## **Contents**

Prej	race — — — — — — — — — — — — — — — — — — —	page 1X
Par	t 1 Functions and Foundations	
1	Introduction	3
	1.1 Programming Languages	3
	1.2 Goals	5
	1.3 Programming Language History	6
	1.4 Organization: Concepts and Languages	8
2	Computability	10
	2.1 Partial Functions and Computability	10
	2.2 Chapter Summary	16
	Exercises	16
3	Lisp: Functions, Recursion, and Lists	18
	3.1 Lisp History	18
	3.2 Good Language Design	20
	3.3 Brief Language Overview	22
	3.4 Innovations in the Design of Lisp	25
	3.5 Chapter Summary: Contributions of Lisp	39
	Exercises	40
4	Fundamentals	48
	4.1 Compilers and Syntax	48
	4.2 Lambda Calculus	57
	4.3 Denotational Semantics	67
	4.4 Functional and Imperative Languages	76
	4.5 Chapter Summary	82
	Exercises	83

Part 2 Procedures, Types, Memory Management, and Cont	Part 2	Procedures.	Types,	Memory	/ Management,	and	Contr
---	--------	-------------	--------	--------	---------------	-----	-------

5	The Algol Family and ML	93
	5.1 The Algol Family of Programming Languages	93
	5.2 The Development of C	99
	5.3 The LCF System and ML	101
	5.4 The ML Programming Language	103
	5.5 Chapter Summary	121
	Exercises	122
6	Type Systems and Type Inference	129
	6.1 Types in Programming	129
	6.2 Type Safety and Type Checking	132
	6.3 Type Inference	135
	6.4 Polymorphism and Overloading	145
	6.5 Type Declarations and Type Equality	151
	6.6 Chapter Summary	155
	Exercises	156
7	Scope, Functions, and Storage Management	162
	7.1 Block-Structured Languages	162
	7.2 In-Line Blocks	165
	7.3 Functions and Procedures	170
	7.4 Higher-Order Functions	182
	7.5 Chapter Summary	190
	Exercises	191
8	Control in Sequential Languages	204
	8.1 Structured Control	204
	8.2 Exceptions	207
	8.3 Continuations	218
	8.4 Functions and Evaluation Order	223
	8.5 Chapter Summary	227
	Exercises	228
Part	t 3 Modularity, Abstraction, and Object-Oriented Programming	
9	Data Abstraction and Modularity	235
	9.1 Structured Programming	235
	9.2 Language Support for Abstraction	242
	9.3 Modules	252
	9.4 Generic Abstractions	259
	9.5 Chapter Summary	269
	Exercises	271
10	Concepts in Object-Oriented Languages	277
	10.1 Object-Oriented Design	277
	10.2 Four Basic Concepts in Object-Oriented Languages	278

		Contents
	10.3 Program Structure	288
	10.4 Design Patterns	290
	10.5 Chapter Summary	292
	10.6 Looking Forward: Simula, Smalltalk,	
	C++, Java	293
	Exercises	294
11	History of Objects: Simula and Smalltalk	300
	11.1 Origin of Objects in Simula	300
	11.2 Objects in Simula	303
	11.3 Subclasses and Subtypes in Simula	308
	11.4 Development of Smalltalk	310
	11.5 Smalltalk Language Features	312
	11.6 Smalltalk Flexibility	318
	11.7 Relationship between Subtyping and	
	Inheritance	322
	11.8 Chapter Summary	326
	Exercises	327
12	Objects and Run-Time Efficiency: C++	337
	12.1 Design Goals and Constraints	337
	12.2 Overview of C++	340
	12.3 Classes, Inheritance, and Virtual Functions	346
	12.4 Subtyping	355
	12.5 Multiple Inheritance	359
	12.6 Chapter Summary	366
	Exercises	367
13	Portability and Safety: Java	384
	13.1 Java Language Overview	386
	13.2 Java Classes and Inheritance	389
	13.3 Java Types and Subtyping	396
	13.4 Java System Architecture	404
	13.5 Security Features	412
	13.6 Java Summary	417
	Exercises	420
Part	4 Concurrency and Logic Programming	
14	Concurrent and Distributed Programming	431
	14.1 Basic Concepts in Concurrency	433
	14.2 The Actor Model	441
	14.3 Concurrent ML	445
	14.4 Java Concurrency	454
	14.5 Chapter Summary	466
	Exercises	469

vii

## viii Contents

15 The Lo	gic Programming Paradigm and Prolog	475
15.1	History of Logic Programming	475
15.2	Brief Overview of the Logic Programming Paradigm	476
15.3	Equations Solved by Unification as Atomic Actions	478
15.4	Clauses as Parts of Procedure Declarations	482
15.5	Prolog's Approach to Programming	486
15.6	Arithmetic in Prolog	492
15.7	Control, Ambivalent Syntax, and Meta-Variables	496
15.8	Assessment of Prolog	505
15.9	Bibliographic Remarks	507
15.10	Chapter Summary	507
Appendix A	Additional Program Examples	509
A.1	Procedural and Object-Oriented Organization	509
Glossary		521
Index		525