The origin of life, cybernetic theory of evolution and oxygen catastrophe.

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Abstract: The process of the origin of life is analyzed on the basis of "self-assembly" of DNA and RNA molecules. The minimum amounts of various DNA/RNA molecules that are necessary for the nucleation and evolution of the biosphere as a whole are calculated, since life is an integral property. A cybernetic theory of evolution is presented, which considers DNA as a genetic program of an organism written in a binary system. The stages of evolution of the biosphere are given, with the calculation of the number of all species at each stage. It is shown that oxygen catastrophe is the main cause of the evolution of the biosphere and global glaciation. Moreover, the evolution of the biosphere inevitably leads to mass extinctions, which are a simple restructuring of the biosphere according to new conditions on the planet.

Keywords: the origin of life and the Fermi paradox, “self-assembly” of DNA and RNA molecules, cybernetic theory of evolution, oxygen catastrophe, Snowball Earth and global glaciations, mass extinctions.

Content:

INTRODUCTION.

Fermi Paradox.

To begin, consider Fermi Paradox [1]. It is well known that for the birth of life we need planets of a certain type (of the Earth type). There are about a billion of such planets in our galaxy, according to experts. And this is only in our galaxy! Given the number of galaxies in the visible part of the Universe, the number of such planets in the Universe becomes a truly huge number. Estimates are also made for how long a civilization colonizes its galaxy: approximately 50 million years. Given the age of the galaxies and the Universe (based on the Big Bang theory), both our galaxy and the Universe should “boil” with alien life, but there are no traces. There is silence of the Universe. And it does not fit into any scientific study, as life should be very common. This is confirmed by the latest astronomical data obtained in our solar system.

For example, on Mars, under the ball of the ground is the usual solid ice. And there is so much of it that if having transferred it to a liquid state, then the surface of Mars will cover an ocean of water 25 meters deep [2 - 5]. On Enceladus (Saturn's satellite) under the surface there is an ocean of liquid water [6 - 10]. On Europe (satellite of Jupiter) under the ice there is a water ocean up to 100 kilometers deep [7 - 14]. On Titan (Saturn's satellite), on the surface of the planet, there are rivers and lakes of liquid methane and ethane [15 - 20]. This is very important, because for the first time a liquid ocean was discovered on the surface of the planet (liquid is necessary for life).

Thus, from the above, we see that even in our solar system, water is not uncommon. Therefore, taking into account that in the Universe billions of solar systems like ours (which have an Earth-like planet), life had to originate and evolve (on a water basis, similar to ours). But, there are no traces of either smart or any biological life. This is very surprising since the diversity of organic substances based on carbon (and their reactions) guarantees the coding of the genetic code, the exchange of substances, etc., things necessary for the origin and evolution of life. Organic carbon-based substances can theoretically be an unlimited number - millions and billions. To be precise, the amount of organic compounds is uncountable infinite set [21]. That is, carbon-based life, for nucleation and its development, has at its disposal literally countless organic substances. Therefore, it is carbon-based life that is most likely: for the emergence and development of life on the basis of another element, substances will also be needed, more precisely, their huge amount, and it is carbon that provides the maximum variety of substances. This strictly follows from the energies and lengths of chemical bonds.

All strong and important chemical bonds (covalent) have a length less than 1.6 - 1.7 Å. Therefore, given the radii of atoms, and the fact that classical single, double, and triple chemical bonds are needed, we inevitably come to elements 2 of the period of the periodic table. Only elements of the 2nd period will be able to form a variety of chemical bonds with a length shorter than 1.6 - 1.7 Å. That is, we come to the carbon atom. The place of carbon in the periodic system Mendeleev is unique in chemical terms. Moreover, carbon, or rather the carbon core, is simply a tripled nucleus of a helium atom, from which it becomes clear that there will be enough carbon in space (recall the evolution of stars, helium synthesis, and carbon synthesis). Therefore, the carbon form of life should be most easily realized in the Universe, since a variety of chemicals is easily realized. And adherents of other forms of biological life can ask a question similar to Fermi: If there is a different form of life, Where is It?

If life forms are possible on the basis of other elements, then there is doubt that they will spontaneously be able to realize a sustainable biosphere, which will require a huge amount of chemicals to function. This can be precisely stated when we can calculate the amount of substances necessary for the implementation of the biosphere of a given complexity. But, this is a matter of time, very soon we will be able to do it. It can be clearly stated that if the biospheres based on other elements are not in the Universe, then in the laboratory we will be able to "assemble" a living cell or a more complex organism based on other elements (not carbon). Since in the laboratory we can provide such an organism with everything necessary for its functioning and evolution.

RESULTS AND DISCUSSION.

Project "Biosphere 2", binary code and DNA molecule.

The number of extraterrestrial civilizations in the galaxy is calculated according to the Drake equation [22 - 26]. Therefore, we further analyze the Drake equation.

In the classic Drake equation the probability of biological life occurring is assumed to be equal to one. That is, if life is possible, then it will necessarily arise. But this is not so! The probability of the occurrence of life tends to zero $P(\text{life}) \to 0$. Moreover, the likelihood that if there is life, then it will develop to a reasonable one, is also taken as a unit, that is, for 100 %. Sometimes this probability is taken as 1 %, but this is not significant, since the probability of the emergence of intelligent life from the biological also tends to zero $P(\text{intelligent life}) \to 0$. This conclusion can be made, if we analyze the origin of life based on organic chemistry. And this directly confirms the Fermi paradox. Why then on our planet is there life, and even intelligent? The answer is simple: the probability of the occurrence of life tends to zero, but if all this is integrated over the infinite Universe, then the probability of the occurrence of life in the Universe is equal to one. That is, once in an infinite universe, life will arise. Not more. There are very significant reasons for the lowering of the probabilities. It is the erroneous values of these probabilities that lead to the fact that Drake's equation yields fantastic results that have nothing to do with reality. But, to understand the reasons for the lowering of probabilities, it is necessary to recall the "Biosphere 2" project [27 - 29].

Biosphere 2 is a closed ecological system built by Space Biosphere Ventures, businessman Edward Bass [30] and system ecologist John P. Allen [31] in the Arizona desert (USA). The main task of Biosphere 2 was to find out whether a person can live and work in a closed environment. But, this was not the main thing in practice. It turned out that people were unable to build a closed ecological system, that is, a "synthetic biosphere" that would be sustainable. The "synthetic biosphere" failed quite quickly: after a few weeks, microorganisms and insects suddenly multiplied, and the oxygen level began to fall by 0.5 % per month. Therefore, the leadership made a decision to inject additional oxygen to maintain the lives of people (the participants in the experiment did not know about oxygen injection).

Biosphere 2 is a lot of sealed buildings with a total area of 1.5 hectares covered with a glass cover (transmits 50 % of sunlight). Look at the picture [27].

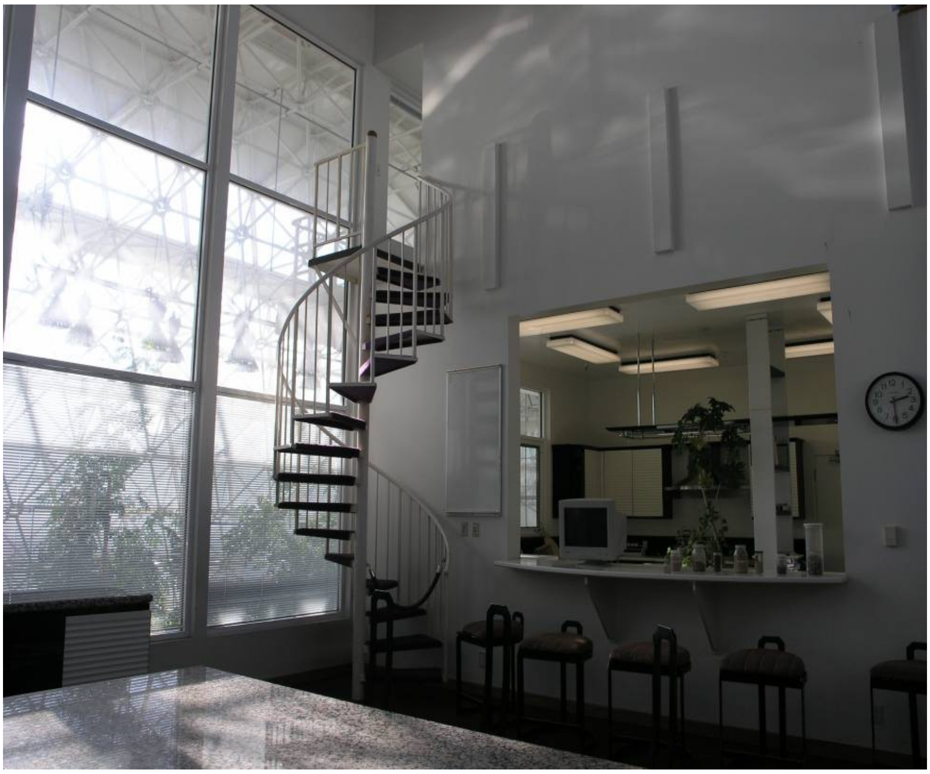
Inside, it is divided into 7 blocks:

a rainforest of 1900 square meters,

850 square meters ocean with coral reef,

450 square meters mangrov swamps,

savannah on 1300 square meters,
1400 square meters desert,
2500 square meter agricultural system,
and human habitats with living quarters, laboratories and workshops [27].



The Biosphere 2 experiment was conducted from September 26, 1991 to September 26, 1993. It was assumed that the complex would function autonomously, but this turned out to be impossible. And this is crucial for our reasoning about the origin of life. This experiment clearly shows that life is not an individual concept (as we perceive), but an integral one. Moreover, analyzing the emergence of life, we come to the same conclusion. Therefore, it is necessary to calculate not the probability of the occurrence of life of an individual organism or population (bacteria, mammals, humans, etc.), but the probability of the emergence and functioning of the biosphere as a whole. That is, the probability of the simultaneous occurrence (or almost simultaneous) of many different types of bacteria, plants, animals, etc. And here there will be completely different probabilities than those used in the Drake equation. It is meaningless to consider the probability of the life of an individual organism, since the body needs an appropriate environment for functioning, and if it does not exist, then life as it has arisen will be destroyed. But, before further analysis, we recall chemistry.

Consider 100 consecutive reactions:

$$A1 \rightarrow A2 \rightarrow A3 \rightarrow A4 \rightarrow \rightarrow \rightarrow A100$$

Suppose that the yield of each reaction is 90 %, and the starting material A1 is taken 100 grams. That is, we will get 90 grams of substance A2 (100*0.9), A3 we will get 81 grams (90*0.9), etc. It is easy to calculate that we get A100 substances of 2.95 milligrams, because:

$$A100 = 100 * 0.9^{99} = 2.95 * 10^{(-3)} = 2.95 \text{ milligrams.}$$

If at each stage we increase the yield to 99 %, but get to A1000:

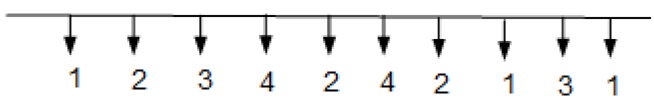
$$A1 \rightarrow A2 \rightarrow A3 \rightarrow A4 \rightarrow \rightarrow \rightarrow A1000$$

then, despite the high yield (99 %), we get the A1000 just 4.36 milligrams. Very small quantities. And this despite 1000 reactions! Millions of reactions are coordinated in living systems, and everything works. Just amazing!

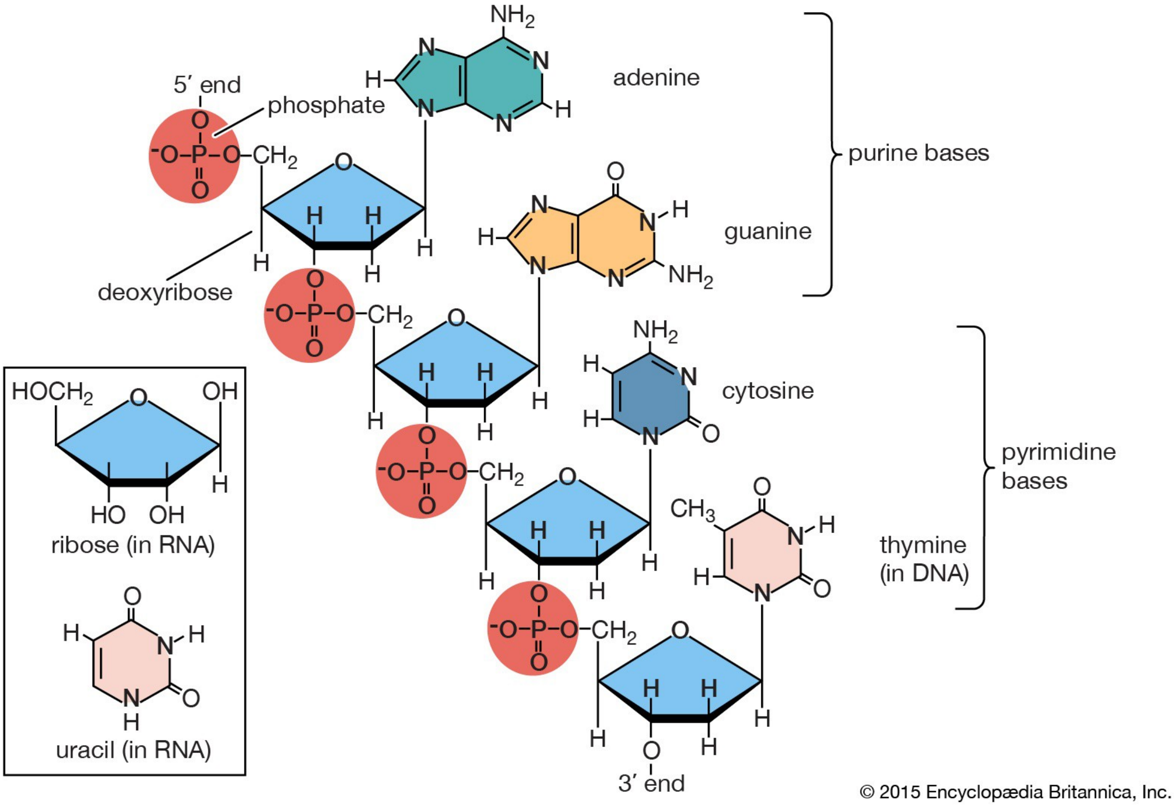
These examples demonstrate how complex any living system, such as a bacterial cell, is. Millions of reactions take place every second in a cell, and everything functions flawlessly. Organic substances are formed in one reaction and can be immediately used in another reaction, and can be used as building material, etc. Compare this with our simple examples. The complexity of living systems is simply unimaginable. Thousands and millions of reactions occur in concert, and the cell functions flawlessly. How, then, is the birth of life possible at all? Consider the cycle of the origin of life from the point of view of organic chemistry.

The basis of life is DNA. A DNA molecule consists of about a billion atoms (maybe less - hundreds of millions of atoms, maybe more - several billion, different DNA - different sizes). In fact, DNA is a program for assembling a living organism, and it differs from computer programs only in that DNA itself is also a hardware (in the computer sense), on which the program is written. Computer programs are more "virtual" because they need the computer "hardware" on which they will be written. DNA is two in one: the program and the hardware.

Let's schematically analyze what DNA is, how life is encoded. A DNA molecule can be represented as an ordinary chain (or line) to which, at equal intervals, 4 substituents are attached at regular intervals. The substituents will be denoted by the numbers: 1, 2, 3, 4. Then, DNA can be schematically depicted as follows, see picture.

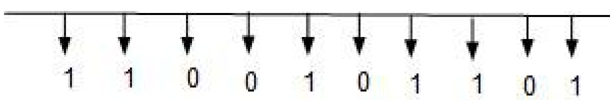


Moreover, this model is accurate and true. The chain in this model is very long, and therefore we will have tens and hundreds of millions of substituents (that is, numbers) (do not forget about a billion atoms). Surprisingly, the length of the DNA molecule (our chain) is approximately 1.8 meters, that is, approximately the height of a person. It should also be taken into account that, in chemical terms, the chain consists of sugar and phosphate group. It is clear that deoxyribose and the phosphate group are connected by chemical bonds in our chain, and these chain links are constantly repeated. It is interesting that it is the substituents (our numbers: 1, 2, 3, 4) that encode information in DNA, and the chain is simply “carrier”, “iron”. Deputies are nitrogenous bases: Adenine, Guanine, Thymine, Cytosine [32].



