Appendix 1
Matrix Presentation of Cascade of Countercurrent Reactors of Mixing

It is a well-known fact that countercurrent interactions are preferable for the effective mass transfer between different phases to cocurrent technique. However, calculations of the efficiency of such interactions are fairly difficult. In the normal case, one assumes that the system of interactions comprises a cascade of some simple reactors of mixing, in which the interacting phases are mixed until getting to the local equilibrium. After that, the phases are separated and transported to other reactors, in which the procedure repeats some times.

Calculative simulation of such countercurrent cascade is allowed only if the number of reactors is specified, e.g., three or five. In such case, one can always write a system of equations for each reactor in the cascade; such system of equations is consistent and always has the single solution. However, if one is interested in the estimation of the optimal number of reactors in such cascade, the problem becomes too difficult.

The proposed matrix method for the presentation of cascade of countercurrent reactors of mixing aims to bring a tool for the description of mass transfer in such cascades in matrix form, that allows

- Simplification of writing systems of equations for their modeling
- Simplification of writing computer programs for the simulation of such cascades
- Simplification of the procedure of the optimization of cascades of countercurrent reactors.

The proposed solution is not applicable (without modifications) to systems, in which mass transfer is accompanied with heat transfer or chemical transformation.

I. DEFINITION OF PROBLEM

Let us consider a cascade of countercurrent reactors of mixing, in which fluid is mixed to high-dispersion solid phase or just two different fluids (in most cases, gas–liquid) are mixed, on purpose to carry out some mass-transfer processes, e.g., absorption, adsorption, desorption, degassing. The principal scheme of such cascade is given on Fig. A1.1 for the case of gas–liquid mixing.

The considered cascade comprises $N_c = 3$ reactors of mixing, in which gas interacts with liquid (for example, in the process of absorptive separation of gas mixture). The gas mixture is involved through a pump into the first reactor and there mixed to the liquid achieving to pass through the cascade. Then, the liquid leaves the cascade, while the gas comes to the next reactor, where the procedure repeats. After mixing N_c times, the gas is removed from the cascade system.

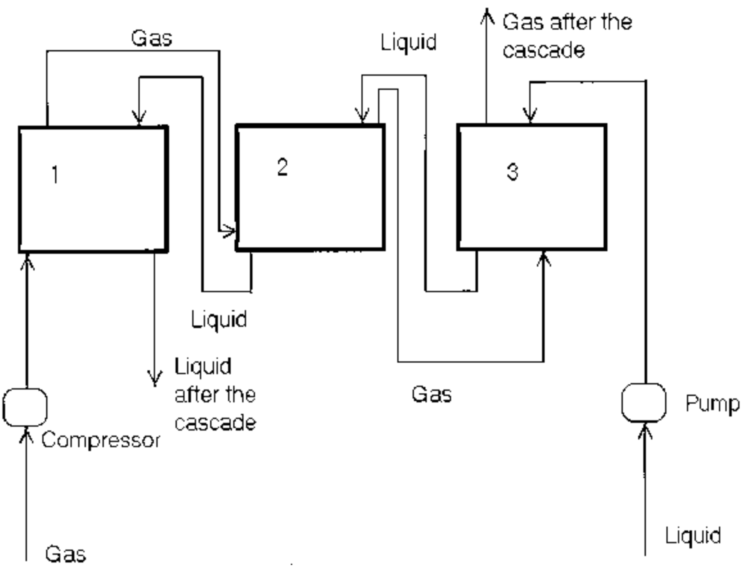

FIG. A1.1 Scheme of cascade of countercurrent reactors of mixing for gas–liquid interactions.

Of course, the real value of N_c can be 2, 3, 4, 5, ..., while the interacting phases can be not only gas–liquid but also gas–solid powder and even liquid–solid or two immiscible liquids; the physics of the mass transfer is always very similar, while the technique for such processes becomes much more complex.

