

# Contents

<b>1</b>	<b>Astrobiology: Approaches to the Origin of Life on Earth and Beyond</b>	<b>1</b>
1.1	Review of Main Approaches to the Origin and Distribution of Life	2
1.1.1	Earth Cradle Direction of Research	2
1.1.2	Panspermia Direction of Research	4
1.1.3	Astrobiology as the Integrative Direction	6
1.2	The Author's Approach to Defining and Origin of Living Systems	7
1.2.1	The Approach to Life Defining	8
1.2.2	The Approach to Life Origin	10
	References	12
 <b>Part I Life and a Principal Way of Its Origin in the Universe</b>		
<b>2</b>	<b>General Thermodynamic Characteristics of Living Systems</b>	<b>17</b>
2.1	Thermodynamic Background for Comparison of Natural Systems	17
2.1.1	Key Notions: Entropy, Free Energy, and Information	17
2.1.2	Universal Spontaneous and Non-spontaneous Processes Related to Entropy Change	19
2.2	All-Round Comparison of Biological and Non-biological Systems	21
2.2.1	Classification of Natural Systems Based on the Thermodynamic Criteria	21
2.2.2	Spontaneous and Non-spontaneous Processes in Passive and Active Natural Systems	28
2.2.3	Two Separating Lines Between Non-biological and Biological Systems	29

2.2.4	Thermodynamic Nature of the Biological Organization . . . . .	32
2.2.5	Negentropy Barrier: Necessity of Thermodynamic Inversion to Launch Life Processes . . . . .	35
2.3	Fundamental Properties of Biological Systems: Detailed Elaboration . . . . .	37
2.3.1	Unique Fundamental Properties of Biological Systems . . . . .	38
2.3.2	Non-unique Fundamental Properties of Biological Systems . . . . .	48
2.4	Specificity of Biological Information . . . . .	49
2.4.1	First Unique Characteristic of Bioinformation: Functionality . . . . .	50
2.4.2	Second Unique Characteristic of Bioinformation: Purposefulness . . . . .	51
2.4.3	Third Unique Characteristic of Bioinformation: Control Over Life's Processes . . . . .	52
2.5	Integrated View on the Thermodynamic Method of Biological Organization . . . . .	52
	References . . . . .	54
<b>3</b>	<b>Principal Way of Life Origin in the Universe . . . . .</b>	<b>57</b>
3.1	Introduction . . . . .	57
3.2	General Aspects of the Transition from Non-living to Living World: Thermodynamics and Chemistry . . . . .	57
3.3	Nonequilibrium Thermodynamics: Start of the Origin-of-Life Consideration . . . . .	58
3.3.1	Theory of Dissipative Structures and Synergetics: Introduction . . . . .	59
3.3.2	Development of the Theory of Dissipative Structures in the Origin-of-Life Context . . . . .	62
3.4	Intermediate State Between Non-life and Life: The Bistate Hypothesis . . . . .	66
3.4.1	Theoretical Substantiation of the Bistate Hypothesis . . . . .	66
3.4.2	Verification of the Bistate Hypothesis . . . . .	72
3.5	Arising of Life Processes: The Inversion Hypothesis . . . . .	80
3.5.1	Theoretical Substantiation of the Inversion Hypothesis . . . . .	80
3.5.2	Verification of the Inversion Hypothesis . . . . .	88
3.6	Thermodynamic Corridor for Chemical Scenarios of the Origin of Life . . . . .	90
	References . . . . .	92

<b>4</b>	<b>General Characteristics of the Origin-of-Life Medium</b>	<b>93</b>
4.1	Consequences of the Inversion Concept for the Origin-of-Life Medium	93
4.1.1	Required Conditions for the Origin of Life	93
4.1.2	Selection of Appropriate Origin-of-Life Medium Based on Terrestrial Geology	96
4.2	Characterization of Hydrothermal Systems as a Medium for the Transition to Life	99
4.2.1	Thermodynamic Modeling of the Fluctuations in Hydrothermal Media	100
4.2.2	Measured Thermodynamic and Physicochemical Oscillations in Hydrothermal Systems	110
4.3	Origin-of-Life Medium on Extraterrestrial Planets: Application of the Terrestrial Model	113
4.3.1	Present Approaches to the Origin of the Solar System	113
4.3.2	Traces of Hydrothermal Activity on the Solar Planets and Smaller Bodies	114
	References	116

