Preface

The author's *inversion* concept of the origin of primary living systems has been outlined in this book. It proposes revolutionary (not evolutionary) transition of prebiotic microsystems into simplest forms of life through the *thermodynamic inversion*. Such transformation demands overcoming the *negentropy barrier* that follows from the 2nd Law from Thermodynamics. The inversion implies the transformation of non-living prebiotic microsystems with prevalent entropy (over free energy and information) into primary living microorganisms with prevalent free energy and information (over entropy). After the inversion, the appeared living units (probionts) possessed the surplus free energy and information being not under the entropy pressing. Such transformation resulted in arising of new, i.e., biological, thermodynamic method of organization. Using the surplus over-entropy free energy and information, probionts acquired the ability for *active* existence in the environment.

The key steps of the inversion concept elaboration have been expressed in the preface. Following them, the train of thought of the author will become clear, as well as a distinction of his concept from other theories in the origin-of-life area. For the whole period of this investigation, the author's attention was focused on the attempt to understand just a *moment* of the transition of a certain prebiotic microsystem into a primary form of life, because the moment (or short period) embraces both the end of existence of non-living chemical microsystem and the beginning of its living state.

There are many approaches in our attempts to understand the origin of life. Their variety is caused by the baffling complexity of this field that embraces a lot of interdisciplinary knowledge. This is a reason why strict criteria in the given scientific area are difficult to formulate. For instance, by now, the following three required conditions for the origin of life have been accepted: availability of organic substance, source of energy, and aqueous medium. However, there are not reliable criteria for their further clarification. Thus, various researchers consider ocean, submarine hot vents, continental hot pools, groundwater aquifers, soda lakes, drops of rain, and even ice cover (i.e., all planetary water systems) as potential aqueous media for the origin of life. Apparently, the origin-of-life science needs some additional reliable criteria to reveal and characterize the most appropriate cradle of life.

One more obstacle on the way to understanding the origin of life consists in unsuccessful experimental attempts to obtain a *living* cell so far. Manifold experimentally obtained protocells, or artificial cells, do not display the ability to self-evolve as living units (this problem has been considered in Chap. 1). Apparently, this obstacle reflects availability of a principal difference between non-living and living types of natural systems. However, at the regular ISSOL conferences on the origin of life (www.issol.org), there is no section devoted to differentiation and comparison of these types of natural systems through definitions of life or key properties of living systems. The set of sections at them includes not so fundamental topics: prebiotic environment, RNA World, protocells, system chemistry, first cell, etc. The definitions and properties of a living system are discussed at the special Workshops on Life. One of them was held at the University of Modena (Italy) in 2000. The scientists offered several tens of definitions of life and/or sets of key properties of living systems (usually 3–5). However, the proposed sets of the properties were *not* based on the comparison of living and non-living systems that is necessary to reveal actually *unique* biological attributes. As for the definitions, any of them cannot be exhaustive due to extraordinary complexity of life.

The first question which the author put before himself in this way was simple: What is a living system? And how it can be characterized in the context of its distinction from non-living systems? The origin of *what* system we try to explain? Thinking over this question, the author led to the following conclusion: The problems of life defining and origin are inseparably related, like two sides of the same coin. On the one hand, we cannot solve the problem of the origin of life, until we understand the origin of what kind of system we strive to comprehend. On the other hand, we cannot characterize a living system beyond the context of its origin, because just at this moment the key properties of biological systems appear. Therefore, both the problems should be investigated in framework of the common concept.

It was a starting point of the inversion concept elaboration. The comprehensive comparison of non-biological and biological systems was carried out on the basis of the three universal notions—entropy, free energy, and information (see Chap. 2). The use of these basic notions turns the origin-of-life problem into the astrobiological context, because they refer to the entire Universe, not only to our planet. The active non-biological systems, like a star, active planet, magmatic or hydrothermal system, simply *dissipate* free energy into surroundings. Unlike them, the biological systems actively *extract* free energy from the environment and concentrate it. In this way, the principal distinction of biological systems consists in availability of *over-entropy* free energy and information, because balances "the contribution of free energy to the contribution of entropy" and "the contribution of information to the contribution of informational entropy" in them are positive. So, the principal transition from non-living to living systems in the thermodynamic context comes to the inversion of the balances—from negative to positive. Developing this approach, along with generalization of the biological properties distinguished by other researchers, the author formulated 31 fundamental properties of biological systems, including 19 unique (which are not peculiar to any other natural system) and 12 non-unique ones.