II. SOLUTION

Let us assume that the fluids contain K_v volatile components able to reversible transfer between the phases. Each reactor allows the obtainment of the equilibrium between the phases. The principal scheme of interactions in kth reactor is given on Fig. A1.2.

The liquid phase comes from $(k+1)$-th reactor to the head of kth reactor. The amount of ith component in the liquid is W_{+iLk}. However, the same component comes also from $(k-1)$-th reactor to the bottom of kth reactor in the gas phase, the amount of ith component being W_{+iGk}. Since no chemical transformation is allowed, ith component leaves kth reactor: from the bottom with the liquid phase (W_{-iLk}) and from the head with the gas phase (W_{-iGk}). We also notice that, as follows from Fig. A1.1, $W_{-iGk} = W_{+iG(k-1)}$ and $W_{-iLk} = W_{+iL(k+1)}$. The balance of ith component is given by the following equation:

$$W_{+iLk} + W_{+iGk} = W_{-iLk} + W_{-iGk} \tag{A1.1}$$

The distribution of ith component between both phases leaving kth reactor is given by the following equation:

$$W_{-iLk} = \beta_{ik} W_{-iGk} \tag{A1.2}$$

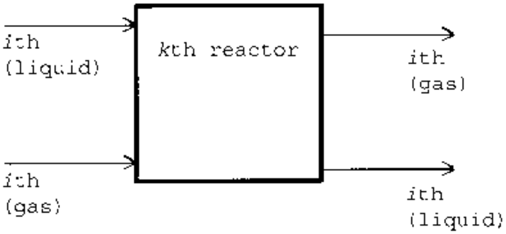

FIG. A1.2 The principal scheme of interactions in kth reactor.

Let us suggest that the process of interactions in kth reactor can be presented in the following matrix form:

$$\vec{W}_{i(k+1)} = B_{ik}\vec{W}_{ik} \tag{A1.3}$$

$$\vec{W}_{ik} = \begin{bmatrix} w_{+iGk} \\ w_{-iLk} \end{bmatrix} \qquad \vec{W}_{i(k+1)} = \begin{bmatrix} w_{+iG(k+1)} \\ w_{-iL(k+1)} \end{bmatrix} = \begin{bmatrix} w_{-iGk} \\ w_{+iLk} \end{bmatrix}$$

From Eqs. (A1.1)–(A1.3) we obtain

$$B_{ik} = \begin{bmatrix} 0 & \beta_{ik} \\ -1 & (1+\beta_{ik}) \end{bmatrix}$$

The process in the cascade entire is described as the following algebraic equation:

$$\vec{W}_{i(N+1)} = \left[\prod_{k=1}^{N} B_{ik}\right]\vec{W}_{i1} \tag{A1.4}$$

If $B_{ik_1} = B_{ik_2}$ (for all k_1, k_2)

$$B_i^N = G_i(N) = \begin{bmatrix} \gamma_{i11} & \gamma_{i12} \\ \gamma_{i21} & \gamma_{i22} \end{bmatrix}$$

$$\gamma_{i11} = -\beta_i \frac{1-\beta_i^{N-1}}{1-\beta_i} = -\beta_i \sum_{k=0}^{N-2} \beta_i^k$$

$$\gamma_{i12} = \beta_i \frac{1-\beta_i^{N}}{1-\beta_i} = \beta_i \sum_{k=0}^{N-1} \beta_i^k$$

$$\gamma_{i21} = \frac{-(1-\beta_i^{N})}{1-\beta_i} = -\sum_{k=0}^{N-1} \beta_i^k$$

$$\gamma_{i22} = \frac{1-\beta_i^{N+1}}{1-\beta_i} = \sum_{k=0}^{N} \beta_i^k$$

The proper eigenvectors for the matrix B_i are

$$\frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix} \qquad \frac{1}{\sqrt{1+\beta_i^2}}\begin{bmatrix} \beta_i \\ 1 \end{bmatrix}$$

the corresponding eigenvalues, respectively, β_i and 1.

