Chapter 9

Development of the Biosphere in the Context of Some Fundamental Inventions of Biological Evolution

Vladimir F. Levchenko, Alexander B. Kazansky and
Marat A. Sabirov

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73297

Abstract

Traditionally, the evolution of flora and fauna on the Earth as well as the evolution of their physical and chemical environment are considered separately. At the same time, when considering the global evolutionary changes, it becomes clear that the evolution of all these components occurs in close relationship and that they together constitute a unified evolutionary process. Thus, we should talk about their co-evolution and that the whole biosphere is a united functional system. In this chapter, we briefly discuss some of the major "inventions" of ancient life that are responsible for global biosphere transformations and which "worked" in the biosphere until now (photosynthesis, eukaryotic cell, multicellular organism, and the other findings). The evolution of the Precambrian life as well as the Phanerozoic stage of the biosphere evolution are considered in this context.

Keywords: evolution, co-evolution, ecosystems, biosphere, inventions of life

1. Introduction

Traditionally, when discussing biological evolution, specialists build independent evolutionary trees for different taxa, such as animals and plants, apart from the fact that many evolutionary events in each case would not have been possible without the concerted events in several macrotaxa. The evolution of life on the planet is the evolution of the entire biosphere as a united system [1–3]. For example, the emergence and development of higher flowering plants is interconnected with the development of pollinating insects. Classic examples of an ancient co-evolutionary relationship are lichens, which are a result of exo-symbiosis (mutualism type) of fungi mycelium and algae cells. More recent examples of symbiotic relationships are some species of ants and aphids, which are so deep that both cannot exist separately [4].

Moreover, the evolution of life on the planet occurs simultaneously with the transformation of biogenic habitat. Thus, in the geological timescale, it makes sense to consider the evolution of the biosphere as an integrated system, which includes not only the biota but also bio-inert and inert matter in terms of Vernadsky [1], as well as ecosystem, landscape, and the whole global planetary structure. Life as an active and most dynamic component of the biosphere permeates the entire environment. It gradually transforms environment and thereby changes the conditions of its own existence. However, bio-inert and inert matter, geological and landscape structure of the upper layer of the Earth's crust with a thickness of about 10 km (i.e., the biosphere) is much more inert.

Life with its activity quickly evolves and adjusts to the environment. Thus, there is a large temporal asymmetry between the processes of evolution of living and inert matter. The evolution of life changes in two ways: by spontaneous self-modification (genetic, epigenetic) and through accumulation of changes in the environment, partly caused by the activity of organisms themselves (ecological inheritance [5–7]). From this standpoint, the evolution of the biosphere consists of a sequence of leaps between qualitatively different stages. Each stage is related with some principally new "invention" of life, has a relatively long history of its own specific organization of its biogeochemical cycles, energy flows, and associated specific ecological relationships: producer (producents)-consumer (consuments)-reducer (reducents).

Small disturbances in balance of each such system caused by small changes of environmental conditions were usually compensated, thanks to adaptive evolution at the species level (appearance and disappearance of some species). At significant violations of the biogeochemical cycles, caused by external and/or internal reasons, global environmental crises took place, associated with mass extinctions of the traditional biological forms, replacing them with fundamentally new ones, the emergence and/or the wide dissemination of which was previously limited by competition.

It is easy to see that classical evolutionary phenomena of aromorphoses and ideoadaptations [8] are observed also at the biosphere level and almost simultaneously in different taxa, indicating the influence on the course of processes of co-evolution mechanisms. For example, the so-called great Permian extinction (end of Permian period, about 250 Mya, when more than 70% of species disappeared) dramatically decreased the total biological diversity [9]. This opened opportunities for the emergence of new forms, primarily in the Triassic.

As a rule, a number of forms of the earlier system do not disappear completely during crises. They are included in new ecosystems as representatives of evolutionary descendants of the more ancient biota. Moreover, despite significant evolutionary change, they usually are conserving successful evolutionary inventions of the past, and these findings allow them to "fit" into the new system of the biosphere. Modern biosphere utilizes many findings of ancient life and even could not exist without them. Among the main evolutionary innovations, which once established have not disappeared, and are used by living organisms of the contemporary biosphere, is the emergence of eukaryotic cells, which opened the road to evolution of multicellular organisms.

There are different ways of using the innovations of the past. One of the most striking examples is the discovery of the process of photosynthesis, which allowed terrestrial life to get out of the clutches of material resources, and the energy deficit of archaic biosphere that existed, apparently due to chemosynthesis. Photosynthesis gave the biosphere a huge gain in energy resources.

