
CONTENTS

<i>Preface</i>	<i>ix</i>
Chapter 1	
The “Regulatory Genome” for Animal Development	1
The Framework	1
The Regulatory Apparatus Encoded in the DNA	3
Genomes, Genes, and Genomic “Space”	3
Overview of Regulatory Architecture	8
Gene Regulatory Networks	11
The Regulatory Demands of Development	16
Readout and Generation of Regulatory Information in Developmental Specification	16
Spatial Gene Expression	18
From Regional Specification to Terminal Differentiation	21
Evolution, Development, and the Regulatory Genome	27
Chapter 2	
<i>cis</i>-Regulatory Modules, and the Structure/Function Basis of Regulatory Logic	31
General Operating Principles	31
Modularity, A General Property of Genomic <i>cis</i>-Regulatory Control Units	33
Inside the <i>cis</i>-Regulatory Module: Logic Processing and Input/Output Relations	47
<i>cis</i> -Regulatory Logic Processors: Examples	48
Target Site Occupancy and Transcriptional Output	57
Generalization: The Combinatorial <i>cis</i> -Regulatory Logic Code	59
<i>cis</i>-Regulatory Design	61
Integration of Spatial Inputs at the <i>cis</i> -Regulatory Level	61
Repression and the Diversity of <i>cis</i> -Regulatory Design	68
<i>cis</i> -Regulatory Design and the Creation of Spatial Complexity in Development	73

Control by Sequence-Specific Interactions Among Distant <i>cis</i>-Regulatory Elements	78
Development and BTA Specificity	79
Control Functions of Sequence-Specific, Intra- and Intergenic Genomic Looping	80
 Chapter 3	
Development as a Process of Regulatory State Specification	87
Developmental Processes of the Pregastrular Embryo	87
Vectorial Embryogenesis	88
Maternal Anisotropy and External Cues for Axial Polarity	90
Spatial Regulatory Complexity and Interblastomere Signaling Territories	94
Comparative View of Embryonic Processes, and the Organization of the Underlying Gene Regulatory Networks	102
Shallow Gene Regulatory Networks of Type 1 Embryos	103
More Complex Forms of Embryonic Process	109
Regulatory State and Network Circuitry in Building Adult Body Parts	114
Steps in the Postembryonic Developmental Process	114
The Progenitor Field Concept	115
Subdivision of the Progenitor Field Regulatory State	121
Body Plan Development and the Organism	122
 Chapter 4	
Gene Regulatory Networks for Development: What They Are, How They Work, and What They Mean	125
General Structural Properties of Developmental Gene Regulatory Networks	126
Overall Network Structure	127
Gene Regulatory Networks from Different Perspectives: Subcircuits to Process Diagrams	135
Qualitative Diversity of Network Components	136
Extensions	140
Gene Regulatory Networks for Embryonic Development	144
The Sea Urchin Endomesoderm Network	144
Regulatory Gene Network for Specification of Mesoderm in the <i>Xenopus</i> Embryo	159
Gene Regulatory Network Controlling Dorsal-Ventral Territorial Specification in the <i>Drosophila</i> Embryo	166

Networks that Control Construction of Components of Adult Body Parts	175
Network Organization in the Specification of Pancreatic β -Cells	176
Cell Fate Exclusion by microRNAs in a Gene Regulatory Controlling Terminal Differentiation in <i>C. elegans</i> Taste Network Neurons	180
Concluding Remarks	184

Chapter 5

Gene Regulatory Networks: The Roots of Causality and Diversity in Animal Evolution

Evolutionary Implications of the Structure and Function of Gene Regulatory Networks	188
The Parts of Gene Regulatory Networks, and the Qualities of Evolutionary Change	188
Linnaean Framework for the Evolutionary Consequences of Alterations in Gene Regulatory Networks	195
Bilaterian Kernels, Predicted and Real	196
Caveats and a Caution	197
Regional Specification in the Bilaterian Nervous System	200
The Bilaterian Gut	212
A Possible Pan-Bilaterian Kernel Underlying Specification of the Heart Progenitor Field	218
Distribution of Kernels	221
Subphyletic Evolution of Bilaterian Body Plans: <i>box</i> Genes as Sources of Labile Network Input/Output Switches	223
Diverse Functional Consequences of <i>box</i> Gene Expression	223
Multiple Examples: Regional Repression and Installation of Patterning Output, and the Evolutionary Diversification of Body Parts	224
<i>box</i> Gene Subnetworks and Spatial Evolution	233
Metazoan Origins and Gene Networks Before Kernels	235
"Deconstructing" Bilaterian Gene Regulatory Networks in Time	235
Concluding Reflection: The Principle of Animal Development and Evolution	239

References	241
Figure Citations	275
Index	279