Appendix 2
"Big" and "Little" Phenomena by Self-Organization— Analogy of Pore Formation with Beginning of the Universe and Life (Chapter 3)

I. BEGINNING OF UNIVERSE BY SELF-ORGANIZATION

(a) General Aspect. Numerous models of the formation of the universe try to explain the beginning of the universe and predict general tendencies of its further evolution. The principal problems which needing a solution by astrophysics are

What was the cause for beginning of universe?
Does the universe expand? If yes, whether the expansion of the universe is unlimited or followed by collapse?
Is there any cosmos outside universe?
Since the principal physical laws are symmetric and do not distinguish past and future, what is the cause of the specified direction of the time arrow?
What were the principal mechanisms of formation of heavy complex particles and nuclei?

(b) Historical Aspect. The problem of beginning of universe attracts not only scientists but also philosophers since ancient ages. The science before the 20th century assumed universe having no principal changes with time. The situation changed after the Einstein general theory of gravity was applied to universe. It was concluded that the universe parameters change with time. Particularly, about 12 billion years ago universe began due to an explosion (big bang) of a very massive singularity.

(c) Models of the Universe Formation. The main problem in studies of the universe formation consists in the impossibility of a direct experimental test of theoretically obtained results. Therefore, all studies in this field are theoretical, and the interpretation of available experimental data is very important.

(d) Big Bang: Closed Model of the Universe. In first microseconds of big bang, the temperature of the universe was so high that complex and massive elementary particles were formed. Then, the temperature decreased, and elementary particles formed nuclei of chemical elements (phase of *nucleogenesis*). The further expansion of the universe and the reduction of the temperature resulted in the appearance of nuclei of galaxies. The evolution of galaxies, accompanied by the further expansion of the universe and the decrease of the temperature of cosmos (background radiation temperature), led to formation of star systems, planets, and other cosmic bodies. Some researchers conclude that big-bang model of universe requires special initial conditions: the early universe was highly homogeneous and isotropic even though there existed causally disconnected regions (horizon problem) [1–6].

In principle, the theory of big bang answers most of above questions, but not all. First of all, the origin of the primary singularity is not clear. Was it a stage of cyclic evolution of the same universe (in the closed model of the universe) or a product of evolution of exterior cosmos (in the open model of the universe)?

Though the concept of big bang is the most widespread and recognized in astrophysics, not all specialists accept it. Some authors suggest alternative theories and deny the main assumptions of big bang theory and even general relativity, based on some results obtained due to observations of recently created galaxies, quasar–galaxy associations, etc. [7]. The existing theory of big bang cannot sufficiently solve some problems, comprising accidental superposition of galaxies and quasars with different red shift, problem of the density of the universe, and some others. Most of such arguments seem to concern first of all not the main idea of big bang but several of its sequences and related interpretations. Nevertheless, it seems obvious that experimental astrophysical data contain several contradictions complicating the image, and no existing model allows complete and clear solution of the mentioned problems. According to the opinion of several specialists, even if the theory of big bang is correct in principle, that stays in stagnation and needs principally new ideas [8,9].

(e) Closed Model. This model assumes that the space of the universe is closed; the universe has a finite lifecycle and should disappear again in no less than 100 billion years. Such assumption, whether or not applicable to the universe now, undoubtedly described some properties of the universe when this was a singularity and then, in the first period after big bang, because then the relation "mass–size" corresponded to black hole formation. However, black hole, though characterized by closed space, has energy and/or mass exchange with the environment. Is the same valid about the closed image of the universe? What about the time arrow? According to Hawking [3,4], the closed universe should have cycles of expansions and collapses, and the collapse phase might have the opposite direction of the time arrow (from future to past). If the time arrow does not change, does the entropy rising change the properties of the universe on each cycle? Can ever the cyclic evolution of the universe be transformed to irreversible expansion?