In order to be preserved, ancient life also changed its habitat. This is particularly noticeable in the case of bacterial forms of life. The traces of ancient biospheres surround us, and their numerous representatives are necessary for the existence of the modern biosphere, for example, the bacterial environment of the rumen of ruminants, where cellulolytic and other bacteria realize chemical transformations based on anaerobic processes—fermentation and decay of plant food components. The digestive system of mammals would be unable to digest plant food without help of endosymbionts—bacterial communities [10]. Thus, organisms with anaerobic metabolism, inhabiting once, apparently, the entire ancient biosphere, now exist in the form of microcosm in organisms of modern animals. Obviously, the evolution of the biosphere is reflected in mutually agreed evolutionary transformations of all life forms. Therefore, speaking about evolution of the biosphere, we should talk about biological co-evolution of all living on the planet. Important aspects—biochemical and physiological—of this process are studied in the framework of evolutionary physiology and biochemistry. However, since the co-evolutionary aspect is usually not discussed at all, many factors and evolutionary mechanisms often attract the attention of researchers who used to work at the organism and population levels.

The aim of this chapter is not to give a coherent and complete account of the events in the biosphere evolution (it is only because of the enormous amount of material that could be included in consideration) but touch only some general trends and some striking evolutionary events, reflected in contemporary forms of life. Our goal is to attract attention to biosphere aspect of the biological evolution [11], which often escapes researchers' notice. We will try to trace some of the most important innovations implemented in the process of evolution of life on Earth. These innovations, actively used by living organisms in both the past and the modern biosphere, were key endogenous factors of biosphere evolution as a whole system.

2. The early stages of the evolution of life

We know very little about the earliest stages of evolution of life on our planet. Most researchers believe that the life on the Earth appeared in the range of 3–4 Gya and was represented by prokaryotic organisms—Archaebacteria (at present allocated also another macrotaxa Archaea, which exists today, and from which, apparently, originated more complex prokaryotic organisms—[12, 13]). There is no doubt that by the end of the Archean (about 2.5 Gya), life was already widespread in the world, mainly in the aquatic environment. The oldest Archean prokaryotic biosphere probably used mineral resources available in the geospheres of the planet, and, in the first place, abiotic organic matter which is a non-renewable resource. Most likely, resources for this life were hydrocarbons that were typical for the crust and surfaces of many small planets in the solar system during its formation and during the early stages of evolution [14, 15]. As for the atmosphere, there is no consensus among geologists on this issue, and specialists suggest that it could be either predominantly methane, ammonia, or a mixture of carbon dioxide and nitrogen with a substantial admixture of methane and ammonia [16]. These hydrocarbons, especially liquid fractions, are possibly related to the so-called Archean and Proterozoic oil, which is poorly suitable for industrial use and has presumably abiotic origin. Sun has contributed to the existence of early life on Earth indirectly, mainly by supporting the chemical cycles and the overall temperature and climate balance of the planet.

About 2 Gya, there was a very important event which predetermined the direction of further evolution of life on the Earth: appearance, rise, and wide dissemination of photosynthetic organisms—cyanobacteria. With the appearance of a significant amount of atmospheric oxygen, ancient biota fundamentally changed because oxygen is poison for most anaerobic organisms, typical of the early Archean. There was the so-called Oxygen Catastrophe [17, 18]. Another—though perhaps no less important factor that contributed to a very rapid change of biota after the emergence of photosynthesis—was probably the exhaustion of available resources, that is, organic matter for the use by anaerobic organisms. You can imagine a variety of scenarios, up to the fantastic (e.g. burning out of hydrocarbons in an oxygen atmosphere) but there is no evidence in favor of any mechanism of the transition to the photosynthetic biosphere.

The result of the emergence and development of the first communities of photosynthetic and aerobic organisms was that biota has changed dramatically, and life and its evolution began to be related not only to the availability of resources of organic matter but also with the solar activity in the diapason of visible spectrum. With certainty, we can say that at this time already existed ecosystem biosphere organization with closed cycle of organic matter, which ceased to be a non-renewable resource. In addition to the phytoplankton in the ocean lived zooplankton [17, 18] and bacterial organisms. It is not difficult to conclude from the previous statement, it is this circular organization (i.e., producer-consumer-reducer) that defines and identifies up to the present time the main features of all forms of co-evolution of the biosphere life. We would also like to draw attention to the fact that, in this case, the organic matter of biotic origin, worked out by the organisms that preceded this "aerobic revolution," as well as atmospheric carbon dioxide have not disappeared and entered into a new metabolic cycle of the biosphere.

Approximately 1 billion years ago, in the life of the biosphere, there was another very important event: eukaryotic organisms appeared and after the phytoplankton crisis at the turn of Vendian and Riphean (about 800 Mya) came to dominate [18]. According to popular conception of symbiogenesis [19–21], they arose as a result of the merger of prokaryotic cells, one of which was to carry out functions of the nucleus. But the most important for the further evolution of life at the same time was the fact that eukaryotes were able to give rise to multicellular organisms. In contrast to the dense cell walls of prokaryotic cells, eukaryotic cell walls became more permeable, making possible a more intense and varied exchange of substances between organism and environment. In parallel, there was also a significant change in the whole system of cell receptors, necessary for the management of permeability, and principally new types of receptors appeared [22]. As a result, all this has contributed to origin of multicellular organisms (which was not possible in the case of prokaryotes) and accompanied with the structural and functional differentiation of individual cells or groups of cells. This

http://dx.doi.org/10.5772/intechopen.73297

was a necessary condition for the emergence of further tissues and organs with specific functions and features of their different structures. The emergence of multicellular organisms was, without doubt, a new revolution in the biosphere. By the beginning of the Cambrian (about 550–570 Mya), which is considered as the beginning of "the era of advanced life," the oceans were already home to many species of multicellular plants and invertebrate animals.