## **Part II Origin of Initial Living Systems on Early Earth**

<b>5</b>	<b>Irreversible Prebiotic Evolution in Hydrothermal Systems</b>	<b>121</b>
5.1	Prebiotic Chemistry in High-Temperature Conditions	121
5.1.1	Organic Matter in Contemporary Hydrothermal Systems	122
5.1.2	Organic Matter in Simulated Hydrothermal Conditions	123
5.1.3	Short Integration of the Data on High-Temperature Prebiotic Chemistry	125
5.2	Geological Parameters of the Hydrothermal Origin-of-Life Medium	126
5.2.1	Subsurface Structure of Hydrothermal Systems	126
5.2.2	Geological Model of the Hydrothermal Origin-of-Life Medium: Prebiotic and Transitional Zones	129
5.3	Formation of Organic Molecular Assemblies and Their Associations	133
5.3.1	Ways of Organic Substance Concentration in the Prebiotic Hydrothermal Medium	133
5.3.2	Behavior of Organic Substance in Course of Hydrothermal Fluid Phase Separation	137
5.3.3	Prebiotic Transformation of Organic Matter in Migrating Fluid	139

5.4	General Characteristics of Prebiotic Microsystems . . . . .	150
5.4.1	Probable Composition of Prebiotic Microsystems . . . . .	150
5.4.2	Processes in Bistate Prebiotic Microsystems . . . . .	152
	References. . . . .	154
<b>6</b>	<b>Exchange of Information During Prebiotic Evolution . . . . .</b>	<b>159</b>
6.1	Key Questions of Bioinformation Emergence. . . . .	159
6.2	Unique Position of Planetary Origin-of-Life Media in the Universe . . . . .	161
6.3	Information Exchange in Nonequilibrium Molecular Assemblies . . . . .	162
6.3.1	Imprints of External Influences in Nonequilibrium Chemical Systems . . . . .	162
6.3.2	External Informational Tracks . . . . .	163
6.3.3	Internal Informational Tracks. . . . .	165
6.3.4	Fixation of External Informational Tracks in Crystals and Organic Assemblies . . . . .	165
6.3.5	Principal Structure of the Informational Tracks in Hydrothermal Medium . . . . .	167
6.4	Reorganization of the Reflected Information in Prebiotic Microsystems: The Reconstruction . . . . .	169
6.4.1	“Reflected World” and “Molecular World” . . . . .	169
6.4.2	Reflected Information as a Source of Biological Information . . . . .	169
6.4.3	Nucleoprotein Complexes as the Most Suitable Macromolecules for Concentration of Information. . . . .	171
6.4.4	Compression of Reflected Information. . . . .	172
6.5	Information Exchange in Bistate Prebiotic Microsystems . . . . .	174
	References. . . . .	176
<b>7</b>	<b>Origin of Primary Living Systems on Earth in Course of Thermodynamic Inversion . . . . .</b>	<b>179</b>
7.1	Introduction . . . . .	179
7.2	General Characteristics of Prebiotic Microsystems and Their Associations Before the Thermodynamic Inversion. . . . .	179
7.2.1	Specificity of the Prebiotic “Bistate” Type of Natural Systems. . . . .	179
7.2.2	Characteristics of the Maternal Hydrothermal Medium. . . . .	180
7.2.3	Probable Chemical Composition of Prebiotic Microsystems. . . . .	181
7.2.4	Informational Processes in Prebiotic Microsystems . . . . .	181
7.2.5	Prebiotic Macrosystems: Associations of Prebiotic Microsystems. . . . .	182