(f) Big Bang: Open Model. This model assumes that the space of the universe is open. As it is noted above, at least the first period of the existence of the universe was described by the closed model, hence, the open model has limited validity in any case. However, the primary singularity might be result of the evolution of exterior cosmos, and big bang could be accompanied by several interactions with exterior cosmos. In any case, the problem of exterior cosmos appears not only in the open model but also in the closed one.

We note that the analysis of the current mass characteristics of the universe gives preference to the open model.

(g) "No-Big-Bang" Theory. Though this concept is presented by minority of researchers, its versions are much more multiple than models of big bang. In the mathematical aspect, this is because the classical general relativity (GR) theory does not lead to some restrictions for admissible values of energy densities for gravitating systems. Different cosmological models and collapsing systems in GR have singular states with divergent energy density and curvature invariants [10].

Opponents of the big bang concept believe it to have shifted its ground frequently under observational constraints. Many of its present deductions are seen to be based on untested physics and unobservable events of the very early universe, while its beginning in a space–time singularity indicates its incompleteness as a physical theory. They may seem to claim sometimes that there is a conspiracy to hide these objects, but they themselves do not quote examples of galactic clusters made of normal galaxies and quasars all having the same red shift and therefore supporting the big bang.

(h) Self-Organization Theory. This theory can be considered as a development of the open model of the universe in the big bang theory. The main idea of the self-organization theory consists in the assumption that thermodynamics is applicable to cosmos before beginning of universe. Then big bang is considered as a process increasing the combinatorial entropy of cosmos [11], and the mechanism of bing bang is very similar to micropore formation (compare to Chapter 3).

Primary matter of cosmos before the universe formation is characterized by the following observed properties:

Primary matter consists of light particles that cannot be distinguished but for their energy only.
Particles of primary matter cannot be distinguished if the difference in their energy values is less than several threshold of distinguishability.
Primary matter is able to self-organization, which might result in the formation of the universe.

A self-organization process in a primary matter system leading to formation of a cell increases the combinatorial entropy of the system, and the additional entropy obtained due to it [11].

The self-organization theory assumes that the entropy rising is the main criterion determining the evolution of primary matter. During big bang, the nucleus of the future universe (singularity) overcomes a critical state characterized by minimum of the local entropy of the near part of the system, that is caused by formation of regular fluxes. Overcoming of the entropy minimum is due to certain fluctuations [11].

The first stage of big bang is related to formation of regular fluxes in form of a sphere, then transformed to the protection layer. This prevents processes of randomization able to destroy the network of self-organization. Near the protection layer containing the freshly captured high-energy particles of primary matter, processes of self-organization of matter are most intensive, while the central zones of universe are characterized by minimum of free energy; there, processes of self-organization are slow. The further expansion of the universe led to growth of the passive nucleus and decrease of its temperature because of various self-organization processes, comprising formation of galaxies, stars, etc. [11].

Now, let us consider the connection of the considered theories with known experimental facts.

(i) Background Radiation. This is considered as the main confirmation of the big bang cosmology. The background radiation (about 3 K) gets an exact explanation in each of considered versions of big bang as its sequence. The self-organization version of the open model of big bang supports such explanation but suggests that the temperature of the background radiation is different through the universe: minimum at the center, maximum at the frontier.

(j) Red Shift. The existence of the red shift in the spectrum of stars gets a similar explanation in all versions of big bang theory: galaxies "run off" the center of universe, as a sequence of big bang. Versions of no-big-bang concept sometimes suggest that the red shift is found because of observational constraints [6].

(k) Young Galaxies. This is one of most serious arguments against the big bang concept. In the closed model of big bang the explanation of this phenomenon is too difficult: if all universes formed in the big bang and galaxy nuclei appeared in the first period, young galaxies cannot exist.

In the open model of big bang, the existence of young galaxies may be explained as a result of the interaction with the exterior cosmos. Moreover, the self-organization version of the open model assumes that different parts of the universe should have different age.

In no-big-bang concept, young galaxies do not make problem.