Exact period of coming organisms ashore is difficult to date because the accidental getting of organisms to coastal, small-scale and temporary existing reservoirs, where they could exist for some period, was not an exceptional event. In the upper Vendian (Ediacaria), in Cambrian, and even Ordovician periods reigned the so-called bacterial mats based on cyanobacteria communities. They covered shallow waters, filling intermittent irregularities of land. However, it is well established that in the Silurian period already existed "true" terrestrial multicellular plants with a complex structure and stem—psilophytes—and to the Carboniferous period the plants fully settled on land.

Further evolution of life on the planet, too, was uneven. This was largely due to the geological events and the impact of external factors of astrophysical nature on the planet, leading to crises and radical change of biota. The most striking well-known crises of this kind were the extinction in the Permian and Cretaceous periods, the beginning of which was characterized by a decrease of carbon dioxide concentration in the atmosphere and planetary cooling [23, 14, 15]. However, the dependence of all life and its evolution on photosynthetic organisms within the Phanerozoic history (i.e., ~570 million years and later) has never decreased, and the biosphere actually was and continues to be the united system that supports its own existence and operation of its components, using solar energy.

3. Phanerozoic eon

Phanerozoic eon of the biosphere evolution, which began with the Cambrian period about 570 Mya and is still ongoing, can be described as the time when life came out from the oceans and confidently conquered the land, which saw the emergence of all the modern types of plants and animals, and at last, man appeared, who became by the figurative expression of V.I. Vernadsky's [1] "geological force." The evolution of life in the Phanerozoic was uneven, as reflected in the fossil and geological records.

The beginning of the Phanerozoic eon was marked by the separation of the paths of the evolution of multicellular animals and dividing them into two large groups: invertebrates and vertebrates. This was due to the emergence of the first chordates (usually mentioned lancetnik that appeared in the lower Cambrian), which gave rise to all the past and present vertebrates, including humans).

As for plants, new groups of multicellular organisms emerged: first lower and then higher vascular organisms, for example, horsetails and ferns, which became a part of a major share of large-sized ground vegetation formed by Carbon. A little earlier, during the Carboniferous period, the ancestors of the first gymnosperms appeared in the upper Devon, and widely spread across the planet just after the Permian crisis, that is, in the Triassic. After the mid-Mesozoic eon, in early Cretaceous period (135–140 Mya), finally, flowering plants appeared, which were pollinated by pollinators insects.

It is hardly appropriate to discuss in this chapter many evolutionary and co-evolutionary events in the evolution of life in the Phanerozoic eon. Many special works are dedicated to the study of such events, including "a skeletal revolution," the emergence of systems of transport of substances inside the body, the "invention" of hemoglobin and blood circulation, the occurrence of thermoregulation of bodies, terrestrial respiration, senses, nervous system, brain, social behavior, and more [24]. From our point of view, the examination of the evolution of the entire biosphere is conveniently conducted in the framework of the so-called energy approach, especially as many evolutionary innovations are related with the global tendency of increasing in time of the energy flow through biosphere. Many researchers (e.g., see [14, 15, 25]) emphasized the importance of the energy characteristics in considering such systems as the ecosystems and biosphere as a whole.

4. The evolution of the biosphere as a united system of planetary life

Based on the earlier view, and also based on the fact that the evolution of life on the Earth should be seen as the *panbiosphere global process* of permanent mutual (reciprocal) adaptation of organisms in ecosystems and biogeocoenoses,[1] the *physico-ecological concept of biosphere evolution* has been developed [14, 15]. In the framework of this concept, the relationships between the various evolutionary processes at different levels of biological organization, as well as general problems of evolution of biosphere, are discussed. Observed during the Phanerozoic eon, increase of energy flow, passing through the biosphere, is understood as the physical evolution of the biosphere. This increase is a result of the process of the emergence of new plant producers and plant communities, which more efficiently used the Sun's energy. The rise of energy flow in its turn leads to increase in the production of organic matter used by consumers and decomposers, strengthening biosphere circulation and other important changes in planetary life.

