  - of *NumberFormat*, 428
- Parse.quote method, 311
- parseDouble method (*Double*), 27
- ParseException, 428
- parseInt method (*Integer*), 27, 184
- partitioning, 347
- partitioningBy method (*Collectors*), 275, 277
- Pascal triangle, 51
- passwords, 33
- Path interface, 106, 298–300
  - get method, 298–300
  - get*xxx* methods, 300
  - normalize, relativize methods, 299
  - resolve, resolveSibling methods, 299
  - subpath method, 300
  - toAbsolutePath, toFile methods, 299
- path separators, 298
- path.separator system property, 248
- paths, 298
  - absolute vs. relative, 298–299
  - filtering, 303
  - resolving, 299
  - taking apart/combining, 300
- Paths class, 106
- Pattern class
  - compile method, 315, 318
  - flags, 318–319
  - matcher, matches methods, 314
  - split method, 317
  - splitAsStream method, 263, 317
- pattern variables, 202
- PECS (producer extends, consumer super), 214
- peek method
  - of *BlockingQueue*, 353
  - of *Stream*, 266
- percent indicator, in string templates, 433
- performance
  - and atomic operations, 355
  - and combined operators, 19
  - and memory caching, 343
- Period class, 405
  - ofDays method, 413
- @Persistent annotation, 389
- PI constant (*Math*), 20, 75
- placeholders, 433–435
- platform class loader, 163
- platform encoding, 292, 438
- plugins, loading, 164
- plus, plus*xxx* methods
  - of *Instant*, *Duration*, 404
  - of *LocalDate*, 61–62, 64, 406–407
  - of *LocalTime*, 409
  - of *ZonedDateTime*, 411–412
- Point class, 146–147

- Point2D class (JavaFX), 321
- poll method (BlockingQueue), 353
- pollXxx methods (NavigableSet), 243
- pop method (ArrayDeque), 250
- portability, 19
- POSITIVE\_INFINITY value (Double), 13
- POST requests, 308
- @PostConstruct annotation, 386, 388
- pow method (Math), 19, 77
- predefined character classes, 310, 312, 314
- @PreDestroy annotation, 386, 388
- predicate functions, 275
- Predicate interface, 116, 121
  - and, or, negate methods, 121
  - isEqual method, 121–122
  - test method, 121, 213
- Preferences class, 439–441
- previous method (ListIterator), 241
- previous, previousOrSame methods (TemporalAdjusters), 408
- previousXxxBit methods (BitSet), 249
- preVisitDirectory, postVisitDirectory methods (FileVisitor), 304
- primitive types, 10–14
  - and type parameters, 220
  - attempting to update parameters of, 68
  - comparing, 149
  - converting to strings, 147
  - functions interfaces for, 122
  - passed by value, 69
  - streams of, 278–280
  - wrapper classes for, 46–47
- printStackTrace method (Throwable), 192
- PrintStream class, 6, 147, 295
  - print method, 6, 33, 195, 294–295
  - printf method, 34–35, 53, 294–295
  - println method, 6, 32–33, 49, 117, 294–295
- PrintWriter class, 294
  - close method, 187–188
  - printf method, 427
- priority queues, 251
- private modifier, 2, 83
  - for enum constructors, 157
- Process class, 366–370
  - destroy, destroyForcibly methods, 369
  - exitValue method, 369
  - getErrorStream method, 368
  - getXxxStream methods, 367
  - isAlive method, 369
  - onExit method, 369
  - supportsNormalTermination method, 369
  - toHandle method, 370
  - waitFor method, 369
- ProcessBuilder class, 366–370
  - directory method, 367
  - redirectXxx methods, 368
  - start method, 368
- processes, 366–370
  - building, 367–368
  - getting info about, 370
  - killing, 369
  - running, 368–369
- ProcessHandle interface, 370
- processing pipeline, 337
- Processor interface, 394
- Programmer's Day, 405
- programming languages
  - dynamically typed, 456
  - functional, 99
  - object-oriented, 2
  - scripting, 448
- programs
  - compiling, 3
  - configuration options for, 247
  - localizing, 421–441
  - packaging, 493
  - responsive, 340
  - running, 3
  - testing, 193
- promises (in concurrent libraries), 336
- properties, 172–173
  - loading from file, 247
  - naming, 173
  - read-only/write-only, 173
  - testing for, 213
- Properties class, 247–248
- .properties extension, 435

