

Contents

1	Devils, Ratchets and Biomolecular Motors	1
1.1	The Century of the Devils	1
1.2	The Unbearable Attractiveness of Irreversibility	3
1.3	The Devil Is a Pawl	6
1.4	Swimming in Molasses	8
1.5	Down in the Bioworld	10
	References	16
2	Entropy and Information	19
2.1	Back to Thermodynamics	19
2.2	The Statistical Character of Entropy	21
2.3	Out of Equilibrium	23
2.4	Shaping the World	27
2.5	The Role of Information	29
2.6	The Physics of Neglecting	30
	References	35
3	A Computer Called the Universe	37
3.1	A Controversial Origin	37
3.2	The Atomic Universe	41
3.3	The Molecular Universe	44
3.4	The Birth of Chemistry	46
3.5	Back to Earth	49
3.6	The Computing Universe	52
	References	54
4	Biomolecules, Networks and Bioenergetics: System Approach to Biology	55
4.1	A New Paradigm	55
4.2	The Molecules of Life	56
4.3	Building the Cells	60

4.4	Viruses	62
4.5	Thermodynamics in Action	63
4.6	The Path of Bioenergy	65
4.7	Life and Energy	68
4.8	Taming the Rates	71
4.9	Towards a System Biology	76
	References	82
5	Making Sense of Life	83
5.1	An Enlightening Contribution	83
5.2	The Nature and Role of Free Energy	84
5.3	The Eighth Day of Creation	87
5.4	A Gentlemen's Club	88
5.5	Central Dogma at Work	91
5.6	Feedback Control	93
5.7	Regulator Gene	94
5.8	Final Remark	96
	References	97
6	Complexity and Information: A Metaphor of Natural and Technological Systems	99
6.1	Complexity: A Philosophy or a Tool?	99
6.2	A World Patterned by Networks	101
6.3	The Language of Nature	103
6.4	Natural Computers	105
6.5	An Abundance of Energy (and Exergy) from the Top	108
6.6	The Emerald Planet	109
6.7	Eating the Sun	113
6.8	Back to the Macroworld	115
6.9	A Glance Towards the Future	116
	References	118
7	The Path of Evolution	121
7.1	The Informational Aspect of Evolution	121
7.2	Evolution and Complexity	122
7.3	Simulating Evolution	124
7.4	Evolution in a Computer	125
7.5	Meta-Biological Darwinism	129
	References	132
8	Imitation of Life: The Cell in a Silicon Chip	133
8.1	The Chemoton	133
8.2	A Challenging Problem	135
8.3	Modeling of Metabolic Reaction Systems	138
8.4	FBA Approach	142
8.5	Exploring the <i>Escherichia coli</i>	143

8.6	Whole Cell	144
	References	146
9	Synthetic Biology at Work	149
9.1	The Synthetic Approach to Biology	149
9.2	Progress in Gene Manipulations	150
9.3	Frontier of Genome Engineering: The CRISPR/Cas System	152
9.4	Technical Issues	154
9.5	Works in Progress	156
9.6	A Renewed Synthetic Chemistry	157
9.7	Metabolic Engineering	158
9.8	Towards a Post-petroleum Era?	161
	References	162
10	Why Life?	165
10.1	Resurrecting Prometheus	165
10.2	The Beginning of Life	166
10.3	Ideas and Theories on the Origin of Life	169
10.3.1	Protein First	169
10.3.2	Nucleic Acids First	172
10.3.3	The Chicken or the Egg?	174
10.3.4	RNA World	176
10.3.5	The Phase Transition Approach to the Emergence of Life	177
10.3.6	Back to Thermodynamics	180
10.3.7	The Revenge of Energy	182
10.3.8	A Merging Point?	186
10.4	The First Synthetic Cell	187
	References	189
	Glossary	191
	Sources	203
	Titles in This Series	205