In the early stages of the evolution of mechanisms for the use of solar energy, which began in the Proterozoic era, physical evolution can be correlated with the improvement of the chemical processes of photosynthesis, increasing the efficiency of chlorophylls. As a result, the evolution worked out the most efficient chlorophylls, used by plants up to the present time. Almost all of the main producers of organic matter in the biosphere, including the most important present producers, such as the highest vascular plants, in varying degrees, rely on sets of chlorophylls ***a*** and ***b*** [26]. Evolution of chemical aspects of photosynthesis completed to the Phanerozoic eon and elaborated optimal for Earth's conditions chlorophylls. Eukaryotic life, appeared in the Proterozoic began to go out on the land [18, 26, 28]. This, as already mentioned, was provided by the unique abilities of eukaryotes to create complex

[1]Biogeocoenosis is a large ecosystem considered within a framework of concrete plant communities [27].

http://dx.doi.org/10.5772/intechopen.73297

multicellular organisms with different functions of specific tissues and organs, which gave a huge number of new possibilities and ways of existence of these organisms in the environment. For example, the extraction of water from under the top layer of soil by roots and carrying out of photosynthesis by organs above the surface, where lighting conditions are usually better—one of the abilities unavailable to single-celled plant organisms.

The growth of the photosynthetic ability of terrestrial plant communities and coupled with this process of physical evolution of the biosphere occurred at this stage due to the occurrence and development of adaptations, which led to the increase of the area of photosynthetic surface of leaves and sometimes other formations. Thus, Phanerozoic evolution of the biosphere has largely been associated with morphological changes [18, 28] of terrestrial plants and, respectively, of multicellular animals—consumers of organic matter and the oxygen which these plants produce.

It is also important to remember one more factor that played a huge role in the evolution of life on the planet during the Phanerozoic era, namely, the presence of an oxygen atmosphere [17, 18, 29]. It was oxygen that offered animals to intensify metabolism, to move from water to land, and significantly increase the size of some of them. The concentration of oxygen in the atmosphere in the Phanerozoic eon fluctuated, and in the epoch of coal accumulation exceeded, apparently, the contemporary one. Here, we return to the thesis about the ecosystem organization of the biosphere, representing the *over-organismal living system* [3, 7, 30], sometimes figuratively called the "super-organism."

The importance of animal components of the biosphere is beyond doubt: animals in combination with plant and reducents organize a closed and well-functioning biosphere cycle; in other words, a continuous process of "biosphere metabolism" [30]. Evidently, evolutionary changes in plant and animal species are linked also via the change of geospheres, including the atmosphere.

Here, we do not consider the mechanism of physical evolution of the biosphere, which is described in the monograph [14, 15, 17] and is based on the well-known notion that the biosphere is a united functional system. Note, however, that in the framework of this approach, the physical evolution is explained as a consequence primarily of external astrophysical factors. These are the factors of the scale of the galaxy, influencing the intensity of geological processes and outgassing of carbon dioxide from the bowels of the Earth with a period of the galactic year of about 200 million years and factors of the scale of the solar system, causing periodic oscillations of orbital parameters of our planet and climatic changes on the Earth every few tens of thousands of years. The impact of these factors stimulates evolutionary processes in the biosphere and leads to an increase in the flow of energy through it, as a result of the selection and wide dissemination of producers, which more effectively are using the flow of solar energy (**Figure 1**).

In the end, during the Phanerozoic eon, new macrotaxons of plants and animals and new ecosystems and biogeocoenoses arose, energy flow through terrestrial plant communities increased by nearly two orders of magnitude, and the speed of circulation of organic matter in the biosphere increased dramatically. All this affected the course of biological evolution [14, 15].