(l) Time Arrow. The irreversibility of time gets a very simple explanation in the self-organization model of universe. As in classical thermodynamics, it is assumed that the time arrow is determined by rising of entropy resulting from self-organization processes and various interactions inside universe and with the exterior cosmos. In the traditional open model, the time arrow can be related to the irreversible expansion and interactions with the exterior cosmos. In the closed model, that is a problem: when the universe expands, the time arrow can be related to the expansion, but the stage of collapse, in such image, should turn back the time. Otherwise, the universe should get irreversible changes on each period expansion–collapse. In no-big-bang concept, this point is very problematic.

(m) Light Nuclei. For all versions of big bang theory, the abundance of light nuclei in universe is easily explained: those were preferably formed in first moments of big bang. In the no-big-bang concept, the explanation depends of the kind of the used version.

TABLE A2.1 Comparison of Existing Models of Beginning of the Universe with Known Experimental Facts.

Problem to solve	Big bang (closed model)	Big bang (open model)	Self-organization model	No big bang
Background radiation	+[a]	+	+	−[b]
Red shift	+	+	+	+
Density or mass	+/−[c]	+	+	+/−
Young galaxies	−	+/−	+	+
Time arrow	?[d]	+	+	?
Light nuclei	+	+	+	+/−

[a]+ connection is good.
[b]− connection is not good.
[c]+/− connection is problematic.
[d]? explanation is difficult.

(n) Methodological Aspect. As follows from the Table A2.1, the self-organization theory has several preference, due to having advantages of the open model without most of its drawbacks. In the experimental aspect, the self-organization theory predicts a significant divergence in values of density and background radiation temperature, which can be tested in the future. As most of existing models, the self-organization theory can be used for evaluation of fundamental constants.

II. BEGINNING OF LIFE BY SELF-ORGANIZATION

(a) General Aspect. Though the great importance of the problem of beginning of life, the existing theories did not still get a sufficient experimental support, meant a living organism formed artificially in a mineral environment.

The enormous importance of problems concerning the beginning of life makes necessary a review of existing theories on this matter, analysis of their advantages and disadvantages, their connection with known experimental facts, and their applicability to problems related to beginning of life.

(b) Beginning of Life on Early Earth and the History of the Problem. The problem of beginning of life interests not only researchers but also philosophers since ancient age. Attempts of its solution are found in all religions, all philosophies. Really scientific studies of this matter began the same time when basic principles of evolution theory were formulated: evolution from primitive and simple to developed and complex life meant also several minimum from which the evolution started.

Until recently, majority of biologists believed that the age of life is about 50% of the age of Earth. Recent discoveries in ancient terrains make us to conclude that life existed during at least 80% of the history of Earth. Microscopic fossils and fossils of microbial mats are found in sedimentary rocks in western Australian and southern African terrains (dated about 3.5 billion years ago) and Isua formation in Greenland (3.8 billion years ago) [12].

Thus, life began when conditions of existence were very strict, absolutely different from those in our habitat. Even the content of carbon in the environment was very low [12–15]. In addition to natural difficulties for life beginning, the conditions of the early Earth provided catastrophes that might seriously obstacle and even stop the development of life. Such catastrophes may be divided into three categories: "normal" events related to season changes (hurricanes, floods, etc.); geological cataclysms: volcano activity, earthquakes, their sequences; cosmic cataclysms: changes in the solar activity, impacts of cosmic bodies.

In many cases, catastrophes might be fatal for the first living organisms on the early Earth. Moreover: impacts of asteroids like Vesta, Pallas, or Hygiea might cause such increase of the temperature on the Earth that the ocean would be evaporated [12]. On the other hand, the catastrophes (especially cosmic ones) might stimulate amino acid formation and furnish biogenic elements [12,13].