Pay attention to one detail: adenine and guanine is a purine cycle, that is, a bi-cycle (the molecule consists of 2 cycles, imidazole and pyrimidine), and thymine and cytosine consist of one cycle (pyrimidine). This will give us the opportunity to translate the encoding of information in DNA into a binary system.

We accept that adenine and guanine are 1, and thymine and cytosine are 0. We accept that 1 and 2 are 1, and 3 and 4 are 0. And we get the encoding of the information in DNA, in the binary system. Look at the picture, we converted the encoding from 1, 2, 3, 4 to the binary system.



Using this approach, any DNA and RNA molecule can be digitized. Moreover, the binary system is universal and in fact is the simplest and most reliable. Therefore, it is logical that the body will "try" to encode information in DNA and RNA in the binary system. How this is implemented, we have demonstrated above. It is very interesting to look at the results of digitization of various DNA and RNA!

It is worth noting that there is no doubt that the genetic information recorded in DNA (RNA) will be recorded in the binary system, that is, just like in a computer. Recall that in a computer all programs written in any programming language are ultimately translated into binary code that the processor “understands” directly, and which is very easily implemented on hardware. The reason for this is that the computer uses the energy of electric current for its functioning. Therefore, the "genetic program" of the computer must be consistent with the energy that feeds it, that is, with electric current. Binary code is perfect for this:

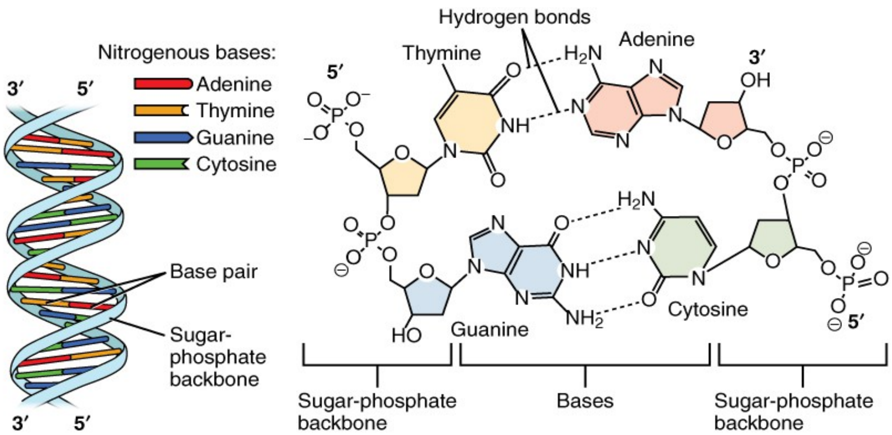
“0” - no current, or weak current;

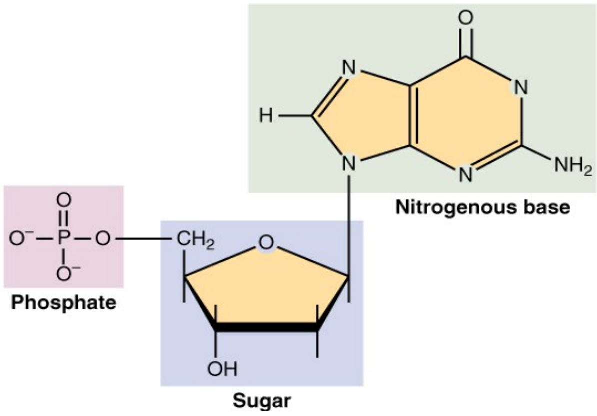
“1” is the current.

Binary code (machine code), more precisely a program written in assembly language, has another important feature: it guarantees the maximum speed of the system (computer) and has a minimum size, and also uses a minimum amount of memory [33]. Operating systems written entirely in machine code are placed on a 1.44 MB diskette [33]. Moreover, these are full-featured operating systems with a graphical interface and multitasking, for example, the MenuetOS operating system [34, 35], and the KolibriOS operating system [36 - 38].

The compactness of programs written in machine code and their maximum performance virtually unambiguously indicate that the writing of information in DNA, that is, in binary code, should likewise take place. Since only binary code can minimize the size of a huge “genetic program” written in DNA, and only binary code can maximize the speed of such a program. Naturally, this follows from the fact that gigantic information is recorded in DNA. And the rate of DNA replication directly depends on the size of the DNA. Since, the larger the size of the DNA, the slower its replication, and hence the rate of cell division, and hence the rate of biochemical processes in the body. Therefore, nature actually had no choice: information in DNA can only be written in the binary system.

But, in most living systems, molecules that encode genetic information (DNA, RNA) form a two-chain structure. Since it is precisely the two chain structures of biopolymers that play a key role in biological processes (DNA replication, transcription of DNA into RNA, storage of genetic information in two chain DNA structures, DNA repair if it is damaged). Sometimes (viruses), for storing genetic information, there are one chain structures, and even combinations of one chain structure and two chain structures. Therefore, we consider the encoding, which is implemented on the basis of two DNA chain structures, see image [39].





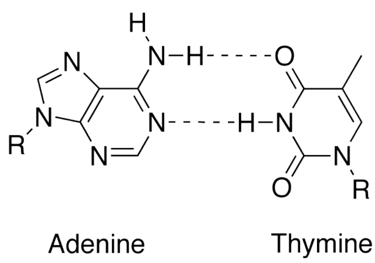
It is important to find out what will be “0”, and what will be “1”, and how it will be implemented in DNA. But, given that DNA is a molecule, which means that the energy of chemical bonds (and not the energy of electric current as in a computer) will be used to implement the program, the translation into the binary system will be as follows:

«1» - is a chemical interaction, that is, a chemical bond is formed;

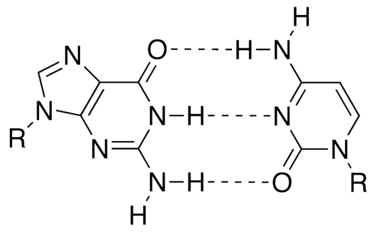
«0» - there is no chemical interaction, that is, a chemical bond is not formed.

And now we will take into account that this is a double helix of DNA, and it is formed using hydrogen bonds between complementary pairs [40]:

1) A = T, Adenine(A) and Thymine(T), two hydrogen bonds form,



2) G≡C, Guanine(G) and Cytosine(C), three hydrogen bonds are formed.



Therefore, the translation into the binary system of two DNA chain structures will be as follows:

"1" - the formation of three hydrogen bonds; in DNA and RNA, it implements a complementary pair of Guanine - Cytosine (G≡C).

"0" - the formation of two hydrogen bonds; in DNA it implements a complementary pair Adenine — Thymine (A = T), and in RNA that implements a pair Adenine — Uracil (A = U).

"Self-assembly" of DNA and RNA molecules.
Evolution according to Lamarck, and according to Darwin.

But back to the analysis of the origin of life. As can be seen from the above, for the emergence of life, it is necessary that the DNA or RNA molecule is "assembled". Molecules of DNA and RNA are readily soluble in water, and therefore it can be imagined that they can "assemble" in the primary ocean under certain conditions. More precisely, that something similar in chemical structure will be "assembled", but meaningless in a cybernetic sense, since a DNA molecule is a book that describes the assembly process of a specific organism, and the DNA molecule itself can initiate this assembly. Moreover, taking into account the experience of "Biosphere 2" and the fact that life is an integral concept, DNA must be collected that will "understand" in which biosphere it will live, what diseases it will hurt, what air to breathe, what food to consume, as well as what is being treated, what species to compete with, etc. It turns out that, in essence, "all-knowing DNA" must spontaneously collect. Naturally, such "smart DNA" does not exist. But how then was life born?

Let's try to answer this question. Obviously, assembling a molecule with a billion atoms is possible. The probability of this process tends to zero ($P \to 0$), but still it is not equal to zero. In the water ocean, one can imagine such possibilities, in the presence of initial blocks. Naturally, in the "primary bouillon", "primary ocean", if one DNA molecule can be synthesized, then all possible similar molecules will be synthesized. That is, all possible DNA, RNA, and other similar molecules.

Therefore, if there is DNA and RNA in the ocean, then viruses appear automatically. After all, a virus is a DNA molecule (or RNA) packed in a protein capsule.

Thus, if at least one DNA molecule (or a similar molecule) can "assemble", then after some time, the ocean will turn into a flask with an unimaginable amount of viruses (both in number and in form). In principle, it is. Modern oceans are flasks filled with a wide variety of viruses, and modern science is just beginning to study them. One can imagine what was happening in the “primary ocean” filled with viruses and various molecules of DNA, RNA, etc. In essence, this is according to Darwin evolution.

The essence of Darwin’s theory is that when we have a certain species, we have the genetic diversity of its individuals, this diversity is there initially (without external influence). Diversity (DNA, RNA, viruses) is an accident that is determined only by copying DNA, that is, by mutations, copy errors, etc. The environment simply selects through "natural selection" what is already formed. This type of evolution is the exact opposite of Lamarck evolution. According to Lamarck, it is the environment that should make genetic changes in the DNA of individuals so that specific individuals of the population are more adapted to life.

After the formation of the first viruses the evolution of viruses will begin. Virus evolution will also occur according to Darwin and Lamarck. According to Darwin, the selection of the most successful viruses will take place, that is, those viruses that can make more copies of themselves, and then they can “successfully” evolve generating new viruses. And according to Lamarck, the genetic code of the virus will change under the influence of the environment. For example, a change when copying the concentration of substances, temperature, etc. After some time of the evolution of viruses in our "natural reactor" we will have a huge number of different viruses. Moreover, the evolution of viruses will simply increase their diversity. In fact, this is a purely mathematical, or rather probabilistic, process.

Now we can decrypt any DNA or RNA, that is, to study the sequence of our 1, 2, 3, 4. We can even chemically “collect” this or that DNA. But, why this or that DNA "collects" the given organism we do not understand. How they differ fundamentally and how encoding occurs is currently unknown. Perhaps translating the structure of DNA and RNA into binary code will help in this understanding. If it is possible to understand the encoding mechanism (precisely in the cybernetic sense), then a person will be able to create new types of organisms, plants, bacteria, viruses, etc. Man really will become a Creator. At this stage, we simply imitate nature, and no more.

But, since DNA, RNA and viruses are chemically one and the same thing, the “primary ocean” which contains All combinations of DNA, RNA, and the entire variety of viruses, actually contains the entire diversity of the biosphere. Moreover, one can state the diversity of all possible biospheres, all potential biospheres. Since each biosphere with its own variety of species will be realized only in appropriate conditions (suitable for it). Therefore, viruses are the foundation on which this or that biosphere will be implemented. And it is viruses (as well as various combinations of DNA and RNA molecules) that contain, in a hidden form, the entire potential of the biosphere.

If we continue the analysis of evolution, then after viruses a cell should appear (in the “primary ocean”). But, any cell is much more complicated than viruses. And if the synthesis of viruses (and DNA, RNA) can still be imagined by some kind of polymerization reaction on the solid phase (for example, on a mineral, etc.), then cell synthesis will not be by definition. Since millions of reactions are coordinated in any cell, and therefore there will be no assembly “in stages”. That is, the probability of spontaneous occurrence of any cell is many orders of magnitude lower than the probability of DNA synthesis. The probability of "self-assembly" of the cell literally tends to zero ($P \rightarrow 0$), or maybe equal to zero ($P = 0$). Therefore, the process of transition from DNA, RNA, and viruses to the cell is not obvious, and very unlikely. But, if such a process occurs, then it will be implemented on the basis of viruses (and DNA, RNA), which are contained in the "primary ocean".

After the evolution of viruses, we have an unimaginable variety of viruses. Moreover, viruses are the most complex living system in our “natural reactor”. Therefore, the first unicellular living organism must be a “more complex" version of viruses. Such a first living organism will be the simplest bacterium, which will not be very different from the virus. But, functionally, it will already be a bacterium. Next will begin the evolution of these simple bacteria, which will lead us to ordinary bacteria.

The above approach to the emergence of life, viruses (along with DNA and RNA) plays a major role. In fact, this is a foundation that contains all the potential biospheres. And the development of a particular biosphere is the realization of part of the potential in specific conditions. That is, life is an integral phenomenon by definition. There are many species at once, since there are already primary DNA (blanks). Moreover, all this is implemented almost simultaneously. Naturally, a certain sequence will be: first bacteria, then plants, then more complex organisms. But, this sequence simply provides the ability to implement the entire diversity of species, as it launches the food chain. But, since there are already primary DNA (blanks), there will be no habitual evolution, but a simple implementation of specific “DNA capabilities”. And if we can decipher DNA, understand its cybernetics, then we can tell how much species can change. It will be possible to know exactly the range of variation of a particular species, that is, to predict the evolution of the species in the classic version. And all this will be based on a DNA molecule.

Thus, we came to the conclusion that the biosphere cannot arise on the basis of one or two species, it can arise only on the countless variety of species that provides the sum of "primary DNA, RNA, viruses" in the "primary ocean". Moreover, the evolution of the biosphere is simply the realization of the potential that contains the "primary bouillon" (we can also say that it contains the diversity of the carbon form of life). And if environmental conditions change, the biosphere itself will change with all the variety of species. Here you have the mass extinctions. And the more radically the conditions change, the more different the biosphere will be (first and subsequent).

It is interesting to note that with such a consideration of evolution, the emergence of intelligent life is no longer necessary; it does not follow anywhere. Intelligent life is realized only when a biosphere is formed in which our DNA can realize its potential. And, yes, we no longer need a consistent evolution to our DNA. Perhaps our DNA billions of years ago floated in the "primary bouline", and was waiting in the wings to "collect" the corresponding species. But, this approach does not prohibit the evolution of simpler DNA to human. Remember that only after understanding the "cybernetics of DNA" can we accurately indicate the range of "DNA evolution". To such an understanding, this is only reasoning. But, importantly, intelligent life is simply a successful implementation of the biosphere. Perhaps you can collect, for example, 100 million different biospheres, and only in one can our DNA be realized. Thus, the probability of intelligent life again rushing to zero.

If all of the above is summarized, it turns out that the processes of the emergence of DNA, cells, organisms, intelligent life all the time become less likely. That is, their probability all the time "more and more" tends to zero. That is, it, the probability of life (and reasonable), is tends to zero [21, p. 6]. But, taking into account the fact that our Universe is infinite, when integrating it will nevertheless turn out that in our Universe life will arise once. She arose. And this is our life, and the life of our biosphere.

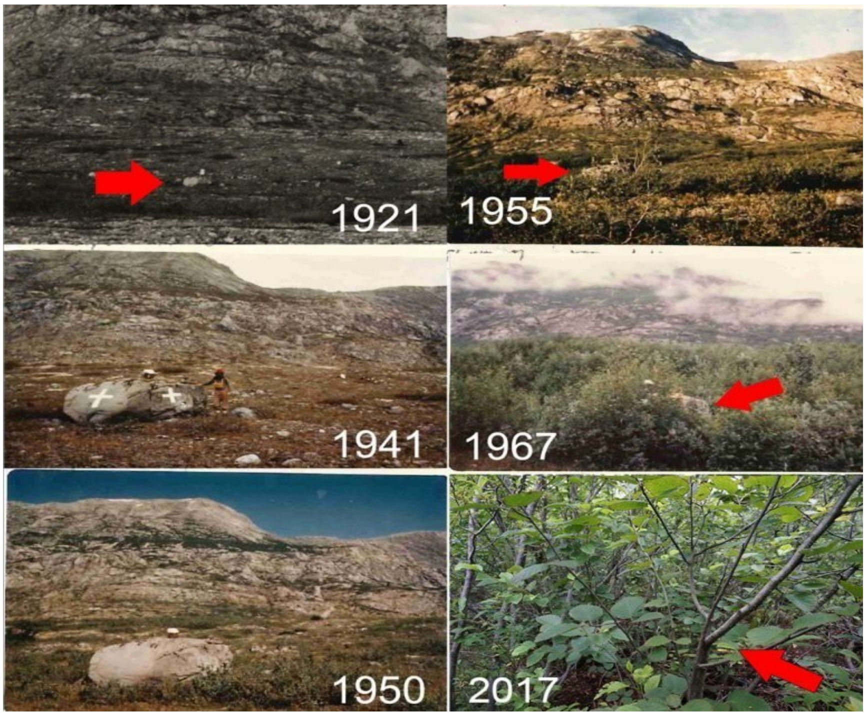
Confirmation that evolution occurs exactly as described above, that is, all potential possibilities are randomly realized, there is an example of another experiment. This experiment began in 1916 by the American scientist William S. Cooper [41].