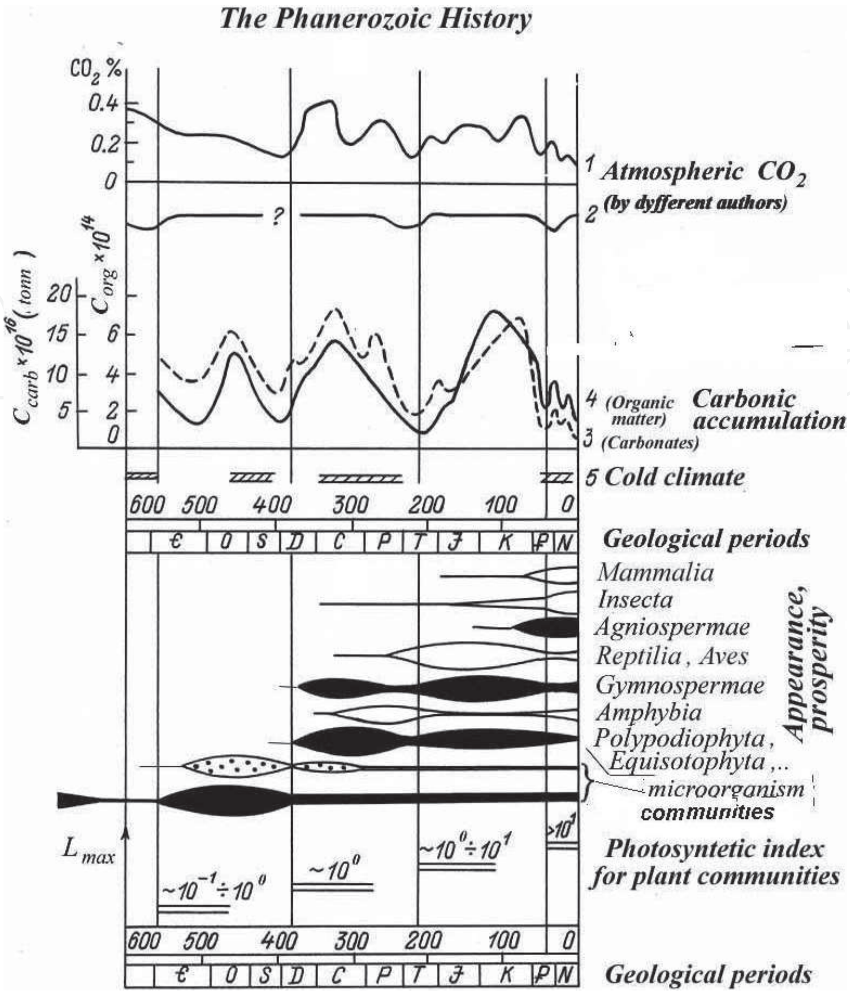

Figure 1. Phanerozoic evolution of the biosphere. The oscillations of carbon dioxide concentration in atmosphere, the epochs of global cooling, the development of different macrotaxa, and increase of photosynthetic index (it characterizes the community productivity) are given by [14, 15].

To conclude this section, we note that to date, the possibility of increasing the energy flow through the biosphere, ecosystems, by traditional ways, that is, by increasing the photosynthetic index of the plant communities, seems to have exhausted—changing the trends of evolution of life on Earth.

5. Some general features of the evolution of the biosphere

Laws of evolution of ecosystems and the biosphere, the known laws of micro and macroevolution, as well as regularities known from evolutionary biochemistry and physiology should be considered and coordinated together. One of the features of the evolutionary processes of the biosphere is that every time they take place in conditions of irreversible changes on the Earth, produced by previous evolutionary process. Therefore, we can speak of a kind of "memory" of the biosphere, and what is contained in this memory to a certain extent directs, canalizes occurring in the biosphere subsequent evolutionary changes. The most important elements of this memory are those which are fixed in the genomes of organisms and, consequently, the particularities of their morphology and biochemical mechanisms and is also reflected in the geospheres of the planet, its geological history. These, for example, are the emergence of an oxygen atmosphere about 2 Gya; the emergences of various biogenic sediments, rocks, and minerals in the bowels of the Earth; the emergence of modern water; and atmospheric balance of the planet. That life controls certain features of its own evolution is reflected in the paradigm of *autocanalization of the biosphere evolution* [30].

All this may suggest that the process of biosphere evolution is similar in some aspects to successive deployment, which resembles the ontogenetic development, when each phase starts only after completion of the previous one. However, this similarity is not complete though, because the biosphere changes are not pre-programmed. The similarity can be discussed only in relation to the evolution of the entire biosphere as a whole but not in relation to changes in ecosystems, populations, or genotypes. After all, the final goal of ontogenesis is the stage an adult organism reaches with certain morphological and physiological characteristics that allow it to exist and reproduce in a particular environment. But the biological and biosphere evolution, most likely, do not have any final goal. The only permanent "goal" (more correct to call it an imperative) of the functioning of the biosphere is the preservation of life itself through new adaptations and co-adaptations of different organisms and ecosystems in a changing environment. In other words, imperative for the biosphere as a system is the maintenance of life on the planet in any way, like using relatively small adaptive changes in the large components or (and) through significant evolutionary changes on the species level, even at the cost of destruction of entire taxa [15, 17, 18].

Observable predetermination and directedness of the physical evolution of the biosphere toward a more energetically developed and, accordingly, productive state with high biodiversity [31] do not mean predetermination of biological evolution. Selection usually acts on a limited number of parameters and fixes the first met biological forms by chance, as long as they meet these conditions. Therefore, features of the natural environment that occurs at a particular stage in the evolution of the biosphere, not rigidly determine the ways of biological evolution [17, 30, 32] does not require that the performer of a particular ecosystem functions were very specific, for example had concrete origin.

Thus, the reason for the directionality of biological evolution toward complication, leading to the emergence of increasingly complex biological forms (while retaining many archaic one), is the evolution of the whole biosphere [14, 15, 17]. As was mentioned above, in the process of this evolution takes place the increase of energy flow through biosphere, as well as the complication of the mechanisms, supporting conditions on the planet, favorable for more advanced life forms ("planetary homeostasis"). Other aspects of this process are the *complication of relationships between components of the biosphere and increase the number of simultaneously present in the biogeochemical cycle of organic matter.* All these phenomena involve irreversible changes of geospheres of the planet and accumulation of "burden of evolution" in the form of morphofunctional and morphogenetic changes of the organisms and, consequently, constraints on possible ways of further biological evolution [17, 30]. Therefore, we should talk about autocanalization of biosphere evolution, which is a consequence of the fixation of the irreversible changes occurring in the geosphere and the biosphere.

