

INTRODUCTION TO
JAVATM

**PROGRAMMING AND
DATA STRUCTURES**

COMPREHENSIVE VERSION

Eleventh Edition

Global Edition

Y. Daniel Liang

Armstrong State University



330 Hudson Street, NY NY 10013

CONTENTS

Chapter 1	Introduction to Computers, Programs, and Java™	23
1.1	Introduction	24
1.2	What Is a Computer?	24
1.3	Programming Languages	29
1.4	Operating Systems	31
1.5	Java, the World Wide Web, and Beyond	32
1.6	The Java Language Specification, API, JDK, JRE, and IDE	33
1.7	A Simple Java Program	34
1.8	Creating, Compiling, and Executing a Java Program	37
1.9	Programming Style and Documentation	40
1.10	Programming Errors	42
1.11	Developing Java Programs Using NetBeans	45
1.12	Developing Java Programs Using Eclipse	47
Chapter 2	Elementary Programming	55
2.1	Introduction	56
2.2	Writing a Simple Program	56
2.3	Reading Input from the Console	59
2.4	Identifiers	62
2.5	Variables	62
2.6	Assignment Statements and Assignment Expressions	64
2.7	Named Constants	65
2.8	Naming Conventions	66
2.9	Numeric Data Types and Operations	67
2.10	Numeric Literals	70
2.11	Evaluating Expressions and Operator Precedence	72
2.12	Case Study: Displaying the Current Time	74
2.13	Augmented Assignment Operators	76
2.14	Increment and Decrement Operators	77
2.15	Numeric Type Conversions	79
2.16	Software Development Process	81
2.17	Case Study: Counting Monetary Units	85
2.18	Common Errors and Pitfalls	87
Chapter 3	Selections	97
3.1	Introduction	98
3.2	boolean Data Type	98
3.3	if Statements	100
3.4	Two-Way if-else Statements	102
3.5	Nested if and Multi-Way if-else Statements	103
3.6	Common Errors and Pitfalls	105
3.7	Generating Random Numbers	109
3.8	Case Study: Computing Body Mass Index	111
3.9	Case Study: Computing Taxes	112
3.10	Logical Operators	115
3.11	Case Study: Determining Leap Year	119
3.12	Case Study: Lottery	120
3.13	switch Statements	122

3.14	Conditional Operators	125
3.15	Operator Precedence and Associativity	126
3.16	Debugging	128
Chapter 4	Mathematical Functions, Characters, and Strings	141
4.1	Introduction	142
4.2	Common Mathematical Functions	142
4.3	Character Data Type and Operations	147
4.4	The String Type	152
4.5	Case Studies	161
4.6	Formatting Console Output	167
Chapter 5	Loops	181
5.1	Introduction	182
5.2	The <code>while</code> Loop	182
5.3	Case Study: Guessing Numbers	185
5.4	Loop Design Strategies	188
5.5	Controlling a Loop with User Confirmation or a Sentinel Value	190
5.6	The <code>do-while</code> Loop	192
5.7	The <code>for</code> Loop	195
5.8	Which Loop to Use?	198
5.9	Nested Loops	200
5.10	Minimizing Numeric Errors	202
5.11	Case Studies	204
5.12	Keywords <i>break</i> and <i>continue</i>	208
5.13	Case Study: Checking Palindromes	211
5.14	Case Study: Displaying Prime Numbers	213
Chapter 6	Methods	227
6.1	Introduction	228
6.2	Defining a Method	228
6.3	Calling a Method	230
6.4	<code>void</code> vs. Value-Returning Methods	233
6.5	Passing Parameters by Values	236
6.6	Modularizing Code	239
6.7	Case Study: Converting Hexadecimals to Decimals	241
6.8	Overloading Methods	243
6.9	The Scope of Variables	246
6.10	Case Study: Generating Random Characters	247
6.11	Method Abstraction and Stepwise Refinement	249
Chapter 7	Single-Dimensional Arrays	269
7.1	Introduction	270
7.2	Array Basics	270
7.3	Case Study: Analyzing Numbers	277
7.4	Case Study: Deck of Cards	278
7.5	Copying Arrays	280
7.6	Passing Arrays to Methods	281
7.7	Returning an Array from a Method	284
7.8	Case Study: Counting the Occurrences of Each Letter	285
7.9	Variable-Length Argument Lists	288
7.10	Searching Arrays	289
7.11	Sorting Arrays	293