Most of existing models of beginning of life are based on the astrophysical concept of evolution of cosmic bodies, according to which planets began as high-temperature massive objects with aggressive atmosphere, intense tectonic changes and large thunderstorm activity. For example, the atmosphere of the early Earth consisted mostly of hydrogen, methane, ammoniac, carbon dioxide, etc. According to experiments of S. Miller (1953), electrical discharges in atmosphere should cause formation of amino acids dissolved in water of the primary ocean. In 1957, Ph. Abelson showed possibility of production of more twenty amino acids and some proteins. Spontaneous polymerization allows formation of various macromolecules, comprising ribonucleic acid (RNA). In 1980s, it was demonstrated that RNA were capable to play role of enzymes (Dyson, 1985; Gilbert, 1986; Joyce, 1991; Cech, 1993). These results may be interpreted as RNA origin of the first living organisms [12,15].

(c) Creation Theory. The main idea of the creation theory consists in the suggestion that the life is created by upper forces. Historically, the creation theory was the first attempt of explanation of beginning of life, based on the Bible. In the general sense, the creation theory comprises also a version that life on the early Earth was due to a super civilization. Such a version does

not seem absurd, but that does not solve the main problem (because also super civilization should begin from a primitive life), and does not provide more information than the cosmic theory (see below). In the further analysis, we do not consider the creation version.

(d) Cosmic Theory. The cosmic theory considers the option of transportation of microorganisms due to an interplanetary motion of cosmic bodies. C. Sagan, C. F. Chyba, P. Thomas, and L. Brookshow (1990) modeled a collision of a bacteria-carrying comet with Earth and found that only exceptional conditions might allow organics to survive [12]. However, it was found possible that microorganisms could migrate between Earth and Mars in the debris ejected from the vicinity of giant impacts [12].

The cosmic theory does not solve the main problem: What was the mechanism of beginning of life? However, this theory enlarges the spectrum of conditions in which life might begin: in addition to early Earth, many of cosmic bodies that existed about 3.8 billion years ago and earlier.

(e) Oparin (Coacervate Droplet) Theory. The coacervate droplet theory suggests that the formation of first living organisms includes a step of separated droplets, as in an emulsion prepared by mechanical mixing of a complex solution with another, these being mutually insoluble or having limited mutual solubility. Such system is called *coacervate droplet* and characterized by developed surface. A coacervate drop could be formed, e.g., from a homogeneously constructed polymer consisting of a protein and a polyglycoside. Droplets have property of selective absorption and accumulation of several substances. Combined with the eventual formation of amino acids and proteins, the mass transfer in the droplets might become a mechanism for spontaneous evolution of nonliving structures to primitive life [15]. Coacervate drops can be considered as models for precellular structures [16].

In the Oparin model, the evolution of carbon compounds is postulated to be the basis of the origin of life on Earth and elsewhere. This process can be divided into three steps [14–20]:

- Formation of primitive organic substances, i.e., hydrocarbons, as in meteorites (carbonaceous chondrites), the abiogenic formation of primitive organic substances (such a situation is widespread in space)
- Formation of the primary soup: an aqueous solution of different and complex organic substances, monomers, and polymers, as well as polypeptides and polynucleotides
- Formation of complex macromolecular open systems, which are the primary forms for the origin of primitive creatures through evolutionary processes

In contrast to modern proteins, the high-molecular-weight polymers in the primary soup had only an accidental order of monomers in the chain. Coacervate droplets could have been formed in the primary soup from a simple mixture of randomly constructed polypeptides and polynucleotides. As soon as a certain level of polymerization had been reached in this mixture, the droplets could appear. These coacervate drops would be very concentrated and able to selective absorption of different low-molecular-weight substances from the external solution. If any of these substances are able to catalytic stimulation of the reactions in these drops, they become open systems. Such open macromolecular systems could easily have formed in the primary soup, owing to the incorporation of different organic and inorganic catalysts from the external medium; such systems are called *protobionts*. Prebiological selection may have ensued based on the growth rate and competition of the protobionts. Natural selection continually filtered out undesirable protobionts, which left only a few efficient ones, containing coenzymes we know today. Finally, the specific, strictly ordered association of mononucleotide residues in large molecules like DNA and RNA could have arisen only during prolonged evolution of living systems [21,22].