6. Some main trends of evolution of the biosphere

Let us summarize now the most important trends in the evolution of the biosphere, some of which have been briefly described earlier. First, it should be noted, that earthly life was very lucky, because even the most severe crises on the planet could not bring to extinction of all taxa or to drive biosphere back to earlier developmental stages. Throughout its evolution, the biosphere coped with the changes; moreover, they stimulated her to further evolution ("everything that does not kill me only gives me new strength"—Nietzsche). The presence of biosphere-geosphere memory and genetic memory of the organisms is allowed not to lose the successful discoveries, which is, in fact, technologies of survival. Thus, the process of evolution led to the emergence of increasingly complex forms.

The main features and trends of evolution of the biosphere are briefly outlined as follows:

- the increase in the flow of energy flowing through the biosphere (this conclusion was made on the basis of data for Phanerozoic eon);
- an increasing amount of organic matter simultaneously involved in the biotic cycle (reliably known for the Phanerozoic eon);
- ecosystem structure of the biosphere (at least from mid-Proterozoic eon);
- increase in the completeness of biogeochemical cycle of the biosphere (from one-directed flow in open ecosystems of bacterial mats up to ~95% completeness of cycle in a number of ecosystems by the end of the Phanerozoic eon);
- expansion of the scope of buried bio-inert substance of the planet (from Archean);
- complication in the structural and functional diversity of the biosphere and its components (differentiation) that was required for the survival of many organisms to have more complex behavior and, ultimately, contributed to the emergence and development of the nervous system and brain (Phanerozoic eon);
- increasing biodiversity [31] and diversity of ecosystem types (at least from the Proterozoic eon);
- increase in the sustainability of the biosphere and its components in the case of non-catastrophic disturbances is related to the increase in biodiversity.

All of the above and a number of other evolutionary changes occurred under the pressure of autocanalization mechanisms, which did not determine strictly each step of biological evolution but, as in the case of ontogeny, implied continuity. This is related to some analogy of the processes of development and evolution, allowing to call the evolution of the biosphere by "non-directed ontogeny," in which concrete specific forms of organisms are not strongly predefined, but the general characteristics of interaction of the whole system of the biosphere with the inanimate nature are more predefined. At least on the Earth, this "ontogenesis" led to the emergence of increasingly complex biological forms right up to the human beings and complication of the system of the biosphere. *The main functional imperative of the biosphere at all stages of its evolution was the preservation of life itself on the planet in any way.*

We do not dwell here on the philosophical premises and conclusions, following from this assertion. Much on this subject can be found in the monograph by O. Bazaluk [33]. Let's look at the process of evolution not from the point of view of changes in the structural and functional features of living things but as the process of creation of new and existing means of survival and exploitation of the environment by life. From this point of view, the evolution of the biosphere is the invention, preservation, improvement, and accumulation of different technologies of storage, and the implementation of process of life. With these positions, in the evolution of life on the Earth were the following main stages:

- the appearance of protobionts with memory to store information about the successful technologies of survival. The main innovation of this phase—the emergence of the genetic code (apparently, early Archean eon);
- the emergence of technologies for the use of mineral resources of the planet. The main innovation of this phase—the emergence of chemosynthesis and of the primitive metabolism (around the same time as the previous stage);
- the emergence and rise of organisms able to use photosynthesis. The main innovation of this phase is the development of mechanisms of photosynthesis to use energy from the Sun. In parallel, the emergence and spread of aerobes and the development of aerobic metabolism; in fact, fixation of the ecosystem organization of planetary life (upper Archean eon, Proterozoic eon) [34];
- the emergence of eukaryotic cells as believed to be the result of symbiosis of prokaryotes [19–21]. The main innovation of this stage—effective new nuclear apparatus of eukaryotic cells and the development of specific method of transfer of genetic information—sexual reproduction. Besides that, there was altered cell membrane, a complex of new cell receptors emerged, allowing better control of the permeability to various chemicals (middle Proterozoic eon);
- the emergence and broad spreading of multicellular organisms. The main innovation of this phase is the emergence of the communication system between cells and the mechanism of their differentiation in the ontogeny of multicellular organisms (upper Proterozoic eon).