The non-unique fundamental properties were used to theoretically investigate the gap between the living and some non-living (physicochemical) systems also possessing similar non-unique properties. All living systems are nonequilibrium. In the framework of the nonequilibrium thermodynamics, Ilya Prigogine with the followers distinguished the specific class of dissipative structures that can be considered as intermediate between "non-life" and "life." A key notion of the theory of dissipative structures is a bifurcation, i.e., radical and unpredictable transformation of a (chemical) system under far-from-equilibrium conditions. Some scientists tried to attract the notions from the theory of dissipative structures (and related synergetics) in their own attempts to explain the origin of life. It is peculiar that just at the period of *unstable* bifurcate transition a chemical system acquires some new "bifurcate" properties, which are at the latent background of life: heterogeneous structure, continuous re-arrangement of molecules, cooperative events, and incessant exchange with the surroundings. The principal obstacle for further application of this theory to investigation of the origin-of-life process is the following: These bifurcate properties, which are necessary for life, disappear as soon as the bifurcation is over and the system transits into a certain new *stable* state. Theoretically investigating this contradiction, the author found only opportunity for a chemical system to sustain the bifurcate properties allowing evolve to life: if the system *oscillates* around the bifurcation point staying in the intermediate position (relatively stabilized) between the initial stable state and new stable state (see Chap. 3). In this paradoxical state "stabilized instability," the system irreversibly evolves from the initial stable state (Past) into a certain new stable state (Future) through boundless oscillations near the point of bifurcation (Present), in the case of favorable external oscillations of parameters. These thoughts express the basis of the *bistate hypothesis* (a part of the common inversion concept) that was published in 2004–2008. According to the author's approach, just through oscillations around the bifurcation point (accompanied with varying contributions of entropy, free energy, and information), prebiotic microsystems on the early Earth underwent thermodynamic inversion. The high-amplitude oscillations of the balance "free energy/entropy" from time to time brought huge temporal contribution of free energy that allowed the microsystems jumped over the negentropy barrier and launched the initial biogeochemical cycles. The reaction of the thermodynamically inversed microsystems—already living units (probionts)—to stress from the environment inversed as well: it became forestalling (instead of retarding) and intensified (instead of weakened).

Necessity of multilevel oscillations of parameters (including a high-frequency constituent) in the cradle of life is a consequence of the inversion concept. The author considers this notion as the fourth required condition for the origin of life. It allows to localize the most appropriate medium for the origin of life: only hydrothermal systems possess such changeable conditions (this aspect has been described in Chaps. 4 and 9).

One more important question that needs to be explained is the emergence of bioinformation. Most scientists do not try to draw a separating line between information in physical and biological systems, although their distinction is obvious. Plenty of experiments on prebiotic chemistry have been demonstrated spontaneous synthesis of long chains of nucleotides and amino acids, comparable with ones in living cells. However, their similarity is only chemical: The chains synthesized in protocells, or artificial cells (for instance, RNA macromolecules), do not contain information that can be considered as biological. So, the often asked question "How pre-RNA World existed?" in the origin-of-life context is not sufficient. According to the author's opinion, the more relevant question in this way is asked by David Abel: "How did an inanimate environment prescribe and process organization, control and regulation of protocellular metabolism, and eventually primordial life?" This question can be continued: What is the source of biological information in primary living units? The idea that can be considered as the author's attempt to respond to this question has been developed in the Chap. 6. Briefly, a changeable hydrothermal medium executes a certain influence upon containing organic microsystems. In the informational context, the influence may either increase uncertainty in a state of the microsystem (this corresponds with contribution of informational entropy), or decrease it (contribution of information). Incessant changes in the medium execute incessant influence upon the microsystem penetrating in them as continuous external informational tracks. In accordance with the Le Chatelier principle, the microsystem must respond to external actions by means of own counteraction. In the considering context, the counteraction should represent itself the continuous internal informational tracks directed outside. In fact, the internal informational track is a *reflection* of the previously penetrated external track. Interaction between the reflections within the prebiotic microsystems, being in fluctuating medium, generated the "Reflected World". Initial sparks of bioinformation appeared within the Reflected World even in oscillating prebiotic microsystems, but the proper bioinformation (possessing foresight, or purposefulness) arose during the thermodynamic inversion, when the microsystems/probionts acquired the over-entropy information and became active with respect to the environment.

The next step of this work consisted in elaboration of the origin-of-life scenario on the early Earth, using the described above general ideas and mechanisms that can be applicable for other habitable worlds as well. The proposed Earth's scenario concerns conditions in the maternal medium, direction of prebiotic chemical evolution, arising of metabolism, formation of primary cellular structures, appearance of bioinformation circulating between the functional sequences of proteins and nucleic acids, formation of codes, etc. (Chaps. 5–7). According to the author's approach, the prebiotic evolution was irreversible and proceeded in hydrothermal fluid rising to the surface. The conditions in this medium were characterized by combination of gradual fall of temperature and pressure with approaching of the fluid to the surface (irreversible process), and multilevel oscillations of temperature, pressure, concentrations of compounds, electric potentials, pH, Eh, etc. (reversible process). Such fluctuating conditions facilitated continuous and directed recombination of self-assembled molecular aggregates within the temperature range from 300–200 °C (prebiotic zone) up to 100–70 °C (biotic zone) in the upper part of hydrothermal systems. In the biotic zone, associations of the oscillating (bistate) prebiotic microsystems were thermodynamically inversed into primary communities of interacting living units—probionts.

Some data to support and itemize this scenario were obtained by the author with collaborators in course of experimental exploration of hydrothermal systems on the Russian Far East, first of all in Kamchatka Peninsula (Chaps. 8–10). That research was aimed to analysis of organic compounds in hydrothermal fluid and characterizing of oscillations of pressure and temperature.

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