"... On a 707-square-meter site recently freed from a glacier in Glacier Bay National Park, Alaska, he pitched the land into squares of one meter each. Since the site was virtually lifeless, it was well suited to track how the biological community develops and species changes in it (that is, succession). Every 5-10 years, a scientist came to the territory and documented the condition of the plots. He kept a record of the species that grew in each square, counted their number and plotted plot each instance plants so that he could trace which plants were the first to settle on the plot, which and when to replace them...

Cooper collected data from 1916 to 1939 ... After the 30s, data from the platform began to be collected by Cooper's pupil, Donald Lawrence, who kept records from 44 to 88, but did not publish them. After 1988, no one visited the platform..." [42].

100 years have passed, and scientists continued this experiment (Brian Buma from the University of Colorado and his colleagues). Thanks to the recordings of Cooper and Lawrence, they found the place where the experiment took place, found the layout of the squares made by Cooper with the help of reinforcement and stones, studied the species composition of the cells, the distribution of plants along them, the age of the trees, the amount of light that falls on the squares and the chemical composition of the soils. The study is published in the journal “Ecology” [43].

See photos (according to the boulder marked by an arrow, scientists estimated the density of the forest in the experimental plot, University of Colorado Denver) [42].



“Judging by what scientists saw on an abandoned experimental site, the “protocol” for changing species actually looked like this: mosses - dryad. There were no further visible patterns ... At the same time, the trees grew at about the same time, regardless of breed. An analysis of soil chemistry showed that there is a correlation between alder distribution and nitrogen content ...

If the change of tree species occurred as expected, then at least young spruce trees would have to grow in areas with alder. But even this was not - spruce and alder almost did not mix among themselves. Forests mainly grew 50 - 70 years ago, and since then their species composition has not changed.

Scientists concluded that the theoretically predicted progression of succession continued until the formation of grass cover, inclusive. Further, everything depended not on the terrain conditions, but on accidents, such as the dispersal of the seeds of trees brought by the wind, birds and animals. After that, the trees, which were lucky to grow, formed a continuous forest canopy on the platform, the growth of other tree species stopped due to a lack of light and the situation was fixed. The authors suggest that if something, such as a fire, does not disturb the platform, then the prevailing species will take their places for an unlimited time.

The authors of the article conclude that the temporal sequences of successive species do not lose their importance. Nutrient content and climate play an important role in identifying species that can grow in places. But random processes that determine which species inhabit the territory are no less important ...” [42].

Now, let's recall the "Biosphere 2" project. This project has shown how all processes and phenomena in the biosphere are interconnected. For example, in the “artificial biosphere” (project “Biosphere 2”) there was no wind, and therefore the trees did not sway from side to side. Surprisingly, this led to the trees becoming fragile and breaking. Biochemistry, genetics, etc., remained the same, but the result was different. Due to the lack of wind! Only this fact alone shows how interconnected everything is in the biosphere. Theoretically, everything to consider to create an “artificial biosphere” will be incredibly difficult. But let's hope that is possible.

It can be argued that the more species will coexist in the biosphere, the more stable it will be for a longer time. But, as the biosphere evolves, the ratio of different species will change (viruses, bacteria, plants, animals, etc.). And therefore, after some time, the biosphere will become unstable with such a “species composition”, and it will turn into a different biosphere in composition. Such a “spasmodic”, “quantum change” of the species composition of the biosphere will be perceived by an external observer as a “mass extinction”. Naturally, massive extinction can be provoked astronomical, climatic, and other phenomena. But, interestingly, the very evolution of the biosphere will inevitably lead to this.

Obviously, the more the “diverse species composition” of the biosphere is, the more stable it will be (and the longer it will take). But, we can assume that in order to get a stable biosphere for several hundred million years (or a billion years), we will need to use a planet like Earth! More “simple, closed biospheres” can be created artificially, but they will be able to sustainably “work” for 5 years, 10 years, 50 years, etc. And the “period of their use” will directly depend on the species diversity of the artificial biosphere, and the “right” accounting for significant factors.

Moreover, if we take into account astronomical phenomena (activity of stars in the central region of the galaxy, gamma-ray flares, supernova explosions, attack of meteorites, “heat” near the

Sun, “cold” in the distance of the Sun), geological (volcanic eruption, atmospheric composition, planet temperature), and many other factors, it is obvious that the probability of the origin and existence of the biosphere will indeed be tending to zero. And for the origin of life, and for the long and stable existence of the biosphere, truly unique conditions are needed that can be realized only once, and only on the scale of the infinite Universe.

But to show this, we need to analyze the theories of evolution of Darwin and Lamarck.

Consider the theory of evolution according to Lamarck. In 1809, Jean Baptiste Lamarck published the work (Philosophie zoologique) in which he formulated the theory of evolution [44 — 46]. Lamarck recognized the possibility of the origin of some species of creatures from others more primitive. The driving forces of the theory of evolution of Lamarck are environmental changes that are in living beings and cause changes in their genetic apparatus. The main thesis of the theory of evolution of Lamarck is the concept of "progressive improvement." This means "exercise of organs", fixed by subsequent generations, that is, the transfer of "beneficial changes" by inheritance. The idea of "organ exercise" was subsequently borrowed by Charles Darwin.

Improving, organisms are forced to adapt to environmental conditions. To demonstrate, Lamarck gave an example of giraffes. Giraffes have to longer crank their neck to reach the leaves growing above their heads. Therefore, their necks become longer, extended. Naturally, in the giraffe example, Lamarck was wrong. Here everything “works” according to Darwin: there is an initial variety of individuals, and there are individuals with the longest neck, and nature selects them through “natural selection”. And therefore, in the end, all giraffes will have a long neck.

Complex multicellular organisms evolve according to Darwin, and there are very important reasons for this. Consider Darwin's theory of evolution. Charles Darwin in 1859 published the book “The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life”, where he showed the variability of plant and animal species, and their natural origin from earlier species [47].

The essence of Darwin’s theory is that when we have a certain species, we have the genetic diversity of its individuals, this diversity is there initially (without external influence). And specific individuals that genetically have “useful features” turn out to be more adapted to the environment, and therefore, give more offspring. This is how “beneficial properties” are inherited. Genetic diversity is an accident that is determined only by copying DNA, that is, by mutations, copy errors, etc. It is especially necessary to note that, according to Darwin, there is no direct influence of the environment on the genetic apparatus of individuals. The environment simply selects through "natural selection" what is already genetically formed. The selection of cats, dogs, horses, plants, etc. also works: just what a person needs is selected from a variety. After a certain number of generations, we will get individuals with the desired properties. In nature, after a long time we get a new species. This type of evolution is the exact opposite of Lamarck evolution. According to Lamarck, it is the environment that should make genetic changes in the DNA of individuals so that specific individuals of the population are more adapted to life.

So who is right Lamarck or Darwin? Both Lamarck and Darwin are right!

Lamarckian evolution proceeds if we consider the evolution of unicellular organisms (bacteria, archaea) that have DNA. A bacterium is a unicellular organism that has DNA, therefore, it is fundamentally possible to "irritate" the external environment (stress), "write" into bacteria DNA. And then, such a "smart" bacterium will be more successful in its life. This is how the evolution of bacteria and archaea takes place. Let's consider this question in more detail.

There are certain viruses that kill bacteria. These viruses are called bacteriophages [48, 49]. When bacteria are exposed to bacteriophages, some bacteria survive. They (bacteria) adapt to the external environment. In this case, the bacteriophage is part of the external environment. And interestingly, the bacterium, to be resistant to the bacteriophage, literally writes part of bacteriophages genetic code into its DNA. This is a complex mechanism CRISP/CAS [50, 51]. In fact, the CRISP/CAS mechanism is a "pure" theory of Lamarck evolution.

Since the bacteriophage is part of the external environment, the direct recording of information about the bacteriophage in the bacterial DNA is a purposeful adjustment of the body to the environment. Therefore, in unicellular organisms (bacteria, archaea) we have the Lamarckian mechanism of inheritance (adjustment to the external environment), that is, Lamarck evolution.

The CRISP/CAS mechanism can be done as follows: we enter information about the bacteriophage into the DNA of a particular bacterium, and it should become resistant to this bacteriophage. This is exactly what happens in reality. Naturally, when we move on to multicellular organisms, the Lamarck evolution will not "work", since it is fundamentally impossible to quickly make changes to all the DNA of a particular organism, since there are trillions of cells in the body! And therefore, in all multicellular organisms, Darwin evolution occurs, that is, through the selection of organisms with "useful" genetic characteristics. In multicellular organisms, it is already impossible to directly make changes to the DNA of a specific organism (due to the huge number of cells).

But, for further presentation, we formulate the cybernetic theory of evolution. "Omnipresent DNA", Lamarck evolution, Darwin evolution will logically lead us to the cybernetic theory of evolution, which can explain how life was born, how many species of living organisms exist on planet Earth, how many species of bacteria exist, how many types of viruses exist, and even which volume of the primary reactor will be in which the first DNA and RNA were synthesized. So, consider the cybernetic theory of evolution.

Cybernetic theory of evolution and origin of life.

The information recorded in DNA is sufficient for the "assembly" of the organism, so the emergence of a DNA molecule is one of the fundamental moments of the origin of life and the theory of evolution. In living organisms, almost all processes occur mainly due to enzymes of protein nature, which are effective catalysts for strictly defined reactions. If we can synthesize all the enzymes of the body, then we can "collect" this organism. But, for the synthesis of enzymes, messenger RNAs are needed. And the messenger RNAs themselves are synthesized based on DNA. DNA is simply a large molecule that consists of hundreds of millions or billions of atoms. Therefore, the probability of spontaneous “assembly” of DNA or RNA for the initiation of life cannot be zero by definition. There is always the possibility that, under certain conditions, spontaneous synthesis of a DNA or RNA molecule will occur.

That is, in the “primary bouillon”, spontaneously, sooner or later, DNA and RNA molecules must “assemble”. The probability of this process is rational zero P(DNA) = 0(R), that is, the smallest rational number, which is still nonzero [21, p. 6]. In fact, we come to the conclusion that the first stage in the evolution of the biosphere and the origin of life is the “RNA world”.

"The “RNA world” is a hypothetical stage in the evolutionary history of life on Earth, in which self-replicating RNA molecules proliferated before the evolution of DNA and proteins...Alexander Rich first proposed the concept of the RNA world in 1962 [1], and Walter Gilbert coined the term in 1986 [2]. Alternative chemical paths to life have been proposed [3], and RNA-based life may not have been the first life to exist [2, 4]. Even so, the evidence for an RNA world is strong enough that the hypothesis has gained wide acceptance [1, 5, 6]. The concurrent formation of all four RNA building blocks further strengthened the hypothesis [7]." [52, 53 – 58].

Consider the origin of the “RNA world”, that is, consider the moment when the “assembly” of one RNA molecule or one DNA molecule happened by chance (the probabilities of their “assembly” are equal). But, there is one caveat: RNA can copy itself, but DNA does not. To copy DNA you need a protein, namely an enzyme called DNA polymerase. And all proteins are synthesized on messenger RNA. Therefore, this world is called the “RNA world”, since the role of RNA is fundamental in this case. Matrix RNA-based proteins are synthesized in the ribosome of the cell. But, in the “world of RNA” there are no ribosomes, cells, or similar complex systems. So how does the copying of DNA, RNA, proteins?

Let's take a schematic look at protein synthesis in the ribosome, based on messenger RNA. The ribosome provides the necessary building blocks for protein synthesis, and the messenger RNA provides a plan for protein “assembly”. That is, the ribosome creates ideal conditions for the rapid "assembly" of proteins, this is the essence of the function of the ribosome. If we assume that the matrix RNA will be fixed on some solid catalyst in the "primary bouillon" (for example, on a mineral, or on volcanic rock, etc.), then the building blocks will come from the surrounding space very slowly, and “assembly” protein will also occur slowly (when compared with the process in the ribosome). But, it is important for us that this process will occur in principle. Moreover, the "assembly" of the protein will occur without a ribosome, that is, without a cell. This is very important and fundamental. We can extend this process to copying DNA and RNA.

From the above it follows that the attachment of DNA and RNA molecules to a natural catalyst in the "RNA world" is a necessary stage of evolution. Moreover, given that the chain of both DNA and RNA consists of residues of phosphoric acid and ribose (or deoxyribose), we can state that the attachment of these molecules to minerals containing silicon dioxide (SiO2) and various metal oxides will be very good. This follows from some similarity between the phosphoric acid molecule and the silicon dioxide molecule (meaning alternating element - oxygen), which will inevitably lead to good binding of the DNA or RNA molecule to various natural minerals (both natural and volcanic origin). Therefore, the attachment of DNA or RNA to the catalyst, in the primary broth of the "RNA world", is an inevitable stage. And the more islands in the ocean, the craters of underwater volcanoes, various seamounts, etc., there will be, the faster the primary RNA molecule will be fixed on the mineral. After fixing the molecule, the process of copying the corresponding molecules (RNA, DNA, proteins) will begin. And in fact, from the moment of fixing the RNA molecules (and DNA) on the natural catalyst, the evolution of the “RNA world” will begin.

Therefore, if at the beginning of the “RNA world” we have at least one RNA molecule, then there will be another such molecule, and the third, and 100th, and 1000th, and so on. Moreover, if the evolution of the original RNA leads us to messenger RNA, then we will get the “assembly” of the protein, and the number of protein molecules will be limited only by building blocks. And if there are proteins, then they can already copy themselves the corresponding DNA molecules, which were spontaneously synthesized. These processes mean the beginning of the evolution of the biosphere and the first stage of the origin of life.

From the above it is clear that the evolution of the “RNA world” will inevitably lead us to a mixture of three types of molecules: DNA, RNA and proteins. That is, the primary bouillon, or rather the “RNA world”, inevitably evolves to a mixture of various RNA molecules, DNA and proteins. This is the first stage of the origin of life, and the most important stage, since then the system simply evolves. Moreover, interestingly, the “RNA world” is evolving according to Darwin and Lamarck. Since there will be “natural selection” of more “successful” molecules (DNA, RNA, proteins) in the primary broth, that is, evolution will occur according to Darwin. But, there will also be a reaction of the molecule (DNA, RNA, protein) to the environment. Moreover, the response to the “stress” of the environment will be a change in the molecule itself (DNA, RNA, protein), which is Lamarck's evolution. For example, mechanical stress can lead to rupture of an RNA molecule.

The second stage of evolution of the Earth's biosphere is the formation of viruses and their evolution. Obviously, at the end of the evolution of the “RNA world” we have all the necessary components for the formation of the virus: we have various RNA and DNA molecules, as well as various proteins. As will be shown below, the number of different combinations of the corresponding molecules (RNA, DNA, proteins) will be simply unimaginably large, as well as their number.

What are viruses? This is a DNA or RNA molecule wrapped in a protein coat. The protein coat is called the capsid of the virus, and consists of various proteins. And if there are necessary components and time, then sooner or later complete viruses will form. Naturally, viroids are formed earlier, that is, RNA viruses without a protein coat.

