

Contents

1	Introduction	1
2	The Early History of Bioenergy	15
	2.1 Energy-Related Phase Transitions Toward Life	15
	2.1.1 Catalysis	16
	2.1.2 Reflexive Activity	20
	2.1.3 Energy Transduction	25
	2.2 Energy Control Mechanisms	31
	2.3 Quantitative Consequences of Energy Control Mechanisms ...	33
	2.4 Distribution of Energy Input	34
3	The Origin of Cell Boundaries and Metabolism	39
	3.1 The Make-up of Life's Boundaries	42
	3.2 The Early Evolution of Cellular Boundaries	44
	3.3 Outcomes of an Early Boundary	50
	3.4 Systems Without Defined Boundaries	51
	3.5 Systems with Non-Specialized Boundaries	51
	3.6 Self-Assembly of Specialized Boundaries	52
	3.7 Boundary-Derived Properties of Life	53
	3.8 Coupling of Spatial Seclusion with a Reflexive Activity	55
	3.9 The Origin of Metabolism	57
4	The Origin of Early Specificity.	
	The Order, Complexity and Diversity of Life	63
	4.1 Order	63
	4.2 Complexity	64
	4.3 Diversity	67
	4.4 Specificity	69
	4.5 Specificity of Polymer-Based Life	70
	4.6 The Origin of Specificity	72
	4.7 Transition from External to Internal Control	75
	4.8 Major Events in the Early History of Specificity	76
	4.9 The Origin of Feedback Mechanisms	
	as a Source of Internal Stability	76
	4.10 The Origin of Forward Regulation	78

4.11	Consequences of Internal Regulation	78
4.12	Forced Oscillations and Periodic Clocks	79
4.13	Specificity-Related Phase Transitions Toward Life	79
4.14	Specificity-Related Minimal Requirements of Life	80
5	The Origin of Handedness	81
5.1	Chirality and Life	83
5.2	Natural Sources of Chirality	85
5.3	Evolutionary Steps Toward Biological Chirality	89
5.4	Handedness-Related Steps Toward Life	93
6	The Early History of Bio-Information	95
6.1	Early Sources of Bio-Information	100
6.2	Contextual vs. Nominative Information and Explicit vs. Cryptic Information	102
6.3	Postulates of the Early Evolution of Bio-Information	109
6.3.1	The Contextual Information Era	110
6.3.2	The Mineral-to-Organic Era	110
6.3.3	The Organic-to-Organic Era	112
6.3.4	The Emergence of Encryption	115
6.3.5	The Rise of the DNA World	117
6.4	Information-Related Fundamental Phase Transitions Toward Life	119
6.5	Minimal Requirements for the Emergence of Bio-Information .	120
7	The Purpose-Like Nature of Life	121
8	Assembling the Early Puzzle of Life	139
8.1	The First Step Toward Life: Coupling Catalysis with Reflexive Activity	142
8.2	Self-Assembly	143
8.3	Seclusion Within Specialized Boundaries and the Origin of Metabolism	144
8.4	Probabilistic Jumps Toward Catalytic Specificity	145
8.5	Feedback Regulation	145
8.6	Internalization of Minimal Specificity	145
8.7	Control over Chirality	146
8.8	Inheritable Variability	147
8.9	Replication	148
8.10	The Last Step Toward Life: The Emergence of Encryption . .	150
8.11	The Non-Life-to-Life Transition	150
8.12	Cosmochemical and Geochemical Requirements for the Origin of Life	152
8.13	Major Trends During the Early History of Life	154
8.14	Differences Between Early Life and Modern Life	155

8.15	Early Life and Artificial Life	157
8.16	The Definition of Life	158
9	The Material-Independent Signatures of Life.	
	Forensic Tools of Astrobiology	159
9.1	Rules of Thumb in Astrobiology	159
9.2	The Main Questions in Astrobiology	161
9.2.1	How Many Parameters are Required to Identify Life? .	162
9.2.2	False Premises and Misguided Fingerprints in Astrobiology	162
9.3	The Material-Independent Signatures of Life	170
Appendix A	Models and Theories of Life	173
A.1	Major Steps Toward Life	173
A.2	The (M,R)-System Model	174
A.3	The Two-Polymerase System	177
A.4	The Hypercycle Model.....	178
A.5	The Autocatalytic Network Model	180
A.6	The Chemoton Model	183
A.7	Pargellis's Model of Artificial Life	188
A.8	The Autopoietic Model	189
A.9	The Algorithmic Chemistry Model	193
A.10	Chemical Reaction Automata	194
Appendix B	Chronology of Definitions and Interpretations of Life	197
Appendix C	Dictionary	207
Appendix D	Abbreviations	225
References	227