- property files
    - encoding, 247, 437
    - generating, 398
    - localizing, 435–437
  - protected modifier, 142–143
  - Provider.get, Provider.type methods, 167
  - provides keyword, 490
  - Proxy class, 175–176
    - newProxyInstance method, 175
  - public modifier, 2, 83
    - and method overriding, 139
    - for interface methods, 101–102
  - push method (ArrayDeque), 250
  - put method
    - of BlockingQueue, 353
    - of FileChannel, 297
    - of Map, 243, 245
    - of Preferences, 440
  - putAll method (Map), 245
  - putIfAbsent method
    - of ConcurrentHashMap, 351
    - of Map, 245
  - putXxx methods (FileChannel), 297
  - putXxx methods (Preferences), 440
- Q**
- \Q, in regular expressions, 311
  - qualified exports, 489
  - Queue interface, 238, 250
    - synchronizing methods in, 360
    - using ArrayDeque with, 250
  - quote method (Parse), 311
  - quoteReplacement method (Matcher), 318
- R**
- \r (carriage return)
    - for character literals, 14
    - in property files, 248
  - \r, \R, in regular expressions, 311, 314
  - race conditions, 281, 344–346
  - Random class, 6
    - ints, longs, doubles methods, 280
    - nextInt method, 6, 38
  - random numbers, 6, 38, 459
    - streams of, 262, 264, 280
  - RandomAccess interface, 237
  - RandomAccessFile class, 296–297
    - getFilePointer method, 297
    - length method, 297
    - seek method, 296–297
  - RandomNumbers class, 77
  - range method (EnumSet), 250
  - range, rangeClosed methods (XxxStream), 279
  - ranges, 253
    - converting to streams, 281
  - raw types, 217, 220–221
  - read method
    - of Files, 289
    - of InputStream, 289
    - of InputStreamReader, 293
  - readAllXxx methods (Files), 289, 293
  - Reader class, 293
  - readers, 288
  - readExternal method (Externalizable), 322
  - readFields method (ObjectInputStream), 325
  - readLine function (shell scripts), 464
  - readLine method
    - of BufferedReader, 294
    - of Console, 33
  - readNBytes method (Files), 289
  - readObject method (ObjectInputStream), 320–323, 325
  - readPassword method (Console), 33
  - readResolve method (Serializable), 322–323
  - readXxx methods (DataInput), 296–297, 322
  - receiver parameters, 67, 383
  - redirection syntax, 33
  - redirectXxx methods (ProcessBuilder), 368
  - reduce method (Stream), 277–279
  - reduceXxx methods (ConcurrentHashMap), 352
  - reducing method (Collectors), 277
  - reductions, 266, 277–279
  - ReentrantLock class, 357–358
    - lock, unlock methods, 358
  - reflection, 168–176
    - and generic types, 222, 226–229
    - and module system, 169–170, 479, 486
    - processing annotations with, 391–393
  - ReflectiveOperationException, 160