7.12	The Arrays Class	294
7.13	Command-Line Arguments	296
Chapter 8	Multidimensional Arrays	311
8.1	Introduction	312
8.2	Two-Dimensional Array Basics	312
8.3	Processing Two-Dimensional Arrays	315
8.4	Passing Two-Dimensional Arrays to Methods	317
8.5	Case Study: Grading a Multiple-Choice Test	318
8.6	Case Study: Finding the Closest Pair	320
8.7	Case Study: Sudoku	322
8.8	Multidimensional Arrays	325
Chapter 9	Objects and Classes	345
9.1	Introduction	346
9.2	Defining Classes for Objects	346
9.3	Example: Defining Classes and Creating Objects	348
9.4	Constructing Objects Using Constructors	353
9.5	Accessing Objects via Reference Variables	354
9.6	Using Classes from the Java Library	358
9.7	Static Variables, Constants, and Methods	361
9.8	Visibility Modifiers	366
9.9	Data Field Encapsulation	368
9.10	Passing Objects to Methods	371
9.11	Array of Objects	375
9.12	Immutable Objects and Classes	377
9.13	The Scope of Variables	379
9.14	The <code>this</code> Reference	380
Chapter 10	Object-Oriented Thinking	389
10.1	Introduction	390
10.2	Class Abstraction and Encapsulation	390
10.3	Thinking in Objects	394
10.4	Class Relationships	397
10.5	Case Study: Designing the Course Class	400
10.6	Case Study: Designing a Class for Stacks	402
10.7	Processing Primitive Data Type Values as Objects	404
10.8	Automatic Conversion between Primitive Types and Wrapper Class Types	407
10.9	The <code>BigInteger</code> and <code>BigDecimal</code> Classes	408
10.10	The <code>String</code> Class	410
10.11	The <code>StringBuilder</code> and <code>StringBuffer</code> Classes	416
Chapter 11	Inheritance and Polymorphism	433
11.1	Introduction	434
11.2	Superclasses and Subclasses	434
11.3	Using the <code>super</code> Keyword	440
11.4	Overriding Methods	443
11.5	Overriding vs. Overloading	444
11.6	The <code>Object</code> Class and Its <code>toString()</code> Method	446
11.7	Polymorphism	447
11.8	Dynamic Binding	447
11.9	Casting Objects and the <code>instanceof</code> Operator	451
11.10	The Object's <code>equals</code> Method	455

11.11	The ArrayList Class	456
11.12	Useful Methods for Lists	462
11.13	Case Study: A Custom Stack Class	463
11.14	The protected Data and Methods	464
11.15	Preventing Extending and Overriding	467
Chapter 12	Exception Handling and Text I/O	475
12.1	Introduction	476
12.2	Exception-Handling Overview	476
12.3	Exception Types	481
12.4	More on Exception Handling	484
12.5	The finally Clause	492
12.6	When to Use Exceptions	493
12.7	Rethrowing Exceptions	494
12.8	Chained Exceptions	495
12.9	Defining Custom Exception Classes	496
12.10	The File Class	499
12.11	File Input and Output	502
12.12	Reading Data from the Web	508
12.13	Case Study: Web Crawler	510
Chapter 13	Abstract Classes and Interfaces	521
13.1	Introduction	522
13.2	Abstract Classes	522
13.3	Case Study: the Abstract Number Class	527
13.4	Case Study: Calendar and GregorianCalendar	529
13.5	Interfaces	532
13.6	The Comparable Interface	535
13.7	The Cloneable Interface	540
13.8	Interfaces vs. Abstract Classes	545
13.9	Case Study: The Rational Class	548
13.10	Class-Design Guidelines	553
Chapter 14	JavaFX Basics	563
14.1	Introduction	564
14.2	JavaFX vs Swing and AWT	564
14.3	The Basic Structure of a JavaFX Program	564
14.4	Panes, Groups, UI Controls, and Shapes	567
14.5	Property Binding	570
14.6	Common Properties and Methods for Nodes	573
14.7	The Color Class	575
14.8	The Font Class	576
14.9	The Image and ImageView Classes	578
14.10	Layout Panes and Groups	580
14.11	Shapes	589
14.12	Case Study: The ClockPane Class	602
Chapter 15	Event-Driven Programming and Animations	615
15.1	Introduction	616
15.2	Events and Event Sources	618
15.3	Registering Handlers and Handling Events	619
15.4	Inner Classes	623
15.5	Anonymous Inner Class Handlers	624