After the formation of the first viruses in the "world of RNA" the evolution of viruses will begin. Virus evolution will also occur according to Darwin and Lamarck. According to Darwin, the selection of the most successful viruses will take place, that is, those viruses that can make more copies of themselves, and then they can “successfully” evolve generating new viruses. And according to Lamarck, the genetic code of the virus will change under the influence of the environment. For example, a change when copying the concentration of substances, temperature, etc., a change in the genetic apparatus of the virus by other viruses. Obviously, changes in the code of one virus under the influence of another virus will occur according to a mechanism similar to the CRISP/CAS mechanism. After some time of the evolution of viruses in our "natural reactor" we will have a huge number of different viruses. Moreover, the evolution of viruses will simply increase their diversity. In fact, this is a purely mathematical, or rather probabilistic, process.

In such a “natural reactor”, after a certain time, a certain equilibrium will be established between viruses with full capsids and viruses without protein shells (a kind of viroid). That is, the transition from the "world of RNA" to the evolution of viruses will be rather arbitrary. We can assume that the evolution of viruses began when the number of viruses with full capsids begins to increase.

In a "natural reactor", which is filled with viruses, DNA molecules, RNA, as well as molecules of various proteins, the formation of a simple single-celled organism is a fairly logical process, since all the complex and necessary components are already there. Fats and other low molecular weight molecules necessary for the origin of life can easily be formed under the conditions in which biopolymers (DNA, RNA, proteins) were formed. The formation of biopolymers is a completely different level of complexity. For the same reason, we did not consider the synthesis of pyrimidine and purine bases, as well as ribose and amino acids, which are necessary for the “assembly” of DNA, RNA and proteins . If spontaneous “assembly” of DNA or RNA is possible, then the presence of the starting components can be taken as an axiom.

Thus, we come to the third stage of the evolution of the biosphere, that is, to the appearance of the first unicellular living organism. After the evolution of viruses, we have an unimaginable variety of viruses. Moreover, viruses are the most complex living system in our “natural reactor”. Therefore, the first unicellular living organism must be a “more complex" version of viruses. Such a first living organism will be the simplest bacterium, which will not be very different from the virus. But, functionally, it will already be a bacterium. Next will begin the evolution of these simple bacteria, which will lead us to ordinary bacteria. That is, the third stage in the evolution of the biosphere is the evolution of bacteria. As we already know, the evolution of bacteria occurs both according to Darwin and Lamarck. Especially important for us is the evolution of bacteria according to Lamarck. Consider it in more detail.

Building simple bacteria from viruses will require building blocks such as fats. Various fats can be obtained from glycerol and the corresponding alkanoic acids. If there is a ribose in the “RNA world”, then there is a triose. And if there is triose, then during recovery we will get glycerin. Similarly with alkanoic acids: if there are amino acids in the “RNA world”, then through a series of transformations we will get alkanoic acids. This means that at the end of the evolution of the “RNA world” there will be all the necessary components for the “assembly” of the simplest bacteria (by complicating the viruses). When “assembling” biopolymers, the presence of low molecular weight organic substances can be taken as an axiom, since the complexity of the synthesis of biopolymers is much orders of magnitude higher.

For bacteria, a bacteriophage (i.e., a virus) is part of the external environment. And therefore, the bacterium, in order to be resistant to the external environment, namely to the bacteriophage, literally writes part of its genetic code into its DNA. If there is no genetic code of a specific virus in the “database” of a bacterium, then it will die from it. Given this fact, and the fact that after the evolution of viruses we have an unimaginable number of viruses in the “natural reactor”, the tasks of the evolution of bacteria are completely obvious. To survive successfully, bacteria must write as many viruses as possible to their genetic code. Otherwise, a meeting with an unknown bacteriophage will end with the elimination of the bacterium.

That is, at the third stage of the evolution of the biosphere, the evolution of bacteria occurs. Moreover, in the course of this evolution, bacteria must “record” in their DNA all possible viruses that are in the “primary reactor”. Therefore, the evolution of bacteria will be completed only when all types of bacteria (which survive), record all types of existing viruses in their DNA (in a "natural reactor"). After this stage, the complication of the system will begin, that is, the transition from unicellular life to multicellular life, and we proceed to the 4th stage of the evolution of the biosphere, that is, the stage of evolution of multicellular organisms (animals, plants, fungi, etc.).

The emergence of complex multicellular organisms that contain trillions of cells precludes Lamarckian evolution, since changes in the external environment can no longer be written into the body’s DNA, since the body contains a lot of cells (and hence DNA molecules). But, we must not forget the fact that a cell in the body evolved from a bacterium, which in its DNA already “recorded” all viruses of the “natural reactor”, or most of them. Therefore, all complex multicellular organisms (and unicellular, of course also) in their own DNA already have a "database" of all viruses of the "natural reactor". This can be confirmed by the example of man.

When we get a viral infection, our body produces certain proteins (antibodies) that kill the virus. But, a set of our antibodies already exists as a set of cells that these antibodies can produce. That is, when we are born, we already have a “database” of all viruses with which we can contact. And upon contact with the virus, our body determines what kind of virus it is (comparing it with the “database”). And only after that it activates the cells that begin to produce antibodies to this particular virus.

This is a very amazing fact! But, this fact confirms that bacteria must “record” all existing viruses in their DNA. This means that if we accidentally encounter a virus that is not in the "database" of mankind, then humanity is likely to disappear as a view from the face of the Earth (since there will be no time and biochemical pathways for generating antibodies). Now recall our statement about “omniscient DNA”? That is exactly the case in reality. DNA must contain all the necessary information about our biosphere, so that the body can exist in this biosphere. So for this, there is a large part of the DNA, which was called "non-coding DNA".

The evolution of bacteria has led to the fact that bacteria "recorded" in their DNA a huge number of bacteriophages. After the formation of multicellular organisms, these "recorded" sections of DNA were inherited by multicellular organisms. Therefore, each multicellular organism had (and has) a “database” of a huge number of viruses. This is the so-called “non-coding DNA”. Each type of organism, in its habitat, comes into contact only with a certain number of viruses. Therefore, each type of organism “develops” precisely its “biochemical weapon” for those viruses that it and its predecessors encountered in their environment. Most viruses “recorded” in DNA have never been found in this species or in its predecessors. Therefore, for such "unnecessary" viruses, the body carries out the operation of archiving information in DNA. That is, information about viruses (which did not and will not) is recorded in the DNA (of the body), more briefly and compactly. Since it is not necessary to store detailed information about the virus, which is needed to develop a biochemical response to the invasion of the virus into the body cell. If, however, a meeting with this virus did occur, then information about the virus can always be obtained by the “unzip” operation. Here we have a complete analogy with archiving/unzipping information on a computer, which is understandable, since the methods of working with information are universal.

The fourth stage in the evolution of the biosphere, namely, the stage of evolution of multicellular organisms (accordingly to Darwin) and leads to the variety of species of living creatures that we observe in reality.

It is clear that species diversity, at every stage of the evolution of the biosphere, will exponentially decrease starting with the evolution of viruses. The reason for the exponential decrease in species at each subsequent stage of evolution is that each previous stage of evolution is the foundation on which only “successful” species develop (from the next stage of evolution). Therefore, an exponential decrease takes place: at each subsequent stage of the “successful” species there will be less and less... In our biosphere, at the top of this evolutionary ladder, there is a person.

If we come from man, the number of species will increase exponentially. This is the inverse problem. So, we consider finding the exponent coefficients $y = e^{(k*n)}$,

where y — number of species,

n — stages of evolution,

k — coefficient that characterizes the growth of the exponent.

Homo sapiens - 1 species, $n = 0$

Primates — 477 species, $n = 1$ [59].

If we write the exponent in the form $y = e^{(k*n)}$, then we can easily calculate k.

$k = 6.167518$

n — are the stages of evolution starting with man.

That is, we have:

$n = 0$, Homo sapiens.

$n = 1$, primates.

$n = 2$, vertebrates.

n = 3, all kinds of living things before bacteria.

n = 4, bacteria.

n = 5, viruses.

n = 6, "RNA world".

Homo sapiens emerged from a variety of primates. Primates came from a variety of vertebrates. Vertebrate animals emerged from a variety of multicellular organisms (animals, plants, fungi, etc.). Multicellular organisms emerged from a variety of unicellular organisms (bacteria, archaea, etc.). Unicellular organisms emerged from a variety of viruses (DNA viruses, RNA viruses, viroids, etc.). The diversity of viruses is the result of the diversity of DNA and RNA molecules in the "RNA world". The "RNA World" was the result of a variety of RNA/DNA-like molecules (various combinations of purine and pyrimidine bases on RNA/DNA-like molecules).

We now determine the number of species at each stage of evolution (y is the number of species).

n = 0, Homo sapiens, y = 1 specie. Have 1, calculated 1.

n = 1, primates, y = e^(6.167518*1) = 477 species. Have 477, calculated 477.

n = 2, vertebrates, y = e^(6.167518*2) = 227.5 thousand species of vertebrates. Have 50 000, calculated 227 500 [60].

n = 3, all kinds of living things before bacteria, y = e^(6.167518*3) = 108.5 million kinds of living things (animals, plants, fungi, etc.), including all kinds except bacteria. Have 1.75 million, calculated 108.5 million [61].

This number of species of living things (calculated exponentially) is the number of all species that can exist in our biosphere. For example, the number of vertebrates on Earth now is approximately 50 000 species, and we calculated 227 500. But, the figure of 227 500 includes those species of vertebrates that existed before us, and which will exist after us. Similarly with species of all multicellular organisms. Now the number of species of multicellular organisms registered on Earth is approximately 1.75 million. But, according to estimates, at the moment there may be about 9 million of them. And by our calculation, we got a value equal to 108.5 million. But, the number of 108.5 million includes both the species that came before us and the species that will come after us (in our biosphere). Therefore, the number of 108.5 million species of multicellular organisms looks quite reliable.

n = 4, bacteria, y = e^(6.167518*4) = 52 billion species of bacteria.

There are about 5*10^30 bacteria on Earth, and the biomass of bacteria exceeds the total biomass of animals and plants [62]. As of 2018, several thousand bacteria have been described [62]. The total number of bacterial species, according to various estimates, ranges from 10^7 to 10^9, but these estimates can be orders of magnitude smaller than the present number of species. The human microflora is 39 trillion bacteria, the human body itself consists of 30 trillion cells.

n = 5, viruses, y = e^(6.167518*5) = 25 trillion types of viruses.

Now more than 6 000 types of viruses are known and described, but it is estimated that there are more than 100 million types of viruses [63]. Viruses are the most common form of life in the ocean (and on Earth), where they contain a huge number. The number of viruses in the ocean exceeds the number of bacteria and archaea by 15 times, and is more than 10^31. A teaspoon of sea water contains about 1 million viruses. Marine viruses are mainly bacteriophages, and therefore absolutely harmless to plants and animals. The biomass of the oceans is 90 % composed of bacteria and other microorganisms, and every day viruses kill about 20 % of this biomass. The organic molecules that are freed up are used to grow new bacteria and algae. Viruses can infect all kinds of life forms on Earth, from animals and plants, to microorganisms (including bacteria and archaea). Therefore, viruses are found in almost every ecosystem on Earth. Earth is a planet populated by viruses.

n = 6, “RNA world”, y = e^(6.167518*6) = 1.1*10^16 of all types of RNA and DNA in a “natural reactor” from the “RNA world”.

For n = 6, we get the types of RNA and DNA that “work” as typical RNA molecules (or DNA molecules), that is, those molecules on which information is recorded. To get all combinations of DNA and RNA, which will include both working molecules and “dummy molecules” (which cannot be a genetic code by definition, as they are information noise), you need to go to the next 7th level (n = 7).

n = 7, all combinations of RNA and DNA, y = e^(6.167518*7) = 5.6*10^18 types of combinations of RNA and DNA, including molecules that carry information noise, not the genetic code.

If we go up another level (n = 8), then we get the number of all molecules that contain all combinations of RNA and DNA from n = 7.

n = 8, y = e^(6.167518*8) = 2.68*10^21 molecules of RNA and DNA, that is, 4.45*10^(-3) moles.

This means that 4.45*10^(-3) moles of RNA/DNA molecules are enough to start the evolution of the biosphere. This is 4.45 millimoles of substance. Let's estimate how much it will be by weight. The molecular weight of the DNA gene is 103.5 kg/mol. A person has about 20 – 25 thousand active genes, which makes up 1.5 % of human DNA. We calculate the mass of 1 mole of human DNA, taking into account the remaining 98.5 % of “non-coding DNA”. Through simple calculations, we get that the mass of 1 mole of a DNA molecule will be 176 thousand tons. Given that human DNA is not the largest molecule, for the convenience of calculations, we assume that 1 mol of the DNA molecule will have a mass equal to 1 million tons. Since, for n = 8, we got 4.45*10^(-3) moles of substance, we get a mass equal to 4 450 tons.

From the above calculations, it follows that to start the evolution of the Earth's biosphere, 4 450 tons of RNA/DNA from the 8th level (n = 8) are enough. We calculate the volume of the solution in which the mass fraction of RNA/DNA molecules will be 20 %. The mass of such a solution will be 22 250 tons, and the volume is 22 250 m^3. Approximately this amount of water is contained in a basin 80 meters long, 30 meters wide, and 10 meters deep (24 000 m^3). If we take a lake which contains 35 million tons of water, then when 1 mole of DNA/RNA is dissolved in it, we will get about 3 % DNA/RNA solution (1 mol of DNA/RNA has a mass of about 1 million tons). This is our “natural reactor”, such a small lake. It should be noted that Lake Titienze, which is located in Germany, has 35 million tons of water. It was in such a reactor that the evolution of our biosphere began. This reactor could be a small lake, or could be a crater of a volcano, could be an underwater crater of a volcano, or could be a small sea, etc.

We can also evaluate the conditions under which evolution began, namely the “assembly" of DNA/RNA molecules. To do this, recall the last universal common ancestor [64]. It is the simplest single-celled organism (LUCA) that lived about 4 to 4.5 billion years ago. The important thing is that all kinds of our biosphere have come from LUCA. Scientists from the University of Bristol (UK) have calculated that LUCA lived at a hot spring on land. That is, it existed in hot water, probably about 70 degrees. But, do not forget that LUCA is the simplest bacterium, and therefore the evolution of viruses and the “RNA world” could exist in more severe conditions.

Thus, we come to the conclusion that the “RNA world” could originate and evolve in a hot lake at a temperature of 70 - 100 degrees (either a volcano crater or an underwater crater). It could be boiling water in the first stage, since it was at this stage that the first RNA molecules were to be formed. And RNA can be formed by the condensation reaction from the starting blocks (phosphoric acid or its esters, ribose, purine and pyrimidine bases or their derivatives). This is essentially a common polycondensation reaction. Under these conditions (temperature 90 - 100 degrees), the initial blocks themselves could form on mineral catalysts. After the initial "assembly" of the RNA molecule, the water temperature could stay within 70 - 90 degrees. In fact, this is a common organic synthesis in the aquatic environment. And the indicated conditions are quite probable for the emergence and evolution of the “RNA world”, especially it becomes probable if we recall that we have a billion years to synthesize.

Mass extinctions and evolution of the biosphere.

The most important cause of all mass extinctions is the evolution of the biosphere. This is easy to understand if you remember that species diversity, at every stage of the evolution of the biosphere, will exponentially decrease starting with the evolution of viruses. That is, on the "ladder of evolution", as organisms become more complex (viruses - bacteria - multicellular organisms - etc.), their diversity and therefore adaptability will also fall exponentially. A simple conclusion logically follows from this: after some time, the “potential for changes” of such a biosphere will end, and this will inevitably lead to a “different biosphere”. That is, there will be a quick transition to other types of organisms, in fact, to a different biosphere. Moreover, this is inevitable.

Moreover, the higher the species of organisms on the "ladder of evolution" stand, the greater their percentage will disappear from the face of the planet. Since both species diversity, and therefore genetic diversity, these species will be small, due to an exponential decrease. The adaptability of species and specific organisms according to Darwin is determined by their genetic diversity. But, since everything decreases exponentially (number of species, genetic diversity, adaptability to the external environment, etc.), complex organisms will be quite severely limited by environmental conditions.