- regular expressions, 310–319
  - finding matches of, 314–316
  - flags for, 318–319
  - groups in, 316–317
  - replacing matches with, 317
  - splitting input with, 317
- relational operators, 22
- relativize method (Path), 299
- remainderUnsigned method (Integer, Long), 20
- remove method
  - of ArrayDeque, 250
  - of ArrayList, 46
  - of BlockingQueue, 353
  - of Collection, 236
  - of Iterator, 241
  - of List, 238
  - of Map, 245
  - of Preferences, 440
- removeIf method
  - of ArrayList, 116
  - of Iterator, 241
- removeNode method (Preferences), 440
- removeXxx methods (Collection), 236
- @Repeatable annotation, 387, 389
- REPL (“read-eval-print” loop), 452–453
- replace method
  - of Map, 245
  - of String, 28
- replaceAll method
  - of Collections, 239
  - of List, 238
  - of Map, 246
  - of Matcher, 317–318
  - of String, 317
- replaceFirst method (Matcher), 318
- requireNonNull method (Objects), 193
- requires keyword, 473, 476–479, 484, 487–489
- resolve, resolveSibling methods (Path), 299
- @Resource annotation, 386, 388
- resource bundles, 435–438
- resource injections, 388
- ResourceBundle class, 199
  - extending, 437
  - getBundle method, 436–438
  - getObject method, 437
  - getString method, 436
- resources, 159–168
  - loading, 162, 481
  - managing, 187
- @Resources annotation, 387
- resume method (Thread, deprecated), 363
- retainAll method (Collection), 236
- @Retention annotation, 384, 387
- return statement, 37, 53, 66
  - in lambda expressions, 114
  - not in finally, 189
- @return tag (javadoc), 92
- return types, covariant, 138, 219
- return values
  - as arrays, 53
  - missing, 266
  - providing type of, 53
- reverse method (Collections), 49, 240
- reverse domain name convention, 79, 472
- reversed method (Comparator), 128
- reverseOrder method (Comparator), 129
- RFC 822, RFC 1123 formats, 414
- rlwrap program, 453
- rotate method (Collections), 240
- round method (Math), 21
- RoundEnvironment interface, 395
- roundoff errors, 13
- RowSetProvider class, 486
- rt.jar file, 493
- runAfterXxx methods (CompletableFuture), 339–340
- Runnable interface, 112, 121, 331, 333
  - executing on the UI thread, 341
  - run method, 121, 330, 363–364
  - using class literals with, 160
- runtime
  - raw types at, 220–221
  - safety checks at, 218
- Runtime class
  - availableProcessors method, 331
  - exec method, 367
- runtime image file, 493
- RuntimeException, 183

**S**

- s formatting symbol (date/time), 416
- s, S conversion characters, 34
- \s, \S, in regular expressions, 312
- safety checks, as runtime, 218
- @SafeVarargs annotation, 224, 386, 388
- Scala programming language
  - REPL in, 453
  - type parameters in, 215
- Scanner class, 32
  - findAll method, 316
  - hasNext, hasNextXXX, next, nextXXX methods, 32, 293
  - tokens method, 263, 294
  - useLocale method, 427
- scheduling applications
  - and time zones, 405, 410
  - computing dates for, 407–408
- ScriptContext interface, 449
- ScriptEngine interface
  - createBindings method, 449
  - eval method, 449–451
- ScriptEngineFactory interface, 451
- ScriptEngineManager class
  - getEngineXXX methods, 448
  - visibility of bindings in, 449
- scripting engines, 448–449
  - compiling code in, 452
  - implementing Java interfaces in, 451
- scripting languages, 448
  - invoking functions in, 450
- searchXXX methods (ConcurrentHashMap), 352
- security, 83
- SecurityException, 170
- @see tag (javadoc), 93–94
- seek method (RandomAccessFile), 296
- sequences, producing, 262
- serial numbers, 321
- Serializable interface, 319–321
  - readResolve, writeReplace methods, 322–323
- serialization, 319–325
- serialVersionUID instance variable, 324
- server-side software, 319
- ServiceLoader class, 166–168, 490
  - iterator, load method, 167
  - ServiceLoader.Provider interface, 167
- services
  - configurable, 166
  - loading, 166–168, 490–491
- ServletException class, 191
- Set interface, 238, 354
  - of method, 252
  - working with EnumSet, 250
- set method
  - of Array, 174
  - of ArrayList, 46
  - of BitSet, 249
  - of Field, 172
  - of List, 238
  - of ListIterator, 241
- setAccessible method (AccessibleObject), 170, 172
- setContextClassLoader method (Thread), 165
- setCurrency method (NumberFormat), 429
- setDaemon method (Thread), 366
- setDecomposition method (Collator), 432
- setDefault method (Locale), 426
- setDefaultUncaughtExceptionHandler method (Thread), 192
- setDoOutput method (URLConnection), 306
- setFilter methods (Handler, Logger), 203
- setFormatter method (Handler), 203
- setLevel method (Logger), 195, 197, 200
- setOut method (System), 76
- setReader method (ScriptContext), 449
- setRequestProperty method (URLConnection), 306
- sets, 242–243
  - immutable, 347
  - threadsafe, 354
  - unmodifiable views of, 254
- setStrength method (Collator), 432
- setUncaughtExceptionHandler method (Thread), 363
- setUseParentHandlers method (Logger), 200
- setWriter method (ScriptContext), 449
- setXXX methods (Array), 174
- setXXX methods (Field), 170, 172
- setXXXAssertionStatus methods (ClassLoader), 195