A serious disease of the coacervate droplet theory consists in difficulty of finding such droplets in nonliving nature, in which majority of liquids is presented by water or aqueous solutions, whereas non-aqueous liquids (e.g., petroleum) are mainly of organic origin and seem products of living organisms. As a result, the above-described process has a very low probability.

(f) Self-Organization Theory. The self-organization theory can be considered a development of the coacervate droplet theory. The principal difference between them consists in the suggested mechanism of the formation of the interface. Instead such event as mixing of two nonmiscible liquids, the self-organization theory suggests Benard-like mechanism that could easily realize, e.g., in the primary ocean near a volcano, or just because of intense solar radiation [23]. Introducing the self-organization mechanism into the explanation of beginning of life, this theory puts such exceptional phenomenon as life into the range of other processes related to self-organization.

The main idea of the self-organization theory is that beginning of life was thermodynamically favorable for mineral nature. The thermodynamic criterion of beginning of life in a planetary system consists in the following suggestion: due to formation of a living subsystem, the Earth system gets a profit in entropy. The formation of complex branched macromolecules contributes the rising of the entropy of the environment. Processes of amino acid polymerization and destruction do not need much energy and can take place not only due to electrical discharges but also due to solar radiation. Another thermodynamic factor stimulating beginning of life was formation of protein cells, which increased the combinatorial entropy of the ocean [23].

Notice the analogy with the formation of porous clusters in processes of micropore formation (see Chapter 3): in the role of the continuous phase is the primary ocean, while protein cells are very similar to micropores.

An intermediary step could comprise RNA-based cells.

After the formation of proteins, the next stage of life beginning comprised the formation of internal flows in protein systems. The change of free energy in polymerization processes was related to the formation of macromolecules and internal flows in the protein structures.

The self-organization theory suggests the following mechanism of evolution of amino acids to living systems [23]:

Reversible polymerization of amino acids
Formation of global protein heat engine
Involving oxygen in the system of global protein heat engine
Self-organization of the global protein structure
Internal self-organization of protein cells and their transformation to self-reproducing biocells

An experimental test for the proposed model of life beginning could be accomplished as follows [23]:

1. Exploration of the equilibrium amino acids RNA and DNA in conditions of various destructive factors supposed to exist on early Earth (solar and electromagnetic radiation, temperature changes, poison chemicals, etc.). Expected information obtained includes conditions of formation of periodical heat engine.
2. Study of destructive influence of the mentioned factors for the estimation of extreme conditions under which the system does not lose its main properties. Expected information includes changes caused by different doses of destructive factors.
3. Exploration of the formation of Benard-like cells in primary soup, in comparison with ordinary Benard cells formed in water. Expected result is the formation of protein cells and spectrum of parameters in which these are stable.
4. Behavior of protein cells treated with mentioned destructive factors. Expected result is the interior self-organization of protein cells and formation of elementary biocells.

TABLE A2.2 Connection of Existing Theories of Beginning of Life with Experimental Facts

Problem to solve	Oparin theory	Cosmic theory	Self-organization theory
Opportunity for RNA-based life	+[a]	+	+
DNA as the base for life on Earth	+/−[b]	−[c]	+
Signs of life in ancient rocks	?[d]	+/−	+
Stability of life	+/−	?	+

[a]+ connection is good.
[b]+/− connection is problematic.
[c]− the model contradicts to the fact.
[d]? the problem was not studied enough.

Now, let us compare the considered theories to known facts (see Table A2.2).

(g) Opportunity for RNA-Based Life. In all considered theories, the existence of RNA-based life is not impossible. In the coacervate droplet theory, the chemical composition of both interacting liquids is important but not decisive, and RNA-based mass-exchange is well possible [12,15,24]. In the cosmic theory, the base for an extraterrestrial life is determined by the conditions on the planet where this life began, and options for nonprotein life are well open. In the self-organization theory, thermodynamics of self-organization does not give absolute preference to proteins.