This is quite logical, since the more complex the body, the more complex its biochemistry, and therefore the less space DNA will have for variety. The magnitude of DNA cannot increase indefinitely, since DNA is copied; moreover, information is read from DNA onto RNA. And all these processes take time. A certain time. Therefore, the DNA size will also have its limit and range (smallest size - largest size). This confirms the DNA of birds, which is the smallest DNA. Birds fly, and therefore their biochemical processes are very intense. Therefore, the DNA of birds should be small, since the time of DNA replication is strictly limited by intensive biochemistry. It is clear that replication of large DNA requires more time, which birds no longer have. If the simplest organisms (bacteria, multicellular, etc.) have “slow biochemistry,” then their DNA can be large. So, they will have more species and genetic diversity. And therefore, according to natural selection, adaptability to the external environment will be greater. Such organisms will be able to survive with stronger changes in the biosphere, which is confirmed by mass extinctions. Here we have a complete analogy with the computer: the program must be of a certain size: with very large programs, the computer runs slower. That is, DNA is an ordinary program for a living organism, the only peculiarity is that it is both a program and “iron” at the same time.

Based on the above, we can conclude that after some time of evolution, the biosphere will completely change its species composition. Moreover, this change to a “different biosphere” will take place as follows: the regular extinction of species occurs as usual, and new species do not form anymore, since they have exhausted their “Darwin potential”, that is, genetic diversity (based on the “old” biosphere). At the same time, fundamentally new species will emerge (from the “new biosphere”), which may exist under new conditions. The processes of departure of the "old" species and the nucleation (and appearance) of "new" species will occur for a certain period of time. This is clear, since nature will actually develop a new biochemistry under the “new conditions” that will gradually appear (as the old species “leave”, and as the biosphere changes).

Moreover, this approach also explains why there are so few “transitional forms” between species. When a “new” biosphere is formed, then it unfolds immediately as a whole, on the basis of already different, “new” DNA. “New” DNAs already pre-existed for all types of the biosphere, and “waited” for environmental conditions to be favorable for the construction of the corresponding organisms (unicellular, plants, fungi, animals, etc.). Therefore, a new biosphere is “built” from pre-existing DNA as a whole, integrally. That is, all kinds of organisms develop simultaneously and immediately: both simple, and more complex, and very difficult organisms. This is possible for the simple reason that the base of all kinds of DNA was “created” back in the “RNA world”, and then, as the biosphere evolved, it was “transmitted” up the “ladder of evolution”. And finally, the time has come when the potential of “new DNA” will be realized, and new species of organisms will be formed from them. But, since there are "ready-made DNA", then their adjustment is not needed. Therefore, “finished species” are formed immediately without “refinement”, and transitions of some species to other species. Therefore, transitional forms are not massively formed.

Transitional forms are formed only when, in the process of changing environmental conditions, some organisms change so much that they form new species. But, since only some species change strongly during evolution, it is clear that there will be much less transitional forms than existing species in the biosphere. Naturally, the range of variation of one species (and the transition of one species to another) is entirely determined by the DNA molecule, and the height of the "evolutionary ladder" of a particular species.

The process of changing one biosphere to another takes tens and hundreds of thousands of years (and millions), which the external observer perceives as "mass extinction." It is this kind of extinct extinction of species that actually rejects the theory of catastrophes (a fallen meteorite, an eruption of volcanoes, etc.), since in this case the extinction would be simultaneous. And this is not so: all mass extinctions occur over fairly long periods of time compared to human life. But, on a geological scale, it looks like a simultaneous great extinction of species, which is why it was called "mass extinctions".

The reason for the "mass extinctions" is the exhaustion of the "Darwin potential" of the biosphere (genetic and species diversity). Therefore, if we assume that the evolution of the biosphere occurs gradually, then there should be some periodicity in the change of the biosphere (mass extinctions). Such a periodicity does exist, it is approximately 60 - 120 million years. It is clear that time periods may vary depending on the "depth" of biosphere restructuring, and the rate of change of the external environment. But, it can be argued that the "evolutionary restructuring" of the biosphere will never take place at the level of evolution of bacteria (or viruses), since this would actually mean the complete destruction of life "before bacteria" (or "before viruses"), which is possible only in the case of truly global catastrophes on a planetary scale.

It should be noted that the biosphere as a whole evolves according to Lamarck (as a living organism). We can say that there is a "progressive improvement" of the biosphere. And the "exercise of the organs" should be considered as the "exercise of the species", and then the evolution of the biosphere is the evolution according to Lamarck in its "pure form". Surprisingly, according to Lamarck, both the biosphere as a whole and bacteria (archaea) evolve.

Evolution according to Lamarck, and evolution according to Darwin complement each other. If the complexity of the organism "resolves", then Lamarckian evolution takes place: there is an improvement, an upgrade of the organism, as this is the simplest and fastest method of improving the organism for new conditions (or when there is only one organism). If the body is extremely complex, then a quick upgrade is no longer possible. And then Darwin's evolution takes place: an organism with the necessary upgrade is quickly selected. But, if we consider the biosphere as a very complex living organism (macro-organism, one organism), then the evolution of the biosphere as a whole again occurs according to Lamarck. Further, by the example of mass extinctions, we will demonstrate that during the evolution of the biosphere, the "species composition" of the biosphere ("exercise of species") naturally changes. That is, there is a "progressive improvement" of the biosphere.

Consider the main mass extinctions.

1. About 450 - 440 million years ago. Ordovician – Silurian extinction events [65]. For 1 million years, two outbreaks of extinction have occurred. More than 60 % of marine invertebrate species disappeared (life lived in the seas and oceans). The cause of extinction is a change in carbon dioxide levels (according to recent studies).

2. Late Devonian extinction. It happened about 374 - 359 million years ago. The extinction period is from 0.5 to 25 million years [66]. The number of species of marine organisms decreased by 50 %. Deposits of sedimentary rocks show that environmental changes had a very strong effect on organisms, which caused extinction. Extinction was accompanied by a lack of oxygen, which allowed the formation of oil.

3. Permian – Triassic extinction event [67]. The greatest mass extinction of all time. It happened about 251.9 million years ago. The extinction duration lasted no less than 30-60 thousand years. There is no generally accepted reason for extinction. 95 % of the species of all living creatures disappeared (96 % of marine species, 73 % of terrestrial vertebrate species). This is the only known extinction of insects (83 % of the species died out). This extinction also affected the world of microorganisms. It took 10 to 30 million years to restore the biosphere.

4. Triassic – Jurassic extinction event [68]. It happened about 199.6 million years ago. Extinction occurred in less than 10 thousand years, and led to the extinction of 50 % of the species living then on Earth. Statistical analysis shows that a decrease in diversity is associated with a decline in the rate of speciation (remember that the potential of the biosphere has exhausted itself !). A reliable cause of extinction has not been established.

5. Cretaceous – Paleogene extinction event [69]. It happened about 66.5 million years ago. The duration of extinction cannot be accurately estimated (incomplete paleontological data). This extinction destroyed 17 % of all species, including dinosaurs. Killed 16 % of the families of marine animals (47 % of the genera of marine animals), and 18 % of the families of terrestrial vertebrates (all large and medium in size). All ecosystems were completely destroyed, which subsequently led to the emergence of birds and mammals. There are no reliably established causes of extinction. Popular impact hypotheses, i.e., collisions with an asteroid, comet, etc.

You may notice that between extinctions there are time intervals of duration:

75 million years,

118 million years,

53 million years,

133 million years.

That is, there is a certain periodicity of 190 million years (75 + 118 = 193, 53 + 133 = 186). And the biosphere, twice in 190 million years, arranges the restructuring of its species composition. Moreover, the period of 190 million years must be divided into three parts (190 : 3 = 63). Then, the first restructuring will be in about 63 million years, and the second restructuring will be in 127 million years (190 - 63 = 127).

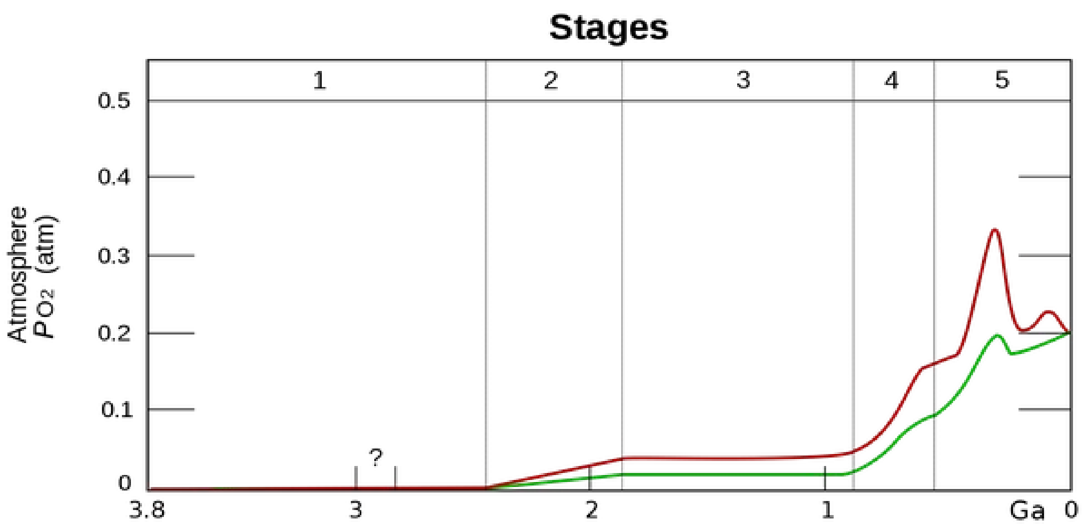
It is interesting to note that 225 - 250 million years is one galactic year for our solar system [70]. Perhaps the extinction is associated with the movement of the solar system around the center of our galaxy, and the passage of the solar system of some "dangerous zones".

Restructuring of the biosphere with some delay in time may be due to different rates of evolution of the biosphere at different levels of the “evolutionary ladder”. Since bacteria, plants, fungi, etc. species, and various animals, it takes different time to exhaust the potential of biodiversity. Due to the complex relationships in the biosphere, this leads to a time delay.

Oxygen catastrophe as the main reason for the evolution of the biosphere.

To demonstrate the influence of the environment on changing the species diversity of the biosphere, consider oxygen catastrophe. An oxygen catastrophe is the appearance of oxygen in the composition of the Earth’s atmosphere, happened about 2.45 billion years ago [71 - 73]. The primary atmosphere consisted of gases released from the mantle: carbon dioxide (CO2), hydrogen sulfide (H2S), ammonia (NH3), methane (CH4). The life that then existed on the planet did without free oxygen.

No oxygen is emitted from the mantle. The source of oxygen is the biosphere [74]. About 3.7 billion years ago, photosynthesis appeared. But, the bacteria that have it. Used, did not produce oxygen. This went on for nearly 1 billion years. About 2.7 billion years ago, cyanobacteria appeared, which began to produce oxygen. Oxygen began to enter the atmosphere, but was used to oxidize the rocks. And only after the oxidation of all rocks, oxygen began to accumulate in the atmosphere. This change in atmospheric composition for living things was revolutionary. The world has begun to change. Look at the picture that depicts changes in the composition of the atmosphere [75].



“O2 build-up in the Earth's atmosphere. Red and green lines represent the range of the estimates while time is measured in billions of years ago (Ga).

Stage 1 (3.85–2.45 Ga): Practically no O2 in the atmosphere. The oceans were also largely anoxic with the possible exception of O2 in the shallow oceans.

Stage 2 (2.45–1.85 Ga): O2 produced, rising to values of 0.02 and 0.04 atm, but absorbed in oceans and seabed rock.

Stage 3 (1.85–0.85 Ga): O2 starts to gas out of the oceans, but is absorbed by land surfaces. No significant change in terms of oxygen level.

Stages 4 and 5 (0.85 Ga–present): Other O2 reservoirs filled; gas accumulates in atmosphere" [75].

As can be seen from the figure, the level of oxygen in the atmosphere, up to 1.1 billion years ago, gradually increased (up to 3 - 4 %). Further, the level of oxygen in the atmosphere began to increase rapidly. The environment has begun to change. Indeed, approximately 0.7 billion years ago, the level of oxygen in the atmosphere had already reached 10 - 17 %. Obviously, this made it possible to develop a full-fledged biosphere based on oxygen life. But, after the development and heyday of the biosphere, when the exhaustion of the diversity potential occurred, the first mass extinction of species occurred (about 0.5 billion years ago). We also note that the first mass extinction exactly coincides with the rapid increase in oxygen in the atmosphere. Naturally, with an increase in oxygen in the atmosphere, the biochemistry of organisms will change significantly, which will lead to the restructuring of the biosphere (mass extinction).

The graph clearly shows that the maximum oxygen content in the atmosphere (20 - 35 %) exactly corresponds to the heyday of giant animals on Earth. Based on the schedule, this happened approximately 250 - 50 million years ago. It could not be otherwise: large animals need a lot of oxygen to feed tissues. "Lack of oxygen could inhibit the development of large complex organisms for a long time. The problem is that the amount of oxygen that an animal can absorb from the environment is limited by its surface area (lungs and gills in the most complex animals, skin in simpler ones). The amount of oxygen required for life is determined by the mass and volume of the body, which grow faster than the area with increasing size. An increase in the concentration of oxygen in air and in water could weaken or completely eliminate this limitation" [76]. Therefore, at a certain concentration of oxygen in the air there will always be a certain maximum size of animals and plants. An animal larger than this size cannot supply enough oxygen to its tissues in any way. This ban on the maximum size of animals can be circumvented if you increase the concentration of oxygen in the inhaled air, or reduce the gravity on the body (animals in water). And therefore, dinosaurs were large, since the amount of oxygen in the atmosphere could reach 35 %, that is, 1.67 times more than now.

With an increase in the percentage of oxygen in the air, there will always be an increase in the size of living creatures (animals, plants, etc.). Since the nutrition of tissues increases, which means that they can develop to large sizes. It was during this historical period that there was a time of giants on Earth. To confirm the above, we give an example of breeding dwarf trees. In fact, a bonsai is the cultivation of dwarf trees from ordinary tree species, but with a limited size of their root system (food restriction). Trees are grown in a small amount of land. And since the size of the root system determines the size of the tree, small trees are obtained.

Moreover, this is confirmed by sequoia, which came to us from the era of dinosaurs.
Sequoia is a giant tree that grows in California in a humid climate. Sequoia grows to 110 meters and above [77]. The maximum theoretical height of sequoia is now limited to 122 - 130 meters due to gravity and friction between water and wood pores [78]. Another sequoia has one feature: the sequoia bark literally protects the tree from fire, it is fireproof. Literally. This is very important for us, since sequoia came to us from the era of dinosaurs. Obviously, the refractory bark of sequoia could develop only to protect trees from fires. So, in the era of dinosaurs, there were strong fires on the planet, and the trees had to adapt to this. They adapted - they developed a refractory bark. In the era of dinosaurs, the percentage of oxygen in the atmosphere was large (up to 35 %), and therefore fires occurred very often. It could not have been otherwise with such a large percentage of oxygen. This is a common chemistry.

Thus, a large percentage of oxygen in the atmosphere leads not only to an increase in the size of organisms, but also to frequent fires. Moreover, the larger the percentage of oxygen, the more often there will be fires. But, during large-scale fires, incomplete combustion usually occurs, and therefore carbon monoxide (CO) is formed, which is fatal to all living things. Carbon monoxide (CO) at a concentration in the air of more than 0.1 %, leads to death within one hour. At a concentration in air (CO) of 0.02 %, it slows down growth and reduces activity (experiments on rats). The biochemistry of carbon monoxide (CO) is elementary: carbon monoxide binds hemoglobin more strongly than oxygen, and therefore, the body dies from suffocation (and this is with the normal presence of oxygen).