- shallow copies, 152–154
- shared variables, 343–347
  - atomic mutations of, 354–357
  - locking, 357–358
- shebang, 464
- shell scripts, 461–464
  - command-line arguments in, 463
  - environment variables in, 463
  - executing, 462
  - generating, 398
  - string interpolation in, 462–463
- shell, redirection syntax of, 33
- shift operators, 23
- Shift\_JIS encoding, 292
- short circuit evaluation, 22
- Short class, 46
  - MIN\_VALUE, MAX\_VALUE constants, 11
- short indicator, in string templates, 433
- short type, 10–12
  - streams of, 279
  - type conversions of, 21
- short-term persistence, 324
- shuffle method (Collections), 49, 240
- SimpleFileVisitor class, 304
- SimpleJavaFileObject class, 446
- @since tag (javadoc), 92
- singletons, 323
- size method
  - of ArrayList, 46
  - of Collection, 237
  - of Map, 246
- skip method (Stream), 264
- sleep method (Thread), 363, 365
- SLF4J (Simple Logging Facade for Java), 196, 472
- SOAP protocol, 471
- SocketHandler class, 200
- sort method
  - of Arrays, 49, 111–112, 116–117
  - of Collections, 49, 215, 240
  - of List, 238
- sorted maps, 253–254
- sorted method (Stream), 265
- sorted sets, 238, 253
  - traversing, 242
  - unmodifiable views of, 254
- sorted streams, 281
- SortedMap interface, 253
- SortedSet interface, 238, 242
  - first, last methods, 243
  - headSet, subSet, tailSet methods, 243, 253
- sorting
  - array lists, 49
  - arrays, 49, 109–111
  - chaining comparators for, 128
  - changing order of, 127
  - streams, 265
  - strings, 26–27, 117, 431–432
- source code, generating, 395–398
- source files
  - documentation comments for, 94
  - encoding of, 438
  - placing, in a file system, 80
  - reading from memory, 445
- space flag (for output), 35
- spaces
  - in regular expressions, 312
  - removing, 28
- split method
  - of Pattern, 317
  - of String, 25, 317
- splitAsStream method (Pattern), 263, 317
- spliterator method (Collection), 237
- sqrt method (Math), 19
- square root, computing, 270
- Stack class, 250
- stack trace, 192–193
- StackWalker class, 192
- standard output, 3
- StandardCharsets class, 292
- StandardJavaFileManager interface, 445–447
- start method
  - of Matcher, MatchResult, 315–316
  - of ProcessBuilder, 368
  - of Thread, 363
- startsWith method (String), 28
- stateless operations, 281
- statements, combining, 43
- static constants, 75–76
- static imports, 85
- static initialization, 164