It is important to note that with the appearance of another main innovation, the old evolutionary findings usually do not disappear. They not only continued to exist and develop but also combined with newly acquired features. Similar features of evolution can be seen not only in the early stages of the evolution of life but also later and also when considering the emergence of organs, physiological systems, and the development of physiological functions. When studying different groups of organisms, a number of particular regularities have been opened to confirm these general regularities (K. Baer, G. De beer, R. Garstang, E. Haeckel, E. Cop, S.V. Meyen, A.N. Severtsov, A.L. Takhtajan, K. Waddington and I.I. Schmalhausen, etc.). These general regularities, apparently, are also applicable to ecosystems and the biosphere [14, 17]. Close in its meaning regularities were also aptly formulated by L.A. Orbeli in the form of "principles of evolutionary physiology" [35]. Among them are the following:

- the principle of intensification of the processes that provide the functionality of biological systems (including in terms of resource consumption);
- the principle of the increasing of multifunctionality of the components of biological systems;
- the principle of the increasing of duplication components of biological systems that perform a particular function;
- the principle of overbuilding (or superstructure): new functions do not simply replace the old one but are built on the old functions, replace them, and manage them.

It is not hard to see that these principles which were formulated for evolutionary physiology can explain events in the evolutionary history of the biosphere. Apparently, they are universal and in varying degrees applicable to explain the evolution of biological systems of various levels of the organization.

Homo sapiens, appeared at the end of Phanerozoic eon, began to use for their needs fossil raw materials and energy sources inaccessible to other organisms (e.g. fire, nuclear energy). They continued general tendency of intensification of energy flow and biogenous cycles in the biosphere evolution. Humans' extremely rapid spreading across the planet and increasing role in biosphere processes is obliged first of all to the fact that they use language for communication and transmission of information about their technological discoveries. Biological evolution has ceased to play a crucial role in their survival on Earth.

7. Conclusion

This chapter is not an exhaustive description of the evolutionary events in the biosphere. However, we hope that we were able to show the resemblance and the connection of the evolution of biological systems at different levels of biological organization in the process of development of life on Earth.

We discussed that the evolution of the biosphere is uneven, that is, periods of abrupt change (crises) is changed by much longer periods of relative stability. What could be the cause of a sharp, "explosive," and at the same time, global changes in the entire biosphere? Based on the earlier description, we can distinguish two types of reasons, conventionally, dividing them into "external" and "internal." The first type includes global change of the abiotic environment that occurred under the influence of planetary and cosmic factors. The second type which consists of the "main innovation" is a radical change in the uses of the environment associated with the emergence of new technologies of survival, including new ways of organizations and associations of living systems (eukaryotes, multicellular organisms, ecosystems, etc.).

In conclusion, it is important to say, that humankind, which, according to V.I.Vernadsky [2] is the new "geological force", plays an increasingly important role in key biosphere processes. Now, we can add, that humankind is the force, which became a new factor of evolution, realizing conception of autocanalization of evolutionary process. However, despite the rapid development of non-biological technology, man, being a biological creature, cannot ignore its own earthly nature, because all the main stages of biosphere evolution are reflected in the human genetic memory and in the processes of his development. That is why existence of man is possible only as co-existence with all other living creatures [6]. This need in the "other" is applied to all organisms and was "imprinted" early in evolutionary history, before the emergence of the mind, and originates probably from Archean times, when the first simplest ecosystems appeared. After all, to find a "friend" and assistant contributed to the survival. This need, combined with the pursuit of invention of new technologies, creates one of the main contradictions of the inner world of modern man. Here, we are coming close to the non-biological evolution of the noospheric environment [2] in which the human beings, the inventors play an important role and have to take responsibility for the destiny of his beautiful home—the biosphere. Whether their inventions are accepted depends largely on the culture in which they exist.

Author details

Vladimir F. Levchenko[1]*, Alexander B. Kazansky[1,2] and Marat A. Sabirov[1]

*Address all correspondence to: lew@lew.spb.org

1 Sechenov Institute of Evolutionary Physiology and Biochemistry of the Russian Academy of Sciences, St. Petersburg, Russian Federation

2 Federal Almazov North-West Medical Research Centre, St. Petersburg, Russian Federation

References

[1] Vernadsky VI. The Biosphere (in Russian); 1926. Transl. Langmuir DB. Mark AS, editors. McMenamin, New York: Copernicus; 1997. 192 p

[2] Vernadsky VI. The biosphere and the noosphere. American Scientist. 1945;**33**:1-12

[3] Lovelock J.E. Gaia: The Practical Science of Planetary Medicine. Gaia Book Ltd, 1991. 192 p

[4] Shaposhnikov GH. Directedness of evolution. Zhurnal Obshcheĭ Biologii. 1977;**38**(5):649-655

[5] Odling-Smee JJ, Laland KN, Feldman MW. Niche Construction: The Neglected Process in Evolution. New Jersey: Princeton University Press; 2003

[6] Kazansky AB. Bootstrapping of life through Holonomy and self-modification. In: Dubois DM, editor. Proceedings of the 9th International Conference on Computing Anticipatory Systems. Vol. 1303. Melville, NewYork: American Institute of Physics; 2010. pp. 297-306

[7] Kazansky AB. Planetary bootstrap: A prelude to biosphere phenomenology. In: Dubois DM, editor. Proceedings of the 6th International Conference on Computing Anticipatory Systems. Melville, New York: American Institute of Physics; 2004. pp. 445-450