(h) DNA as the Base for the Life on the Earth. Though RNA-based life does not seem impossible, it is the fact that the life on the Earth now is based only on DNA. It is difficult to find any explanation of this fact in the coacervate droplet theory, while for the cosmic theory the situation is much worse: if the life came to Earth from another planet, why not from two or three different planets with different bases for life?

In the self-organization theory, the explanation of thermodynamic preference (not absolute but relative preference!) for DNA is given by the fact that macromolecules of DNA and their combinations in proteins are more complex and allow more microstates—hence, structures based on them have more entropy [23].

(i) Signs of Life in Ancient Rocks. The old age of the life on Earth does not get appropriate explanation in the Oparin theory [14,15,21,22,25–28]. Since the probability of coacervate droplet formation was very low, it is very

TABLE A2.3 Methodological Aspect: Usefulness of Existing Theories of Beginning of Life for Further Studies

Opportunity for reproduction of life by mankind	+/−[a]	+/−	+[b]
Recommendations for experiments for reproducing life	−[c]	−	+

[a]connection is problematic.
[b]connection is good.
[c]connection is not good.

strange that the life could begin almost immediately after the formation of the early Earth. In the cosmic theory, the situation is not much better: though bacteria might eventually get onto the early Earth, the probability of such event is too low. However, for the self-organization theory that is a normal result: as soon as the primary ocean was formed and amino acids appeared due to electrical discharges, all the mineral nature stimulated the formation of complex amino acid–based macromolecules (for the reason of rising entropy).

(j) Stability of Life. In the cosmic theory, this problem is not studied. In the Oparin theory, the stability of early life is probably determined by the stability of the environment, while this question is not analyzed. In the self-organization theory, the stability of life against little perturbations of the environment is described by the stability of the solution of thermodynamic equations for cell [23]. This result, being applied to a microorganism, means reflex; applied to a group of living organisms, it means evolution [23].

(k) Methodological Aspect. All three theories conclude positively about the principal possibility for an artificial reproduction of life (see Table A2.3). However, the theory of Oparin finds the probability of success of such experiment very low (at least, for conditions close to the early Earth). The cosmic theory can be tested, e.g., by the observation of other planetary systems [29–31]. The self-organization theory suggests an experimental way for the reproduction of life (see Ref. 23).

III. "BIG" PHENOMENA AND MICROPORE FORMATION

In Chapters 3 and 5 we considered the self-organization aspect of micropore formation. Above we have analyzed (brief) the same aspect for beginning of the universe and life.

TABLE A2.4 Analogy Between "Big" Phenomena (Big Bang and Beginning of Life) and Formation of Porous Clusters in Processes of Micropore Formation

Criterion for comparison	Big bang	Beginning of life	Micropore formation
Exterior phase	Big cosmos	Early Earth	Continuous phase
Mechanism of the process	Evolution of perturbed big cosmos	Evolution of macromolecular components	Evolution of metastable solid phase
Driving force for the process	Increase of the entropy of big cosmos	Increase of the entropy of the early Earth	Increase of the entropy of the solid phase
Resulting cluster of interior phase	The universe	Biological cells	Porous clusters

Let us notify the following factors of similarity between the above "big" phenomena and the "little" phenomenon of micropore formation:

For all these phenomena, the notion of the exterior phase is applicable: for the universe it is big cosmos; for life it is nonliving matter, and for micropores it is the continuous phase.

In all cases, the mechanism of the main process has the thermodynamic origin. For universe beginning it is the relaxation of eventually perturbed big cosmos; for life beginning it is the polymerization and destruction reactions of amino acids, having the tendency to form temporary-dissipative structure because of day-night changes, while for micropore it is the relaxation of the unstable solid phase.

Driving force for all three processes is the entropy increase for the exterior phase.

The result of all three processes consists in the formation of several clusters of the interior phase: universe, living organisms, or microporous cluster.

The above analysis is illustrated by Table A2.4.

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