15.6	Simplifying Event Handling Using Lambda Expressions	627
15.7	Case Study: Loan Calculator	631
15.8	Mouse Events	633
15.9	Key Events	635
15.10	Listeners for Observable Objects	638
15.11	Animation	640
15.12	Case Study: Bouncing Ball	648
15.13	Case Study: US Map	652
Chapter 16	JavaFX UI Controls and Multimedia	665
16.1	Introduction	666
16.2	Labeled and Label	666
16.3	Button	668
16.4	CheckBox	670
16.5	RadioButton	673
16.6	TextField	676
16.7	TextArea	677
16.8	ComboBox	681
16.9	ListView	684
16.10	ScrollBar	687
16.11	Slider	690
16.12	Case Study: Developing a Tic-Tac-Toe Game	693
16.13	Video and Audio	698
16.14	Case Study: National Flags and Anthems	701
Chapter 17	Binary I/O	713
17.1	Introduction	714
17.2	How Is Text I/O Handled in Java?	714
17.3	Text I/O vs. Binary I/O	715
17.4	Binary I/O Classes	716
17.5	Case Study: Copying Files	726
17.6	Object I/O	728
17.7	Random-Access Files	733
Chapter 18	Recursion	741
18.1	Introduction	742
18.2	Case Study: Computing Factorials	742
18.3	Case Study: Computing Fibonacci Numbers	745
18.4	Problem Solving Using Recursion	748
18.5	Recursive Helper Methods	750
18.6	Case Study: Finding the Directory Size	753
18.7	Case Study: Tower of Hanoi	755
18.8	Case Study: Fractals	758
18.9	Recursion vs. Iteration	762
18.10	Tail Recursion	762
Chapter 19	Generics	773
19.1	Introduction	774
19.2	Motivations and Benefits	774
19.3	Defining Generic Classes and Interfaces	776
19.4	Generic Methods	778
19.5	Case Study: Sorting an Array of Objects	780

19.6	Raw Types and Backward Compatibility	782
19.7	Wildcard Generic Types	783
19.8	Erasure and Restrictions on Generics	786
19.9	Case Study: Generic Matrix Class	788
Chapter 20	Lists, Stacks, Queues, and Priority Queues	797
20.1	Introduction	798
20.2	Collections	798
20.3	Iterators	802
20.4	Using the <code>forEach</code> Method	803
20.5	Lists	804
20.6	The <code>Comparator</code> Interface	809
20.7	Static Methods for Lists and Collections	813
20.8	Case Study: Bouncing Balls	816
20.9	Vector and Stack Classes	820
20.10	Queues and Priority Queues	821
20.11	Case Study: Evaluating Expressions	825
Chapter 21	Sets and Maps	837
21.1	Introduction	838
21.2	Sets	838
21.3	Comparing the Performance of Sets and Lists	846
21.4	Case Study: Counting Keywords	849
21.5	Maps	850
21.6	Case Study: Occurrences of Words	855
21.7	Singleton and Unmodifiable Collections and Maps	857
Chapter 22	Developing Efficient Algorithms	861
22.1	Introduction	862
22.2	Measuring Algorithm Efficiency Using Big O Notation	862
22.3	Examples: Determining Big O	864
22.4	Analyzing Algorithm Time Complexity	868
22.5	Finding Fibonacci Numbers Using Dynamic Programming	871
22.6	Finding Greatest Common Divisors Using Euclid's Algorithm	873
22.7	Efficient Algorithms for Finding Prime Numbers	877
22.8	Finding the Closest Pair of Points Using Divide-and-Conquer	883
22.9	Solving the Eight Queens Problem Using Backtracking	886
22.10	Computational Geometry: Finding a Convex Hull	889
Chapter 23	Sorting	903
23.1	Introduction	904
23.2	Insertion Sort	904
23.3	Bubble Sort	906
23.4	Merge Sort	909
23.5	Quick Sort	912
23.6	Heap Sort	916
23.7	Bucket and Radix Sorts	923
23.8	External Sort	925