- static methods, 53, 77–78
  - accessing static variables from, 77
  - importing, 85
  - in interfaces, 105–106
- static modifier, 2, 16, 53, 74–78, 158
  - for modules, 488
- static nested classes, 85–86
- static variables, 74–75
  - accessing from static methods, 77
  - importing, 85
  - visibility of, 343
- stop, suspend methods (Thread, deprecated), 363
- Stream interface
  - collect method, 271–272, 279
  - concat method, 265
  - count method, 261, 266
  - distinct method, 265, 282
  - dropWhile method, 265
  - empty method, 262
  - filter method, 261–263, 267
  - findAny method, 267
  - findFirst method, 168, 267
  - flatMap method, 264
  - forEach, forEachOrdered methods, 271
  - generate method, 262, 279
  - iterate method, 262, 266, 279, 349
  - iterator method, 271
  - limit method, 264, 282
  - map method, 263
  - mapToInt method, 278
  - max, min methods, 266
  - of method, 261–262
  - ofNullable method, 271
  - peek method, 266
  - reduce method, 277–279
  - skip method, 264
  - sorted method, 265
  - takeWhile method, 265
  - toArray method, 118, 271
  - unordered method, 282
  - xxxMatch methods, 267
- stream method
  - of Arrays, 262, 279
  - of BitSet, 249
  - of Collection, 237, 260–261
  - of Optional, 270–271
- streams, 259–283
  - collecting elements of, 271–274
  - computing values from, 277–279
  - converting to/from arrays, 262, 271, 281, 350
  - creating, 261–263
  - debugging, 266
  - empty, 262, 266, 277–278
  - filtering, 270
  - finite, 262
  - flattening, 264, 270
  - infinite, 261–262, 264, 266
  - intermediate operations for, 261
  - locating services with, 167
  - noninterference of, 283
  - of primitive type values, 278–280
  - of random numbers, 280
  - ordered, 281
  - parallel, 260, 267, 271, 274–275, 278, 280–283, 348–349
  - processed lazily, 261, 266, 283
  - reductions of, 266
  - removing duplicates from, 265
  - sorting, 265
  - splitting/combining, 264–265
  - summarizing, 272, 280
  - terminal operation for, 261, 266
  - transformations of, 263–264, 280
  - vs. collections, 261
- strictfp modifier, 19
- StrictMath class, 20
- String class, 6, 28
  - charAt method, 31
  - codePoints, codePointXxx methods, 31–32
  - compareTo method, 26–27, 109, 431
  - compareToIgnoreCase method, 117
  - contains method, 28
  - endsWith method, 28
  - equals method, 25–26
  - equalsIgnoreCase method, 26
  - final, 141
  - format method, 427
  - hash codes, 150
  - immutability of, 28, 347
  - indexOf, lastIndexOf methods, 28

- join method, 25
- length method, 6, 31
- offsetByCodePoints method, 31
- replace method, 28
- replaceAll method, 317
- split method, 25, 317
- startsWith method, 28
- substring method, 25
- toLowerCase method, 28, 263, 427
- toUpperCase method, 28, 427
- trim method, 28, 428
- string interpolation, in shell scripts, 462–463
- StringBuilder class, 25
- strings, 6, 24–32
  - comparing, 25–27
  - concatenating, 24–25, 147
  - converting:
    - from byte arrays, 292
    - from objects, 146–147
    - to code points, 263
    - to numbers, 27
  - empty, 26–27, 147
  - formatting for output, 34
  - internal representation of, 32
  - normalized, 432
  - sorting, 26–27, 117, 431–432
  - splitting, 25, 263
  - templates for, 433–435
  - transforming to lower/uppercase, 263, 427
- StringSource class, 445
- StringWriter class, 295
- strong element (HTML), in
  - documentation comments, 91
- subclasses, 136–137
  - anonymous, 143–144, 157
  - calling toString method in, 147
  - constructors for, 139
  - initializing instance variables in, 139
  - methods in, 137
  - preventing, 141
  - public, 139
  - superclass assignments in, 139
- subList method (List), 238, 253
- subMap method (SortedMap), 253
- subpath method (Path), 300
- subSet method
  - of NavigableSet, 243
  - of SortedSet, 243, 253
- substring method (String), 25
- subtractExact method (Math), 20
- subtraction, 18
  - accurate, 24
  - not associative, 278
- subtypes, 103
  - wildcards for, 212
- sum method
  - of LongAdder, 356
  - of XxxStream, 280
- summarizingXxx methods (Collectors), 272, 276
- summaryStatistics method (XxxStream), 280
- summingXxx methods (Collectors), 276
- super keyword, 108, 138–139, 145, 213–215
- superclasses, 136–137
  - annotating, 381
  - calling equals method, 149
  - default methods of, 144–145
  - in JavaScript, 460
  - methods of, 137–139
  - public, 139
- supertypes, 103–105
  - wildcards for, 213–214
- Supplier interface, 121, 336
- supplyAsync method (CompletableFuture), 335–337
- supportsNormalTermination method
  - of Process, 369
  - of ProcessHandle, 370
- @SuppressWarnings annotation, 37, 220, 386, 388–389, 474
- swap method (Collections), 240
- Swing GUI toolkit, 113, 341
- SwingConstants interface, 105
- SwingWorker class (Swing), 341
- switch statement, 37
  - using enumerations in, 158
- symbolic links, 302–303
- synchronized keyword, 358–361
- synchronized views, 254