[8] Severtsov AN. Essays on the Theory of Evolution: Individual Development and Evolution. Berlin: Publishing House RSFSR; 1921. 309 p

[9] Zherichin VV, Rautian AS. Phylocoenogenesis and evolutionary crises (in Russian). Zhurnal Obshcheĭ Biologii. 1997;**58**(4):20-47

[10] Golikov AN, Bazanova NU, Karabekov ZK. Physiology of Farm Animals (in Russian). Agropromizdat: Moscow; 1991. 432 p

[11] Starobogatov YI, Levchenko VF. Ecocentric concept of macroevolution (in Russian). Zhurnal Obshcheĭ Biologii. 1993;**4**:389-407

[12] Schopf J. Fossil evidence of Archaean life. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences. 2006;**361**(1470):869-885

[13] Vidal G. The oldest eukaryotic cells (in Russian). V Mire Nauki. 1984;**4**:14-24

[14] Levchenko VF. The three Stages of the Evolution of Life on Earth (Monograph in Russian). Germany: Lambert Academic Publishing; 2011

[15] Levchenko VF. The Biosphere: The Stages of Life (the Evolution of the Parts and the Whole) (Monograph in Russian). ISVOE: Saint-Petersburg; 2012. 264 p

[16] Kenyon DH, Steinman G. Biochemical Predetermination. New York, London: McGraw-Hill Book Company; 1969

[17] Levchenko VF, Kazansky AB, Sabirov MA, Semenova EM. Early Biosphere: Origin and Evolution. In: Ishwaran N, editor. The Biosphere. InTech; 2012

[18] Fedonkin MA. Two Annals of Life: Comparison Experience (a Paleobiology and Genomics about Early Stages of Evolution of Biosphere) (in Russian). Geoprint: Syktyvkar; 2006

[19] Kozo-Polyansky BM. A New Principle of Evolution. Essay on the theory of symbiogenesis (in Russian). Moscow; 1924. Transl. by Fet V, Fet V, Margulis L. editors. Cambridge, Mass.: Harvard University Press; 2010

[20] Margulis L. Symbiogenesis. A new principle of evolution rediscovery of Boris Mikhaylovich Kozo-Polyansky (1890-1957). Paleontological Journal. 2010;**44**:1525-1539

[21] Margulis L. Symbiosis in Cell Evolution. 2nd ed. New York: Freeman WH; 1993. 452 p

[22] Shpakov AO, Pertseva MN. Signaling systems of lower eukaryotes and their evolution. International Review of Cell and Molecular Biology. 2008;**269**:151-282

[23] Yablokov AV, Levchenko VF, Kerzhentsev AS. Sketches of biospherology. 1. There is a solution: Go to the controlled evolution of the biosphere. Philosophy and Cosmology. 2015;**14**:91-117

[24] Svidersky VL. Modern problems of evolutionary physiology. In: Darwinism: History and our Time. Leningrad: Nauka; 1988. pp. 202-210

[25] Odum PE. Energy flow in ecosystems: A historical review. American Zoologist. 1968; **8**(1):11-18

[26] Meyen SV. Fundamentals of Paleobotany (in Russian). Moscow: Nauka; 1987. 228 p

[27] Sukachev VN. Fundamentals of Forest Typology and the Biogeocoenology (in Russian). FAV Works. Vol. 1. Leningrad: Nauka; 1972. 424 p

[28] Zherikhin VV. Selected Works in Paleoecology and Philocoenogenomics (in Russian). Moscow: KMK; 2003. 542 p

[29] Levchenko VF. Evolution of Biosphere before and after the Appearance of Man (Monograph in Russian). Saint-Petersburg: Nauka; 2004. 166 p

[30] Levchenko VF, Starobogatov YI. Self-regulatory evolution of the biosphere: The dynamics of the diversity of the organic world in time and space (in Russian). In: Materials 40-Th UPR Session. Saint-Petersburg: VSEGEI; 1994. pp. 30-32

[31] Brodsky AK. Biodiversity: structure, problems, and perspectives of conservation. Archives of Zoological Museum of Moskow State University. 2016;**54**:380-396

[32] Levchenko VF, Starobogatov YI. Succession changes and evolution of ecosystem (some problems of evolutionary ecology) (in Russian). Zhurnal Obshcheĭ Biologii. 1990;**5**:619-631

[33] Bazaluk OA. The Theory of Evolution: From the Cosmic Vacuum to Neural Ensembles and in the Future (in Russian). ISPC: Kiev; 2015. 312 p

[34] Kovalev OV, Kazansky AB. Two Faces of Gaia. University of East London: Gaia Circular; 1999;**2**(2):9

[35] Orbeli LA. The main problems and methods of evolutionary physiology (in Russian). In: Evolutionary Physiology, Part 1. Leningrad: Nauka; 1979. pp. 12-23