7.3	Jump Over the Negentropy Barrier: Principal Transformation of Prebiotic Microsystems into Living Probiotics . . . . .	182
7.3.1	General Description of the Thermodynamic and Informational Inversion: Reconstruction and Its Verification . . . . .	183
7.3.2	Arising of Bioinformational Processes: Reconstruction and Its Verification . . . . .	185
7.3.3	Arising of Initial Metabolic Processes: Reconstruction and Its Verification . . . . .	187
7.4	Molecular Reorganization in the Microsystems and Formation of (Proto)Cellular Structures: Reconstruction and Verification . . . . .	189
7.4.1	Transitional Chemistry (Reconstruction) . . . . .	189
7.4.2	Formation of Nucleoid, Ribosomes, and Membrane (Reconstruction) . . . . .	191
7.4.3	Verification of the Proposed Reconstruction . . . . .	194
7.5	Transformation of Microsystems' Associations into Primary Communities of Microorganisms . . . . .	195
7.6	Further Evolution of Probiotics to Prokaryotes . . . . .	197
7.7	Future Laboratory Experiments on the Origin of Life. . . . .	198
	References. . . . .	198

### **Part III Kamchatka Geothermal Region as a Testing Ground for Investigation of the Origin-of-Life Process**

<b>8</b>	<b>Hydrothermal Systems in Kamchatka Peninsula and the Adjoining Region: Geological and Hydrochemical Characteristics. . . . .</b>	<b>203</b>
8.1	Introduction into the Part III. . . . .	203
8.2	Description of Mutnovsky Hydrothermal System . . . . .	205
8.3	Description of Uzon Hydrothermal System. . . . .	211
8.4	Description of Pauzhetsky Hydrothermal System . . . . .	213
8.5	Brief Description of Other Hydrothermal Systems in Kamchatka . . . . .	219
8.6	Kuldur Hydrothermal System (Beyond Kamchatka) . . . . .	220
	References. . . . .	222
<b>9</b>	<b>Changeability of Pressure, Temperature, and Concentrations of Components in the Explored Hydrothermal Systems. . . . .</b>	<b>225</b>
9.1	Multilevel Fluctuations of Pressure and Temperature in Mutnovsky Hydrothermal System. . . . .	225
9.1.1	High-Frequency Dynamics of Fluid Pressure Measured at a Depth of Well № 30 . . . . .	225

9.1.2	High-Frequency Dynamics of Fluid Pressure Measured at a Depth of Well № 12 . . . . .	231
9.1.3	Low-Frequency Dynamics of Pressure and Temperature Measured at the Twelve Wellheads . . . . .	233
9.2	Variations of Pressure and Geochemical Indicators in Pauzhetsky Hydrothermal System. . . . .	235
9.3	Variations of Hydrochemical Composition in Kuldur Hydrothermal System . . . . .	239
9.4	Influence of Dislocations in the Earth's Crust upon Fluctuations in Hydrothermal Systems . . . . .	243
9.5	Interpretation of the Obtained Results in the Context of the Inversion Approach to Life Origin . . . . .	243
9.5.1	General Integration of the obtained Experimental Data. . . . .	243
9.5.2	Experimental Verification of the Proposed Origin-of-Life Scenario in Fluctuating Hydrothermal Medium . . . . .	244
	References. . . . .	247
<b>10</b>	<b>Organic Matter in the Hydrothermal Systems of Kamchatka Peninsula and Nearby Area . . . . .</b>	<b>249</b>
10.1	Method of Organic Compound Analysis. . . . .	249
10.2	Detected Organic Compounds in Hydrothermal Systems of Kamchatka and Nearby Area . . . . .	251
10.2.1	Mutnovsky Hydrothermal System . . . . .	251
10.2.2	Uzon Hydrothermal System. . . . .	256
10.2.3	Pauzhetsky Hydrothermal System . . . . .	260
10.2.4	Kuldur Hydrothermal System . . . . .	260
10.3	Organic Matter in Hydrothermal Systems of Kamchatka Analyzed by Other Researchers . . . . .	265
10.4	Generalization: Homologous Series of Organics in Hydrothermal Systems of Kamchatka and Nearby Areas . . . .	266
10.5	Interpretation of the Obtained Results in the Context of the Inversion Approach to the Origin of Life . . . . .	268
	References. . . . .	270
	<b>Index . . . . .</b>	<b>273</b>

Thermodynamic Inversion

Origin of Living Systems

Kompanichenko, V.

2017, XIX, 275 p. 85 illus., 48 illus. in color., Hardcover

ISBN: 978-3-319-53510-4