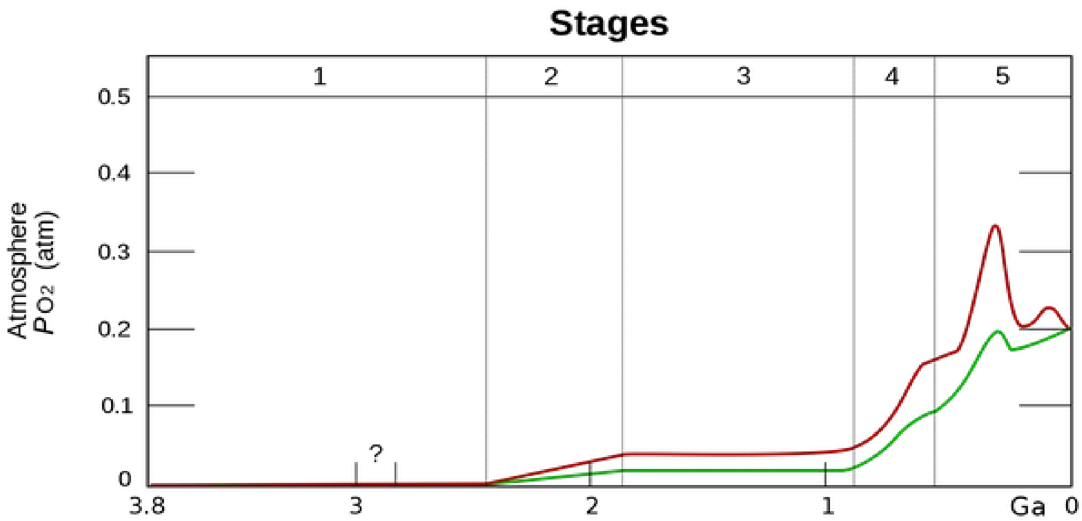
In an era of large percentages of oxygen in the atmosphere, not only fires destroyed all life, but also carbon monoxide (CO). Therefore, when reaching the maximum oxygen in the atmosphere, there was a maximum number of fires. And gradually, evolution began to change the vector of development. That is, a gradual transition to the biosphere began with small animals, and with less oxygen, which made it possible to reduce the content of carbon monoxide (CO) in the atmosphere. Note that our oxygen biosphere contains 21 %.

The scenario of a global fire that destroyed all life is possible, but unlikely. More plausible is the scenario for achieving a critical concentration of carbon monoxide (CO) in the atmosphere for some species (for example, for dinosaurs). Then, indeed, some species of large animals could die out within 1 to 3 days. And in the presence of large fires, their remains could be partially destroyed.
Thus, the cause of mass extinctions is the evolution of the biosphere, which leads to the exhaustion of the "Darwin potential" of diversity (genetic, species). Further, the biosphere changes its species

composition according to the environment. There is also a correlation between the oxygen content in the atmosphere and mass extinctions. That is, the change in oxygen in the atmosphere was a key cause of the change in the environment, and as a result of the restructuring of the biosphere.

Oxygen catastrophe as the main cause of global glaciation.

With the onset of Snowball Earth, the planet was completely covered with ice 2 to 3 kilometers thick, and this glaciation lasted 85 million years (occurred between 850 and 630 million years ago) [79 - 82]. But another thing is interesting: it was during this period in the Earth's atmosphere that the oxygen concentration began to increase rapidly, see the figure [75].



Please note that the rapid growth of oxygen in the atmosphere coincides in time with the beginning of Snowball Earth, that is, approximately 850 million years ago. Another grand event took place in the history of the Earth during this period: during this period, the supercontinent Rodinia collapsed [83, 81, 84].

Rodinia was formed approximately 1.1 - 0.9 billion years ago. Rodinia disintegrated into other continents approximately 750 - 633 million years ago (this is the final collapse). That is, the process of the collapse of Rodinia falls on the period when the global glaciation took place (Snowball Earth), in time it is 850 - 630 million years ago. At the same time, there is a sharp increase in oxygen in the atmosphere. Is there a connection between these events?

To answer this question, recall the oxygen catastrophe. The oxygen catastrophe began about 2.5 billion years ago. Moreover, 630 million years ago, the oxygen concentration in the atmosphere reached approximately 17 - 18 %, that is, it was sufficient for full evolution. The cause of the appearance of oxygen in the Earth's atmosphere is cyanobacteria, which produce oxygen through photosynthesis. But, it is obvious that during the existence of Snowball Earth, oxygen could not be produced by cyanobacteria, since the Earth was covered with ice and the temperature was 40 - 50 degrees below zero. Moreover, during the Snowball Earth period, biological life is believed to have been endangered. But, it was during this period that the amount of oxygen increased to maximum values in the entire history of the Earth. How then could the amount of oxygen increase in the Earth’s atmosphere? Before answering this question, we recall the longest glaciation on Earth, that is, the Huron glaciation [85 - 89].

The Huron glaciation began about 2.4 billion years ago and ended 2.1 billion years ago. The duration of the Huron glaciation was 300 million years, this is the longest glaciation in the history of the Earth. But, interestingly, it was during this period that the oxygen catastrophe began. That is, approximately 2.4 billion years ago, oxygen began to appear in the atmosphere of the planet (moreover, quite intensively). By the end of the glaciation (2.1 billion years ago), the oxygen concentration reached 3 - 4 %.

The cause of the Huron glaciation is considered to be an oxygen catastrophe, during which oxygen entered the atmosphere, which oxidized part of the methane, which led to a decrease in the greenhouse effect (to a decrease in the concentration of CH4). But, about 2.5 billion years ago, the supercontinent of Vaalbara collapsed [90, 91]. That is, we have a complete analogy with the period of Snowball Earth, when the supercontinent Rodinia also disintegrated. Perhaps the collapse of the supercontinent is the cause of the oxygen catastrophe? We will try to answer this question.

We describe the process of decomposition of supercontinet and oxygen synthesis in the atmosphere in the general case. If we consider supercontinet during its decay, the mechanism is simple: faults appear in the Earth's crust, where lava from the mantle rushes.

With the collapse of the continent, these faults greatly increase. Most of the crust is covered with water (oceanic crust), and has a small thickness (only 5 - 10 kilometers, in our time). Therefore, during the collapse of supercontinents, faults will more often occur in the ocean (thinner than the crust), and lava will pour into the ocean. And since the temperature of the lava is about 2000 degrees Celsius, the water will turn into steam, and partially decompose into oxygen and hydrogen.

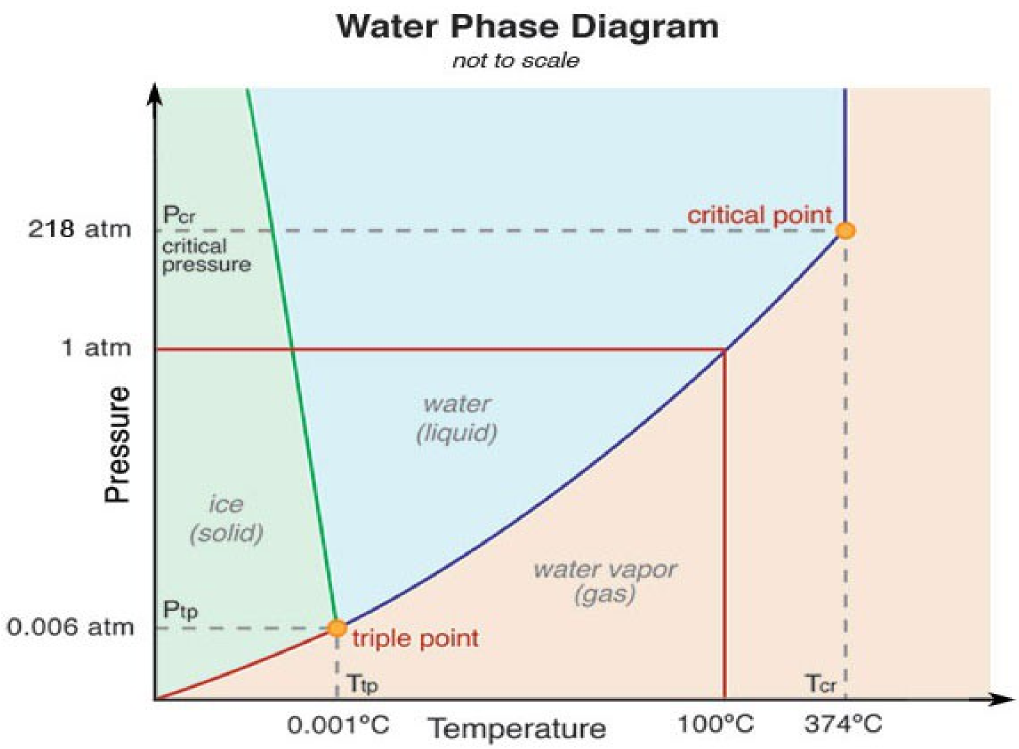
$$2H20 = 2H2 + O2$$

On hot lava, the thermal decomposition of water into oxygen and hydrogen will occur at temperatures around 1000 degrees.

That is, when supercontinents decay, a huge amount of water vapor, and some oxygen and hydrogen will be emitted into the atmosphere. It should be noted that the water in the fault areas will be heated, so oxygen and hydrogen will dissolve a little in the water. Oxygen will oxidize methane in the atmosphere, and lower the greenhouse effect. But, water vapor in the atmosphere will increase the greenhouse effect. Since there should be a lot of water vapor in the atmosphere, the greenhouse effect will increase (as long as water vapor exists in the atmosphere). Hydrogen will leave the atmosphere and escape into space.

But, there is one caveat. Since a huge amount of hot water vapor will be released into the planet's atmosphere, at the first moment of time the planet's atmosphere will warm up a little. Naturally, as water vapor moves upward, it will cool. At a certain height, the water vapor cools so that a triple point of water is reached, i.e., the temperature of the steam is 273.16 K (0.01 °C) and the partial pressure of the steam is 611.657 Pa (0.006 atm) [92, 93].

In even higher atmospheric layers, the temperature drops below 273.16 K (0.01 °C), and the pressure drops below 611.657 Pa (0.006 atm). That is, according to the phase diagram of water, under such conditions, ice crystals will begin to form in the upper atmosphere [93].



Moreover, since cooling will occur very quickly (upward movement of water vapor), small ice crystals will form. And we will get, in the upper layers of the atmosphere, the equilibrium system of "water vapor - ice crystals". But, as water vapor from the oceans continues to flow, ice crystals will form. This will occur until the cessation of water vapor into the atmosphere. After some time, the Earth will be closed from the Sun by a layer of small crystals of ice. Ice crystals will reflect the sun's rays, so the Earth will begin to cool. With gradual cooling, all the water in the atmosphere will gradually turn into ice. Then the planet will cool, and after a while, the Earth will be covered with a layer of ice.

Thus, glaciation of the planet sets in. The ice covering the oceans will isolate the oceans from the oxygen that is in the atmosphere. But note that cooling will occur from the atmosphere (water vapor is also a gas that has a greenhouse effect, so the planet will not cool), and therefore the oceans should not be much cooled. The layer of ice that will cover the oceans will protect them from further cooling. Such a thermo shirt. The cooling mechanism described above practically guarantees the protection of the oceans from strong cooling and freezing, which was the reason for the conservation of biological life with Snowball Earth.

The duration of glaciation and its temperature will be determined by the amount of water vapor released from the oceans into the atmosphere. And the amount of water vapor released into the atmosphere will be determined by the size (and depth) of the faults of the Earth's crust. Therefore, it is the faults of supercontinent that led to global glaciation (Huron, Snowball Earth). The collapse of smaller continents will lead to more "light" glaciations (both in time and in temperature). But, we did not answer the question: how is oxygen formed during glaciation? And from the graph of the oxygen catastrophe it can be seen that the more global the glaciation, the more oxygen is formed. Therefore, after the Snowball Earth, the Cambrian explosion began.

Recall that ocean water on hot lava will decompose into oxygen and hydrogen, which enter the atmosphere. Oxygen will remain and accumulate in the atmosphere, and hydrogen will escape into space. Part of the oxygen will be spent on the oxidation of the atmosphere and rocks (as long as they are not covered with snow). But this is one way. There is another. Since there was no oxygen in the atmosphere, there was no ozone. So the Earth's atmosphere was not protected from ionizing radiation. And therefore, water in the atmosphere (especially in the upper layers) will be rapidly decomposed into oxygen and hydrogen. In general, any energy quantum that has sufficient energy to break the O-H bond will decompose water into oxygen and hydrogen (hard UV radiation, X-ray radiation, gamma radiation, accelerated microparticles, etc.). This process will occur continuously in the presence of water in the atmosphere (and the presence of corresponding quanta). The amount of oxygen synthesized in this way will depend only on the duration of the process, and the amount of water in the atmosphere (and in the form of ice crystals also). The more water in the atmosphere, the more oxygen is released from the ocean, and the more oxygen is synthesized in the atmosphere. At a certain concentration of oxygen in the atmosphere, a layer of ozone can form, which will begin to protect both the atmosphere and the surface of the planet from ionizing radiation. This will lead to the possibility of migration of life from the ocean to land. Therefore, after Snowball Earth, the amount of oxygen increased to 17 - 18 %, and then the Cambrian explosion followed.

The presence of trace amounts of oxygen in the ocean can explain the evolution of the “RNA world” before the formation of viruses, then prokaryotes, and then eukaryotes (red-hot lava acts on water and oxygen is formed, which dissolves slightly in water).

When we have the “RNA world”, there will be traces of oxygen in the water. The “RNA world” evolves according to Lamarck, and must respond to aggressive oxygen. Oxygen, and its aggressive forms, can oxidize both RNA and DNA. Therefore, as an answer, viruses appear. That is, both RNA and DNA are now sealed in a protein shell (capsid), which protects them from oxygen and its forms. This also explains why nature chose DNA to record genetic information: DNA is more resistant to oxidizing agents (and other damaging factors) than RNA.

The cell wall of bacteria and archaea, which consists of peptidoglycan (murein) was formed similarly [94, 95]. Peptidoglycan (murein) [94] is similar in structure to proteins, and it is obvious that its function is also protection against oxygen (and its aggressive forms). Oxygen dissolves much better in the hydrophobic phase (fatty phase), and very poorly in the hydrophilic phase. Therefore, living things to protect themselves from oxygen, synthesize hydrophilic protection (capsid, cell wall). Thus, non-nuclear organisms (prokaryotes) appeared, that is, bacteria, archaea, etc.

But, as the oxygen concentration increased, it penetrated more and more into the cell, and therefore it was necessary to protect the DNA more reliably. Therefore, in the course of evolution, the nucleus of the cell (eukaryotes) was formed. The core consists of a variety of substances (and proteins as well) that will protect it from oxygen and other harmful factors [96]. In fact, the reason for the formation of multicellular organisms (during evolution) is the protection of organisms from oxygen and its active forms. Further on, the transformation mechanism will be analyzed in detail.

If we consider this issue from a more general point of view, then it can be argued that the reason for the formation of multicellular organisms from unicellular (during evolution) is the adaptation of organisms to an aggressive environment (oxygen, cold, pressure, etc.). This is “pure” evolution according to Lamarck. By aggressive environment we mean such damaging factors as molecular oxygen, low temperature and high pressure of water (atmosphere). It is oxygen (more precisely, oxygen catastrophe) that played a key role in the evolution of unicellular organisms into multicellular organisms, so we will consider this issue in more detail.

The oldest multicellular organisms already existed 2.1 billion years ago. About 1.9 billion years ago there were already multicellular eukaryotes (1.6 — 2.1 billion years ago) [97]. “...For reasons that are not completely understood, multicellularity is more characteristic of eukaryotes, although among prokaryotes there are also the beginnings of multicellularity...” [98]. Note that upon further consideration, this “reason” will be logically explained.

About 2 billion years ago, multicellular organisms appeared (oxygen level in the atmosphere is 2 – 3 %), but multicellular organisms flourished only 610 million years ago (oxygen level in the atmosphere is 17 – 18 %). Now, let's look at a graph of the level of oxygen in the Earth’s atmosphere. We clearly see that both the appearance of multicellular organisms and their explosive development occurred during periods when a rapid increase in the amount of oxygen occurred in the Earth's atmosphere. And this is no coincidence. “O2 is a small neutral molecule that prefers the hydrophobic phase of the cell to the hydrophilic one (in the fat/water system, oxygen is about 10 times more in fat). Therefore, biological membranes made of fat-like substances - phospholipids and hydrophobic proteins, do not constitute a barrier to the penetration of O2, that is, the membrane cannot be protected from oxygen” [99]. Moreover, since the oxygen molecule is small, it accidentally, sometimes, will penetrate through the hydrophilic cell wall (which should protect unicellular organisms from oxygen). "Accidental penetration" of oxygen into the cell will always occur. But, the greater the concentration of oxygen in the external environment (atmosphere, in water), the more there will be these “accidental penetrations” into the cell, and the greater will be the damage that oxygen will cause to a single-celled organism.