- synchronizedXxx methods (Collections), 240
  - System class
    - getProperties method, 248
    - getProperty method, 163
    - setOut method, 76
  - system class loader, 163, 165
  - system classes, enabling/disabling
    - assertions for, 195
  - system properties, 248
  - System.err constant, 192, 200, 366, 444
  - System.in constant, 32
  - System.out constant, 6, 16, 32–35, 49, 53, 76, 117, 195, 294, 444
  - systemXxx methods (Preferences), 439
- T**
- T, in dates, 414
  - t, T conversion characters, 35
  - \t
    - in regular expressions, 311
    - tab, for character literals, 14
  - %t pattern variable, 202
  - tab completion, 9
  - tagging interfaces, 153
  - tailMap method (SortedMap), 253
  - tailSet method
    - of NavigableSet, 243
    - of SortedSet, 243, 253
  - take method (BlockingQueue), 353
  - takeWhile method (Stream), 265
  - tar program, 80–81
  - @Target annotation, 384–385, 387
  - Task class (JavaFX), 341
  - tasks, 330–335
    - cancelling, 333–334
    - combining results from, 333–335
    - computationally intensive, 331
    - coordinating work between, 352–353
    - defining, 112
    - executing, 112, 331
    - groups of, 366
    - long-running, 340–341
    - running, 330–332
    - short-lived, 331
    - submitting, 333
    - vs. threads, 331
    - working simultaneously, 336
  - Temporal interface, 408
  - TemporalAdjuster.ofDateAdjuster method, 408
  - TemporalAdjusters class, 408
  - terminal window, 4
  - test method
    - of BiPredicate, 121
    - of Predicate, 121, 213
    - of XxxPredicate, 122
  - @Test annotation, 378–379, 384
  - TextStyle enumeration, 431
  - thenAccept method (CompletableFuture), 335, 339
  - thenAcceptBoth, thenCombine methods (CompletableFuture), 339–340
  - thenApply, thenApplyAsync methods (CompletableFuture), 337–339
  - thenComparing method (Comparator), 128–129
  - thenCompose method (CompletableFuture), 338–339
  - thenRun method (CompletableFuture), 339
  - third-party libraries, 484–485
  - this reference, 67–68
    - annotating, 383
    - capturing, 118
    - in constructors, 71, 348
    - in lambda expressions, 124
  - Thread class
    - get/setContextClassLoader methods, 165
    - interrupted, isInterrupted methods, 364
    - join method, 363
    - properties, 366
    - resume, stop, suspend methods (deprecated), 363
    - setDaemon method, 366
    - setDefaultUncaughtExceptionHandler method, 192
    - setUncaughtExceptionHandler method, 363
    - sleep method, 363, 365
    - start method, 363
  - ThreadLocal class, 365–366
    - get, withInitial methods, 365
  - threads, 331, 362–366
    - and visibility, 342–344, 360
    - atomic mutations in, 354–357

- creating, 112
  - daemon, 366
  - groups of, 366
  - interrupting, 333, 364–365
  - local variables in, 365–366
  - locking, 357–358
  - names of, 366
  - priorities of, 366
  - race conditions in, 281, 344–346
  - running tasks in, 112
  - starting, 363
  - states of, 366
  - temporarily inactive, 364
  - terminating, 331–332
  - uncaught exception handlers of, 366
  - vs. tasks, 331
  - waiting on conditions, 360
  - worker, 340–341
- throw statement, 183
- Throwable class, 183
- getStackTrace, printStackTrace methods, 192
  - in assertions, 194
  - initCause method, 191
  - no generic subtypes for, 225
- throwing method (Logger), 198
- throws keyword, 185
- type variables in, 225–226
- @throws tag (javadoc), 92, 186
- time
- current, 402
  - formatting, 413–416, 429–431
  - measuring, 403
  - parsing, 415
- Time class, 416–417
- time indicator, in string templates, 433
- time zones, 410–413
- TimeoutException, 333
- Timestamp class, 150, 416–417
- timestamps, 413
- using instants as, 403
- TimeZone class, 417
- ™ (trademark symbol), 432–433
- toAbsolutePath method (Path), 299
- toArray method
- of Collection, 237
  - of Stream, 118, 271
  - of XxxStream, 280
- toArray method
- of BitSet, 249
  - of ByteArrayOutputStream, 288–289
- toCollection method (Collectors), 272
- toConcurrentMap method (Collectors), 274
- toEpochSecond method
- of LocalDate, 406
  - of LocalTime, 409
- toFile method (Path), 300
- toFormat method (DateTimeFormatter), 415
- toGenericString method (Class), 161
- toHandle method (Process), 370
- toInstant method
- of Date, 416
  - of ZonedDateTime, 410, 412
- toIntExact method (Math), 22
- tokens method (Scanner), 263, 294
- toList method (Collectors), 272
- toLocalXxx methods (ZonedDateTime), 412
- toLongArray method (BitSet), 249
- toLowerCase method (String), 28, 263, 427
- toMap method (Collectors), 273–274
- ToolProvider.getSystemJavaCompiler method, 444
- tools.jar file, 493
- toPath method (File), 300
- toSet method (Collectors), 272, 275
- toString method
- calling from subclasses, 147
  - of Arrays, 49, 147
  - of BitSet, 249
  - of Class, 161
  - of Double, Integer, 27
  - of Enum, 156
  - of Modifier, 162
  - of Object, Point, 146–147
- toUnsignedInt method (Byte), 12
- toUpperCase method (String), 28, 427
- toXxx methods (Duration), 403
- ToXxxFunction interfaces, 122, 220
- toXxxOfDay methods (LocalTime), 409
- toZonedDateTime method (GregorianCalendar), 416–417
- transferTo method (InputStream), 290

