Contents

Themes, xiii

1. Conceptual Outline of Current Evolutionary Theory, 3
The Emergence of the Neo-Darwinian Synthesis, 3
Enlarging the Framework, 16
Summary, 25

PART I ADAPTATION ON THE EDGE OF CHAOS, 29

2. The Structure of Rugged Fitness Landscapes, 33
Fitness Landscapes in Sequence Space, 36
The *NK* Model of Rugged Fitness Landscapes, 40
Summary, 66

3. Biological Implications of Rugged Fitness Landscapes, 69
Phylogenetic Implications of Rugged Landscapes, 70
Population Flow on Rugged Fitness Landscapes, 95
Summary, 117

4. The Structure of Adaptive Landscapes Underlying Protein Evolution, 12 1
Adaptive Maturation of the Immune Response, 122
Evolution of Novel Catalytic Functions, 142
Applied Molecular Evolution: Direct Exploration of DNA, RNA, and Protein Sequence Spaces, 156
Summary, 17 1

5. Self-Organization and Adaptation in Complex Systems, 173
Dynamical Systems and Their Attractors, 175
Spontaneous Order and Chaos in Complex Dynamical Systems, 18 1

Adaptation in Dynamical Systems, 209
Summary, 234

6. The Dynamics of Coevolving Systems, 237
Coevolution in Ecosystems, 242
Structured Ecosystems and Self-Organized Criticality: Coevolution to the Edge of Chaos, 255
Coevolutionary Conclusions., 278
Summary, 279

PART II THE CRYSTALLIZATION OF LIFE, 285

7. The Origins of Life: A New View, 287
Background of the Origin of Life Problem, 288
Autocatalytic Sets of Catalytic Polymers, 298
Growth on the Infinite Graph of Polymers and Thermodynamic Behavior, 3 12
Evolutionary Capacities of Autocatalytic Sets Without a Genome, 329
Experimental Consequences, 337
Summary, 340

8. The Origin of a Connected Metabolism, 343
Crystalization of a Connected Metabolism as a Percolation Problem, 346
New Experiments, 354
Summary, 355

9. Hypercycles and Coding, 357
The Logic of Hypercycles, 357
Bedian's Paradigm for the Onset of Coding, 364
Summary, 366

10. Random Grammars: Models of Functional Integration and Transformation, 369
Jets and Autocatalytic Sets: Toward a New String Theory, 372
Infinite Boolean Networks and Random Grammars: Approaches to Studying Families of Mappings of Strings into Strings, 377
Applications to Biological, Neural, and Economic Systems, 387
Summary, 402

PART III ORDER AND ONTOGENY, 407

11 The Architecture of Genetic Regulatory Circuits and Its Evolution, 41 1
Independence of the Molecular Evolutionary Clock and Morphological Evolution, 4 12

Components in the Genetic Regulatory Systems of Prokaryotes and Eukaryotes, 4 12
An Ensemble Theory Based on Random Directed Graphs, 4 19
Summary, 439

12. Differentiation: The Dynamical Behaviors of Genetic Regulatory Networks, 441
Simple Genetic Circuits and the Boolean Idealization, 444
Large-Scale Features of Cell Differentiation, 454
The Conceptual Framework: Cell Differentiation in Boolean Networks, 462
Ensembles of Genetic Regulatory Systems: Generic Properties, 470
Implications for Ontogeny, 48 I
Cell Types as a Combinatorial Epigenetic Code, 507
Summary, 520

13. Selection for Cell Types, 523
The Framework, 524
Genomic Network Space, 525
Experimental Avenues, 533
Summary, 534

14. Morphology, Maps, and the Spatial Ordering of Integrated Tissues, 537
Induction as a Basic Intercellular Conversation, 540
Evidence for Long-Range Order in Tissues: Duplication, Regeneration, and Positional Continuity, 549
The Spontaneous Generation of Spatial Patterns: Turing Models, 566
Compartmental and Segmental Patterns in ***Drosophila melanogaster, 577***
Pattern Formation in the Early ***Drosophila*** Embryo, 594
Spatial Harmonics Suggested by Mutants Affecting Segmentation: Longitudinal Deletions and Mirror-Symmetric Duplications, 60 1
Sinusoidal Transcription and Protein Patterns: A Bifurcation Sequence of Higher Harmonics on the Egg, 605
The Four Color Wheels Model of Positional Specification, 6 14
Turing and Beyond, 630
Summary, 64 1

Epilogue, 643

Bibliography, 647

Index, 695