Chapter 24	Implementing Lists, Stacks, Queues, and Priority Queues	939
24.1	Introduction	940
24.2	Common Operations for Lists	940
24.3	Array Lists	944
24.4	Linked Lists	951
24.5	Stacks and Queues	965
24.6	Priority Queues	969
Chapter 25	Binary Search Trees	975
25.1	Introduction	976
25.2	Binary Search Trees	976
25.3	Deleting Elements from a BST	989
25.4	Tree Visualization and MVC	995
25.5	Iterators	998
25.6	Case Study: Data Compression	1000
Chapter 26	AVL Trees	1011
26.1	Introduction	1012
26.2	Rebalancing Trees	1012
26.3	Designing Classes for AVL Trees	1015
26.4	Overriding the insert Method	1016
26.5	Implementing Rotations	1017
26.6	Implementing the delete Method	1018
26.7	The AVLTree Class	1018
26.8	Testing the AVLTree Class	1024
26.9	AVL Tree Time Complexity Analysis	1027
Chapter 27	Hashing	1031
27.1	Introduction	1032
27.2	What Is Hashing?	1032
27.3	Hash Functions and Hash Codes	1033
27.4	Handling Collisions Using Open Addressing	1035
27.5	Handling Collisions Using Separate Chaining	1039
27.6	Load Factor and Rehashing	1039
27.7	Implementing a Map Using Hashing	1041
27.8	Implementing Set Using Hashing	1050
Chapter 28	Graphs and Applications	1061
28.1	Introduction	1062
28.2	Basic Graph Terminologies	1063
28.3	Representing Graphs	1064
28.4	Modeling Graphs	1070
28.5	Graph Visualization	1080
28.6	Graph Traversals	1083
28.7	Depth-First Search (DFS)	1084
28.8	Case Study: The Connected Circles Problem	1088
28.9	Breadth-First Search (BFS)	1090
28.10	Case Study: The Nine Tails Problem	1093

Chapter 29	Weighted Graphs and Applications	1107
29.1	Introduction	1108
29.2	Representing Weighted Graphs	1109
29.3	The WeightedGraph Class	1111
29.4	Minimum Spanning Trees	1119
29.5	Finding Shortest Paths	1125
29.6	Case Study: The Weighted Nine Tails Problem	1134
Chapter 30	Aggregate Operations for Collection Streams	1145
30.1	Introduction	1146
30.2	Stream Pipelines	1146
30.3	IntStream, LongStream, and DoubleStream	1152
30.4	Parallel Streams	1155
30.5	Stream Reduction Using the reduce Method	1157
30.6	Stream Reduction Using the collect Method	1160
30.7	Grouping Elements Using the groupingby Collector	1163
30.8	Case Studies	1166

Chapter 31–44 are available from the Companion Website at www.pearsonglobaleditions.com/Liang

Chapter 31	Advanced JavaFX and FXML
Chapter 32	Multithreading and Parallel Programming
Chapter 33	Networking
Chapter 34	Java Database Programming
Chapter 35	Advanced Java Database Programming
Chapter 36	Internationalization
Chapter 37	Servlets
Chapter 38	JavaServer Pages
Chapter 39	JavaServer Faces
Chapter 40	Remote Method Invocation
Chapter 41	Web Services
Chapter 42	2-4 Trees and B-Trees
Chapter 43	Red-Black Trees
Chapter 44	Testing Using JUnit

APPENDIXES	1177
Appendix A Java Keywords	1179
Appendix B The ASCII Character Set	1180
Appendix C Operator Precedence Chart	1182
Appendix D Java Modifiers	1184
Appendix E Special Floating-Point Values	1186
Appendix F Number Systems	1187
Appendix G Bitwise Operations	1191
Appendix H Regular Expressions	1192
Appendix I Enumerated Types	1197
QUICK REFERENCE	1203
INDEX	1205