- transient modifier, 321
  - transitive keyword, 487–489
  - TreeMap class, 243, 274
  - TreeSet class, 242
  - trim method (String), 28, 428
  - true value (boolean), 14
  - try statement, 186–190
    - for visiting directories, 302
  - tryLock method (FileChannel), 298
  - trySetAccessible method (AccessibleObject), 170
  - try-with-resources statement, 187–189
    - closing output streams with, 290
    - for file locking, 298
  - type bounds, 210–211, 229
    - annotating, 382
  - type erasure, 216–219, 224
    - clashes after, 224–225
  - Type interface, 228
  - type method (ServiceLoader.Provider), 167
  - type parameters, 109, 208–209
    - and primitive types, 209, 220
    - annotating, 380
  - type variables
    - and exceptions, 225–226
    - in static context, 224
    - no instantiating of, 221–223
    - wildcards with, 214–215
  - TypeElement interface, 395
  - TypeVariable interface, 228
- U**
- \u
    - for character literals, 13–14, 437–438
    - in regular expressions, 311
  - %u pattern variable, 202
  - UnaryOperator interface, 121
  - uncaught exception handlers, 363, 366
  - unchecked exceptions, 183
    - and generic types, 226
    - documenting, 186
  - UncheckedIOException, 293
  - Unicode, 30–32, 279, 290
    - normalization forms in, 432
    - replacement character in, 295
  - unit tests, 377
- Unix operating system
  - bash scripts, 461
  - path separator, 81, 248
  - specifying locales in, 426
  - wildcard in classpath in, 82
- unlock method (ReentrantLock), 358
  - unmodifiableXxx methods (Collections), 240
  - unordered method (Stream), 282
  - until method (LocalDate), 405–406
  - updateAndGet method (AtomicXxx), 355
  - URI class, 308
  - URL class, 308
    - final, 141
    - getInputStream method, 306
    - openConnection method, 306
    - openStream method, 288
  - URLClassLoader class, 163
  - URLConnection class, 306–307
    - connect method, 306
    - getHeaderFields method, 307
    - getInputStream method, 307
    - getOutputStream method, 306
    - setDoOutput method, 306
    - setRequestProperty method, 306
  - URLs, reading from, 288, 306
  - useLocale method (Scanner), 427
  - user directory, 299
  - user interface. *See* GUI
  - user preferences, 439–441
  - user.dir, user.home, user.name system properties, 248
  - userXxx methods (Preferences), 439
  - uses keyword, 491
  - UTC (coordinated universal time), 411
  - UTF-8 encoding, 290–291
    - for source files, 438
    - modified, 296
  - UTF-16 encoding, 13, 31, 279, 291
    - in regular expressions, 311
  - Util class, 165
- V**
- V formatting symbol (date/time), 416
  - \v, \V, in regular expressions, 312
  - valueOf method
    - of BitSet, 249