It should be noted that from a chemical point of view, an oxygen molecule is one of the smallest diatomic molecules. It is very difficult to protect oneself from such small molecules: they pass through any membranes (both hydrophobic and hydrophilic), both natural (cell membranes) and technological (reverse osmosis membranes). Of course, in a small amount, but still pass (due to the small size). And this is fundamental. Therefore, a single-celled organism, from the constantly increasing number of oxygen penetrations into the cell, can be protected in only one way: if it can greatly reduce the area of contact with the external environment (and hence with the number of oxygen molecules). Evolution did just that: from unicellular, colonial organisms of the Volvox type were first formed [100]. Note that the Volvox colonies have a spherical shape, since the ball is a figure that is limited to a minimum surface area (sphere).

Further, in the course of evolution, full-fledged multicellular organisms were formed. In a multicellular organism, the area through which an oxygen molecule will penetrate will be much smaller than the area of individual cells. And these are not just words: the reduction in area is simply enormous (and therefore the area of contact with a damaging factor). For clarity, we demonstrate this with two examples.

Example 1. Compare the area of 1000 drops of water with a volume of 1 milliliter each (1 cm^3) and the area of a ball of water with a volume of 1 liter (recall that 1 liter = 1000 milliliters).

We take the density of water equal to 1. Therefore, 1 milliliter of water will have a mass equal to 1 gram.

Recall that the volume of the ball is calculated by the formula

$$V = (4*\pi*R^3)/3$$

where R — is the radius of the ball.

The area of the ball is calculated by the formula

$$S = 4*\pi*R^2$$

Therefore, each droplet of water weighing 1 gram, which has the shape of a ball (1 milliliter volume), will have a radius of 0.622 centimeters.

$$V = (4*\pi*R^3)/3, \text{ when } 1 = (4*\pi*R^3)/3, R = 0.622 \text{ centimeters.}$$

The area of such a drop will be 4.8617 cm^2.

$$S(1) = 4*\pi*R^2 = 4*\pi*0.622^2 = 4.8617 \text{ cm}^2.$$

Then 1000 such drops will have an area a thousand times larger:

$$S(1000) = 1000 * 4.8617 = 4861.7 \text{ cm}^2.$$

Let us now have 1 liter of water, in the shape of a ball. By similar calculations, we get the radius of such a ball: this is 6.2036 centimeters. The area of such a ball (1 liter) will be equal to 483.612 cm^2.

$$V = 1 \text{ liter} = 1000 \text{ cm}^3, R = 6.2036 \text{ centimeters,}$$
$$S(1\text{liter}) = 483.612 \text{ cm}^2.$$

That is, when combining 1000 droplets into one ball, their area decreased by 10 times.

$$S(1000)/S(1 \text{ литр}) = 4861.7/483.612 = 10.053$$

Just think about the result: combining a thousand drops into one big drop reduced the area of contact with the environment exactly 10 times. That is, aggressive factors also decreased by 10 times.

Example 2. Compare the total area of 1 million drops (1 milliliter each), and 1 ball of water weighing 1 tone (1 million drops).

So, 1 drop has an area of 4.8617 cm^2 (see example 1). Then 1 million of these drops will have an area equal to 4861700 cm^2.

$$S(1 \text{ million drops}) = 4861700 \text{ cm}^2.$$

Now let's calculate the radius of the ball with a mass of 1 tone (this is the mass of 1 million drops), and a volume of 1000 liters.

V = 1000 liter = 1 000 000 cm^3, R = 62.03505 centimeters,

S(1000 liters) = 48359.74998 cm^2.

S(1 million drops)/S(1000 liters) = 4861700/48359.74998 = 100.532

That is, when combining 1 million drops into one ball, their area decreased by more than 100 times. It is clear that when 1 billion drops are combined, their area will decrease by more than 1000 times, and when 1 trillion drops are combined, their area will decrease by more than 10,000 times. If we now take cells (a unicellular organism) instead of drops, then we will get why they are combined in colonies: when combined in a colony, the area of contact with the external environment is greatly reduced (thousands and tens of thousands of times), therefore, it decreases by the same number of times the effect of damaging environmental factors (oxygen, cold, pressure).

From the foregoing, it is obvious why, with a strong increase in oxygen in the atmosphere (and in water; during an oxygen catastrophe), evolution led to the emergence of multicellular organisms: only in this way can the damaging effect of oxygen on the cell be reduced. That is, the transition from unicellular to multicellular organisms is logical, and is due to “pure physics”: the damaging effect of oxygen on body cells is reduced tens of thousands of times, since the area of contact with the aggressive environment (with oxygen molecules) is reduced. As we have already said, the transition of prokaryotes to eukaryotes is also explained by the damaging effect of oxygen (and other aggressive factors), and therefore, the nucleus of the cell forms, which protects the DNA from various damaging factors.

The human body is made up of several tens of trillions of cells. This means that their combination has reduced the aggressive effects of oxygen, cold, atmospheric pressure by tens of thousands of times. That is, separately our cells would quickly be destroyed by the external environment. And in a macro organism they are reliably protected. They are protected by a specially formed organ for this - human skin. Since the cells are reliably protected from the environment, they do not need to spend their resources (genetic, biochemical, etc.) on the fight against harmful factors. Therefore, such cells can be highly specialized, that is, use their resources for specific, specific purposes that are determined by the macro organism. In approximately this way, in the process of evolution according to Lamarck (if we consider from the general standpoint the influence of an aggressive external environment), complex macroorganisms are formed that have different types of cells. There are 230 types of different cells in the body of an adult [101]. Hese different types of cells provide the functioning of our body, including the functioning of our brain. That is, in fact, narrowly specialized cells have led to the emergence of the human mind. Are no specialized cells - there is no mind, since there are no neurons - cells of the nervous system that receive, process, store, and transmit information using electrical and chemical signals. Consequently, the appearance of the human mind is a consequence of the oxygen catastrophe, which led to the appearance of multicellular organisms and highly specialized cells.

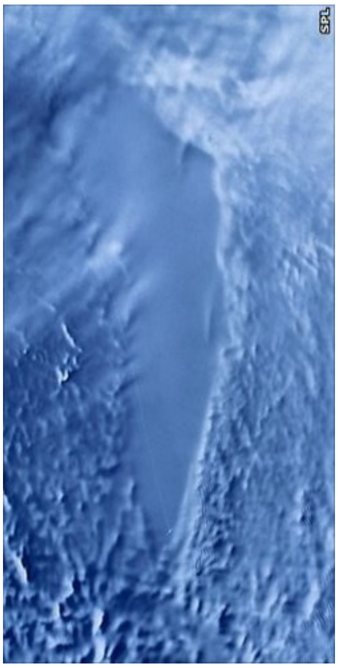
It must be understood that a decrease in the area of contact with the environment when combining cells into one organism is a fundamental characteristic of the process of combining, we will call it the reduction of environmental aggression (REA). REA helps a lot to save life even at low temperatures, for example during the time of the Snowball Earth. During the Snowball Earth age the Earth was covered with a 3 to 4 kilometer layer of ice. And life was preserved only in the ocean, which was under the ice. Under such conditions, the water temperature in the ocean was low, from about 3 degrees below zero (water-ice boundary) to 10 degrees above zero (in the depth of the water). Moreover, the water in the ocean was under tremendous pressure - about 300 atmospheres. Therefore, in order to survive under these conditions, unicellular organisms had to withstand cold and pressure. The adaptation under these conditions was the formation of colonial organisms (stage 1), and then the transition to multicellular organisms.

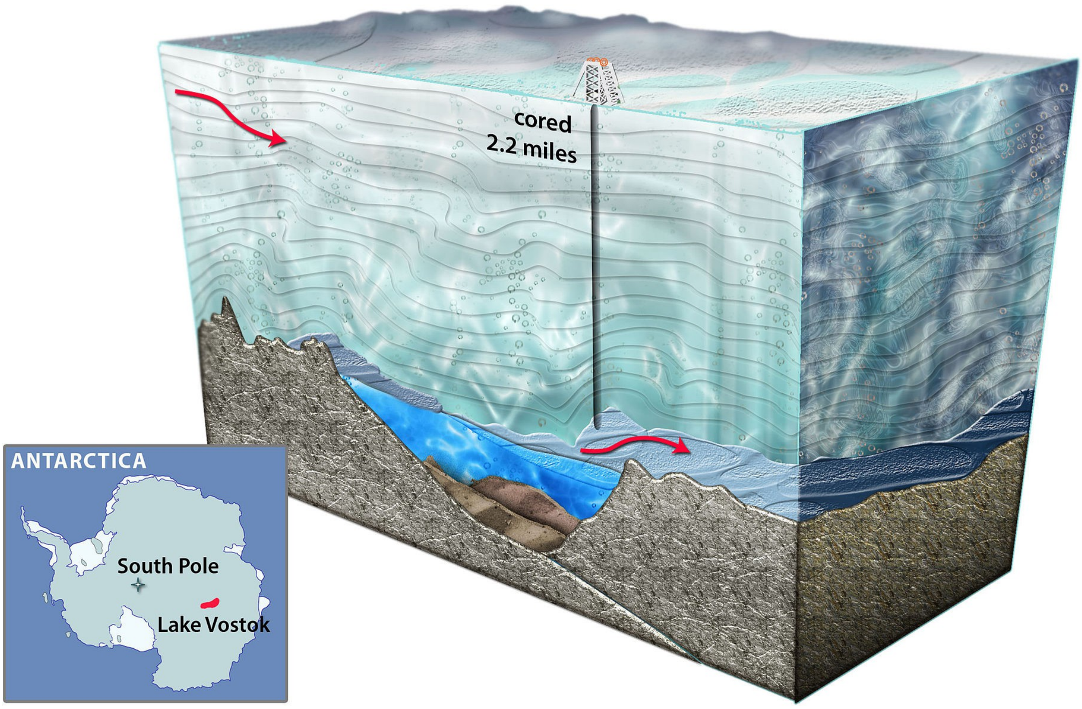
At low temperatures, the unicellular organism will be very cold very fast, as it has a large surface area of the body, and therefore intense heat exchange with cold water will occur. The cell membrane, which consists of lipids, is a natural heat insulator, and therefore it will greatly reduce cell cooling. But, at low water temperatures, the protective effect of the membrane will be insufficient, and the unicellular organism will begin to cool. The protection in such conditions will be the formation of a colonial organism. Then, the heat will leave only through the surface of the colonial organism, and it (the surface) is much less than in a single unicellular organism. Further evolution will inevitably lead to the emergence of full-fledged multicellular organisms. Since the solution in this situation was precisely a decrease in the area of contact of the body with an external aggressive environment (with water), that is, the formation of multicellular organisms. In this case, heat transfer with water will slow down significantly (the area is much smaller, which means less heat loss by the body). In addition, in a multicellular organism, it is possible to create a type of cells that will withstand increased water pressure, and the area that needs to be protected will be minimal (an increased pressure of 300 atmospheres can simply crush a unicellular organism). The question may arise how do we know the temperature and pressure of the water in the ocean (under the ice) in the era of the Snowball Earth so precisely. Surprisingly, now similar conditions exist in Antarctica, in the famous Lake Vostok [102, 103].

Vostok Lake is the largest subglacial lake in Antarctica, located under an ice thickness of 3.7 kilometers (at the under of the Vostok Antarctic Research Station). Lake Vostok has a length of 250 kilometers and a width of 50 kilometers, an estimated area of 15.5 thousand square kilometers, an average depth of 432 meters. On February 5, 2012, at a depth of 3769.3 meters, scientists completed drilling and reached the surface of the subglacial lake. On January 10, 2013, the first sample was obtained from clear lake ice 2 meters long. But, here is a very informative and instructive story of the discovery of this lake.

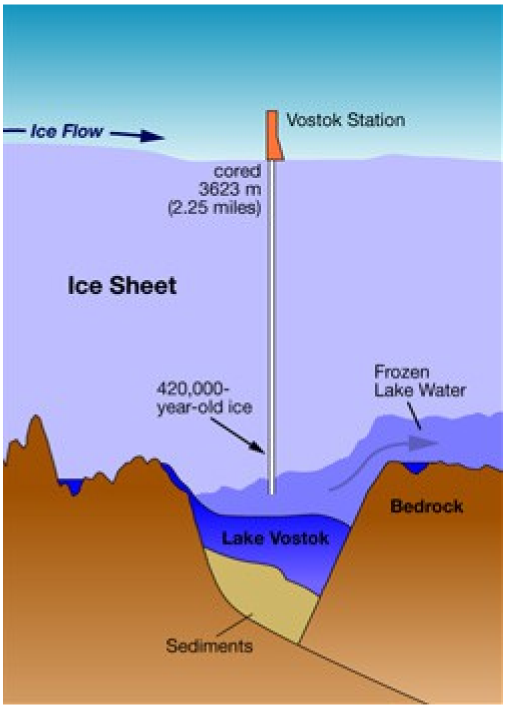
The existence of the subglacial Lake Vostok was theoretically predicted by the Soviet geographer Andrei Kapitsa as early as 1955 – 1957 [104], but the discovery itself was relatively recent, in 1996 by russian scientists. This is one of the largest discoveries in geography. The theoretical rationale for this issue is interesting. It has been worked out since the 19th century by many scientists (meaning the melting of glaciers at the lower border). The idea is simple and ingenious: if we have a glacier, then with a very large thickness of the glacier, at a certain depth, we will get the melting temperature of the ice. This follows from the fact that low temperatures exist on the surface of the glacier. And therefore, sinking to the depths of the glacier, the temperature will increase, as heat transfer slows down, and pressure increases. And, at a certain depth, the melting temperature of ice (at the lower boundary of the glacier) will be reached.

Various scientists have proposed various temperature dependences on depth. But, in 1955, the English glaciologist Gordon Robin [105] showed (his work became classical) that the temperature field in thick Antarctic glaciers is not linear. In 1961, Igor Zotikov performed thermophysical calculations (solving the heat equation for a glacier). And, it was shown that the temperature of ice under the Vostok scientific station, at its lower boundary, is equal to the melting temperature of ice (− 2 °C) at a pressure of more than 300 atmospheres. Then there were numerous drilling attempts that ultimately led to success. That is, in Antarctica, at a depth of 3.7 kilometers, the melting temperature of ice is 2 degrees below zero (the temperature is below zero, since the pressure is 300 atmospheres). Therefore, under the glacier there must be a lake. It exists. This is Lake Vostok. Look at the pictures of Lake Vostok [103].





Lake Vostok has been isolated from the earth's surface for several million years, with an estimated 15 - 25 million (a 4-kilometer layer of ice serves as an insulator) [103, 106 - 108]. Lake Vostok contains fresh water, in which the oxygen content is approximately 50 times higher than in ordinary fresh water. The increased water pressure in the lake (300 atmospheres) dissolves more oxygen [109 - 111]. Pressure is created by the thickness of the ice: the thicker the glacier, the greater the pressure. Oxygen in the water of Lake Vostok is delivered by the upper layers of ice gradually descending into the depths. Calculations show that the entire volume of the lake is replaced every 13 300 years [112].



The fact of the sinking of ice is very important to us. Since in this way, oxygen is delivered to the ocean water under the glacier (oxygen is contained in ice). And in this way, in the Snowball Earth era, oxygen was delivered to the oceans. And the fact that there are no traces of oxygen in the fossil deposits of the Snowball Earth age unequivocally indicates that there was life in the ocean. Moreover, this life consumed all the oxygen dissolved in the ocean, otherwise the presence of oxygen would be reflected in the sediments of that time. Given the above, there is no doubt that in the era of the great glaciations (Snowball Earth, Huron glaciation), water in the oceans was saturated with oxygen. Since oxygen was in the atmosphere, and ice was delivered to the ocean. And in the oceans, an oxygen catastrophe began, which greatly accelerated evolution.