- of Enum, 155–156
- values method
  - of Enum, 155
  - of Map, 246, 252
- varargs parameters
  - corrupted, 388
  - declaring, 54
- VarHandle class, 482
- variable handles, 482
- VariableElement interface, 395
- variables, 6, 14–16
  - atomic mutations of, 354–357
  - capturing, in lambda expressions, 124–127
  - declaring, 14–15
  - defined in interfaces, 105
  - deprecated, 93
  - documentation comments for, 91–92
  - effectively final, 126
  - final, 343, 347
  - holding object references, 63–64
  - initializing, 14–16
  - local, 41–43
  - naming, 14–15
  - parameter, 68
  - private, 65, 83
  - public static final, 105
  - redefining, 42
  - scope of, 41, 83
  - shared, 343–347, 357–358
  - static final. *See* constants
  - static, 74–75, 77, 85, 343
  - thread-local, 365–366
  - using an abstract class as type of, 142
  - visibility of, 342–344, 360
  - volatile, 343–344
- @version tag (javadoc), 91, 95
- versioning, 324
- views, 252–254
- virtual machine, 4
  - instruction reordering in, 343
- visibility, 342–344
  - guaranteed with locks, 360
- visitFile, visitFileFailed methods (FileVisitor), 304

- void keyword, 2, 53
  - using class literals with, 160
- volatile modifier, 343–344

## W

- \w, \W, in regular expressions, 312
- wait method (Object), 146, 361–362
- waitFor method (Process), 369
- waiting on a condition, 361
- walk method (Files), 302–305
- walkFileTree method (Files), 302, 304
- warning method (Logger), 197
- warnings
  - for switch statements, 159
  - suppressing, 220, 224, 388
- weak references, 251
- weaker access privilege, 139
- WeakHashMap class, 251
- weakly consistent iterators, 350
- WeakReference class, 252
- web pages
  - extracting links from, 337
  - reading, 338, 340
- whenComplete method (CompletableFuture), 336, 338–339
- while statement, 38–39
  - breaking/continuing, 40
  - continuing, 40
  - declaring variables for, 42
- white space
  - in regular expressions, 312
  - removing, 28
- wildcards
  - annotating, 382
  - capturing, 216
  - for annotation processors, 394
  - for types, 212–214
  - in class path, 81
  - unbounded, 215
  - with imported classes, 83–84
  - with type variables, 214–215
- WildcardType interface, 228
- Window class, 83
- WindowAdapter class, 106
- WindowListener interface, 106
- with method (Temporal), 408

- withInitial method (ThreadLocal), 365
- withLocale method (DateTimeFormatter), 413, 430
- withXxx methods
  - of LocalDate, 406
  - of LocalTime, 409
  - of ZonedDateTime, 411
- words
  - in regular expressions, 312
  - reading from a file, 293
  - sorting alphabetically, 431–432
- working directory, 367
- wrapper classes, 46–47
- write method
  - of Files, 295, 302
  - of OutputStream, 290
- writeExternal method (Externalizable), 322
- writeObject method (ObjectOutputStream), 320–322
- Writer class, 294–295
  - write method, 294
- writeReplace method (Serializable), 322–323
- writers, 288
- writeXxx methods (DataOutput), 296–297, 322

## X

- x formatting symbol (date/time), 416
- x, X conversion characters, 34

- \x, in regular expressions, 311
- XML descriptors, generating, 398
- @XmlElement annotation, 480
- @XmlRootElement annotation, 480
- xor method (BitSet), 249

## Y

- y formatting symbol (date/time), 416
- Year, YearMonth classes, 407

## Z

- z, Z formatting symbols (date/time), 414, 416
- \z, \Z, in regular expressions, 314
- ZIP file systems, 305
- ZipInputStream, ZipOutputStream classes, 305
- zoned time, 404–407, 410–413
- ZonedDateTime class, 410–413
  - and legacy classes, 417
  - getDayOfXxx methods, 411
  - getMonthXxx, getYear, getXxx, isXxx methods, 412
  - minus, minusXxx, now, ofInstant methods, 411
  - of method, 410–411
  - parse method, 430
  - plus, plusXxx methods, 411–412
  - toInstant method, 410, 412
  - toLocalXxx methods, 412
  - withXxx methods, 411
- ZoneId class, 410