There are approximately 140 lakes under Antarctica, but they are much smaller than Lake Vostok. Therefore, in the era of the Snowball Earth, there should be millions of such lakes. Moreover, given that volcanic activity was much higher during the Snowball Earth era, it can be argued that the water temperature in the lakes should also be significantly higher than 10 degrees Celsius. At least in some of them. Water in such lakes was heated by geothermal springs and various volcanoes. Such conditions not only made it possible to preserve life under the conditions of glaciation, but also intensely accelerated evolution through an oxygen catastrophe in the ocean. In approximately this way eukaryotes and then multicellular organisms appeared, which led to the

Cambrian explosion. But, first, after the Snowball Earth, the Vendian fauna appeared [113], which probably represents the result of an oxygen catastrophe in the ocean during the Snowball Earth period. Look at the picture of the Ediacaran organism (Dickinsonia costata), looking at it, you immediately remember the pressure of 300 atmospheres [113].

In conclusion, we say that large multicellular anaerobic organisms could not have arisen before the oxygen catastrophe. Since it is the oxygen catastrophe that first leads to global glaciation, in which the oxygen concentration in the ocean increases significantly [114], and therefore the rate of evolution in water increases. And then, after a period of glaciation, when the oxygen concentration in the atmosphere reached 17 - 18 %, the Cambrian explosion began, which led to the emergence of a full biosphere with large animals.

Life began much earlier than the Cambrian explosion. Bacteria and archaea appeared 2 billion years before the Cambrian explosion. The cell’s nucleus appeared 1.5 billion years before the Cambrian explosion. But, over billions of years, evolution has not progressed much (when compared to the Cambrian explosion). After the Snowball Earth, a Cambrian explosion followed. That is, literally, over the course of several tens of millions of years an unimaginable diversity of species has appeared. In fact, a full biosphere has formed with numerous and diverse types of living creatures. And the difference from the “unsuccessful 1.5 billion evolution” consists only in the fact that there is a huge amount of oxygen in the atmosphere (17 – 35 %). Therefore, the answer is obvious: an oxygen catastrophe is the main reason for the evolution of our biosphere.

CONCLUSION.

Thus, in this work, the process of the origin of life on the basis of "self-assembly" of DNA and RNA molecules (in small lakes) in the time of ancient eras is analyzed. Using the cybernetic theory of evolution, it is shown that 4.45 millimoles of DNA/RNA molecules are enough to start the full-fledged evolution of the biosphere on planet Earth. Moreover, the reason for the transition (in the process of evolution), from pre-nuclear organisms to eukaryotes, as well as from unicellular to multicellular organisms, is analyzed and explained. This reason was the adaptation of organisms to an aggressive external environment (oxygen, cold, pressure). Moreover, the aggressive behavior of oxygen molecules plays a fundamental role in the evolution process. It is shown that the oxygen catastrophe is the first cause of the evolution of our biosphere. And mass extinctions are an inevitable consequence of the evolution of the biosphere, and are a simple restructuring of the biosphere according to new conditions on the planet.

REFERENCES.

1. Fermi paradox. Wikipedia. https://en.wikipedia.org/wiki/Fermi_paradox .

2. Phoenix (spacecraft). Wikipedia. https://en.wikipedia.org/wiki/Phoenix_(spacecraft)#cite_note-Smith2009-83 .

3. Smith P. H., Tamppari L. K., Arvidson R. E., Bass D., Blaney D., Boynton W. V., Carswell A., Catling D. C., Clark B. C., Duck T., DeJong E. H2O at the Phoenix landing site. Science. 2009, 325 (5936): 58 – 61. DOI: 10.1126/science.1172339. https://doi.org/10.1126%2Fscience.1172339 .

4. Rayl A. J. S. Holy Cow, Snow Queen! Phoenix Landed on Ice Team Thinks. The Planetary Society (2008-06-01). https://web.archive.org/web/20080605010056/http://www.planetary.org/news/2008/0601_Holy_Cow_Snow_Queen_Phoenix_Landed_on.html .

5. Mellon M., et al. The periglacial landscape at the Phoenix landing site. Journal of Geophys. 2009, res. 114. E00E07.

6. Enceladus. Wikipedia. https://en.wikipedia.org/wiki/Enceladus .

7. Thomas P. C., Tajeddine R., et al. Enceladus's measured physical libration requires a global subsurface ocean. Icarus. 2016, 264: 37 – 47. DOI: 10.1016/j.icarus.2015.08.037. https://doi.org/10.1016%2Fj.icarus.2015.08.037 .

8. Cassini Finds Global Ocean in Saturn's Moon Enceladus. NASA. http://www.nasa.gov/press-release/cassini-finds-global-ocean-in-saturns-moon-enceladus .

9. Billings, Lee. Cassini Confirms a Global Ocean on Saturn's Moon Enceladus. Scientific

American (September 16, 2015). http://blogs.scientificamerican.com/observations/cassini-confirms-a-global-ocean-on-saturn-s-moon-enceladus/ .
10. Under Saturnian moon's icy crust lies a 'global' ocean. Cornell Chronicle. Cornell University. http://www.news.cornell.edu/stories/2015/09/under-saturnian-moons-icy-crust-lies-global-ocean .
11. Europa (moon). Wikipedia. https://en.wikipedia.org/wiki/Europa_(moon) .
12. Planetary Satellite Physical Parameters. JPL's Solar System Dynamics group (3 September 2013). http://ssd.jpl.nasa.gov/?sat_phys_par .
13. Prockter L. M., Pappalardo R. T. Europa. Encyclopedia of the Solar System. Lucy-Ann McFadden, Paul R. Weissman, Torrence W. Johnson. Academic Press. 2007, pp. 431 – 448. ISBN 978-0-12-088589-3.
14. Greenberg, Richard. Europa: The Ocean Moon: Search for an Alien Biosphere. Springer Praxis Books. 2005, ISBN 978-3-540-27053-9. DOI: 10.1007/b138547. https://dx.doi.org/10.1007%2Fb138547 .
15. Titan (moon). Wikipedia. https://en.wikipedia.org/wiki/Titan_(moon) .
16. Dermott S. F., Sagan C. Tidal effects of disconnected hydrocarbon seas on Titan. Nature. 1995, vol. 374, p. 238 — 240. DOI: 10.1038/374238a0. https://dx.doi.org/10.1038%2F374238a0 .
17. Stofan E. R., Elachi C., et al. The lakes of Titan. Nature. 2007, vol. 445, 1, pp. 61 — 64. DOI: 10.1038/nature05438. https://dx.doi.org/10.1038%2Fnature05438 .
18. Caitlin A. Griffith, Juan M. Lora, Jake Turner, Paulo F. Penteado, Robert H. Brown, Martin G. Tomasko, Lyn Doose & Charles See. Possible tropical lakes on Titan from observations of dark terrain. Nature. 2012, iss. 486, pp. 237 — 239. DOI: 10.1038/nature11165. https://dx.doi.org/10.1038%2Fnature11165 .
19. Maggie McKee. Tropical lakes on Saturn moon could expand options for life. Nature. 2012. DOI: 10.1038/nature.2012.10824. https://dx.doi.org/10.1038%2Fnature.2012.10824 .
20. Cordier D., Mousis O., Lunine J.-I., Lavvas P. & Vuitton V. An estimate of the chemical composition of Titan's lakes (2009). arXiv: 0911.1860v1. http://www.arxiv.org/abs/0911.1860v1 .
21. Bezverkhniy V. D. The Amount of organic compounds. SSRN Electronic Journal. 2019. DOI: 10.2139/ssrn.3469654, https://dx.doi.org/10.2139/ssrn.3469654 , http://vixra.org/pdf/1910.0224v1.pdf .
22. Drake equation. Wikipedia. https://en.wikipedia.org/wiki/Drake_equation .
23. Burchell M. J. W(h)ither the Drake equation?. International Journal of Astrobiology. 2006, 5 (3): 243–250. DOI: 10.1017/S1473550406003107. https://doi.org/10.1017%2FS1473550406003107 .
24. Glade N., Ballet P., Bastien O. A stochastic process approach of the drake equation parameters.

International Journal of Astrobiology. 2012, 11 (2): 103–108. DOI: 10.1017/S1473550411000413. https://doi.org/10.1017%2FS1473550411000413 .
25. Chapter 3. Philosophy: Solving the Drake Equation. Ask Dr. SETI. SETI League. December 2002. http://www.setileague.org/askdr/drake.htm .
26. Drake N. How my Dad's Equation Sparked the Search for Extraterrestrial Intelligence. National Geographic (30 June 2014). http://news.nationalgeographic.com/news/2014/06/140630-drake-equation-50-years-later-aliens-science/ .
27. Biosphere 2. Wikipedia. https://en.wikipedia.org/wiki/Biosphere_2 .
28. Fast Facts: Biosphere 2. biosphere2.org. http://biosphere2.org/visit/about-biosphere2/fast-facts .
29. Nelson M., Burgess T. L., Alling A., Alvarez-Romo N., Dempster W. F., Walford R. L., Allen J. P. Using a Closed Ecological System to Study Earth's Biosphere. Bioscience. 1993, 43 (4): 225 – 236. DOI: 10.2307/1312123. https://doi.org/10.2307%2F1312123 . JSTOR 1312123. https://www.jstor.org/stable/1312123 .
30. Ed Bass. Wikipedia. https://en.wikipedia.org/wiki/Ed_Bass .
31. John P. Allen. Wikipedia. https://en.wikipedia.org/wiki/John_P._Allen .
32. Polymer. Science. Encyclopedia Britannica. https://www.britannica.com/science/polymer .
33. Assembly language. Wikipedia. https://en.wikipedia.org/wiki/Assembly_language .
34. MenuetOS. Wikipedia. https://en.wikipedia.org/wiki/MenuetOS .
35. MenuetOS homepage. http://www.menuetos.net/ .
36. KolibriOS. Wikipedia. https://en.wikipedia.org/wiki/KolibriOS .
37. Kolibri-A: a lightweight 32-bit OS for AMD platforms. University of Exeter, PCCAT 2011 p. 20-22 (2011). http://www.pccat.ex.ac.uk/2011/PCCAT2011-Proceedings.pdf .
38. KolibriOS homepage (ru). http://kolibrios.org/ru/ .
39. Nucleotide. Wikipedia. https://en.wikipedia.org/wiki/Nucleotide .
40. Complementarity (molecular biology). Wikipedia. https://en.wikipedia.org/wiki/Complementarity_(molecular_biology) .
41. William S. Cooper. Wikipedia. https://en.wikipedia.org/wiki/William_Skinner_Cooper .
42. Abdulaev M. A forgotten experiment of a century ago talked about the reasons for changing one tree species with another. PostNauka. https://nplus1.ru/news/2019/09/18/glacierbayexperiment .
43. Buma B., Bisbing S. M., Wiles G., Bidlack A. L. 100 yr of primary succession highlights

stochasticity and competition driving community establishment and stability. Ecology. 09 september 2019. https://doi.org/10.1002/ecy.2885 .

44. Lamarck J. B. Philosophie zoologique. Volume 1. (Philosophie zoologique, 1809). Translated from French by S. V. Sapozhnikov. Editors and biographical sketch of V. P. Karpov. Introductory article by V. L. Komarov. State publishing house of biological and medical literature. Moscow - Leningrad. 1935. Series: Classics of biology and medicine.

45. Lamarck J. B. Philosophie zoologique. Volume 2. (Philosophie zoologique, 1809). Translation from French by H.V. Sapozhnikov. Introductory article by M. M. Polyakov. Editor A. Gaysinovich. Artist A. Kreichik. State publishing house of biological and medical literature. Moscow - Leningrad. 1937. Series: Classics of biology and medicine.

46. Lamarck J. B. Philosophie zoologique.
1830, vol. I (Michigan): https://books.google.com/books?vid=OCLC69003856&hl=en ;
1830, vol. II (Michigan): https://books.google.com/books?vid=OCLC11974573&hl=en .

47. Darwin C. On the origin of spices by means of natural selection, or the preservation of favoured races in the struggle for life (1859, 1st ed.). London: John Murray. http://darwin-online.org.uk/content/frameset?itemID=F373&viewtype=text&pageseq=1 .

48. McGrath S., and van Sinderen D., (editors). Bacteriophage: Genetics and Molecular Biology (2007, 1st ed.). Caister Academic Press. ISBN 978-1-904455-14-1. http://www.horizonpress.com/phage .

49. Bacteriophage. Wikipedia. https://en.wikipedia.org/wiki/Bacteriophage .

50. Barrangou R. The roles of CRISPR-Cas systems in adaptive immunity and beyond. Current Opinion in Immunology. 2015, 32: 36–41. DOI: 10.1016/j.coi.2014.12.008. https://doi.org/10.1016%2Fj.coi.2014.12.008 .

51. CRISPR. Wikipedia. https://en.wikipedia.org/wiki/CRISPR .

52. RNA world. Wikipedia. https://en.wikipedia.org/wiki/RNA_world .

53. Neveu M., Kim H. J., Benner S. A. The "strong" RNA world hypothesis: fifty years old. Astrobiology. 2013, 13 (4): 391 – 403. DOI: 10.1089/ast.2012.0868 , https://doi.org/10.1089%2Fast.2012.0868 .

54. Cech T. R. The RNA worlds in context. Cold Spring Harbor Perspectives in Biology. 2012, 4 (7): a006742. DOI: 10.1101/cshperspect.a006742 ,

https://doi.org/10.1101%2Fcshperspect.a006742 .

55. Patel B. H., Percivalle C., Ritson D. J., Duffy C. D., Sutherland J. D. Common origins of RNA, protein and lipid precursors in a cyanosulfidic protometabolism. Nature Chemistry. 2015, 7 (4): 301–7. DOI: 10.1038/nchem.2202 , https://doi.org/10.1038%2Fnchem.2202 .

56. Robertson M. P., Joyce G. F. The origins of the RNA world. Cold Spring Harbor Perspectives in Biology. 2012, 4 (5): a003608. DOI: 10.1101/cshperspect.a003608 , https://doi.org/10.1101%2Fcshperspect.a003608 .

57. Copley S. D., Smith E., Morowitz H. J. The origin of the RNA world: co-evolution of genes and metabolism. Bioorganic Chemistry. 2007, 35 (6): 430 – 43. DOI: 10.1016/j.bioorg.2007.08.001 , https://doi.org/10.1016%2Fj.bioorg.2007.08.001 .

58. Becker Sidney, Feldmann Jonas, Wiedemann Stefan, Okamura Hidenori, Schneider Christina, Iwan Katharina, Crisp Antony, Rossa Martin, Amatov Tynchtyk, Carell Thomas. Unified prebiotically plausible synthesis of pyrimidine and purine RNA ribonucleotides. Science. 2019, 366 (6461): 76 – 82. DOI: 10.1126/science.aax2747 , https://doi.org/10.1126%2Fscience.aax2747 . ISSN 0036-8075, https://www.worldcat.org/issn/0036-8075 .

59. Primate. Wikipedia. https://en.wikipedia.org/wiki/Primate .

60. Vertebrate. Wikipedia. https://en.wikipedia.org/wiki/Vertebrate .

61. Species. Wikipedia. https://en.wikipedia.org/wiki/Species .

62. Bacteria. Wikipedia. https://en.wikipedia.org/wiki/Bacteria .

63. Virus. Wikipedia. https://en.wikipedia.org/wiki/Virus .

64. LUCA. Wikipedia. https://en.wikipedia.org/wiki/Last_universal_common_ancestor .

65. Ordovician–Silurian extinction events. Wikipedia. https://en.wikipedia.org/wiki/Ordovician%E2%80%93Silurian_extinction_events .

66. Late Devonian extinction. Wikipedia. https://en.wikipedia.org/wiki/Late_Devonian_extinction .

67. Permian–Triassic extinction event. Wikipedia. https://en.wikipedia.org/wiki/Permian%E2%80%93Triassic_extinction_event .

68. Triassic–Jurassic extinction event. Wikipedia. https://en.wikipedia.org/wiki/Triassic%E2%80%93Jurassic_extinction_event .

69. Cretaceous–Paleogene extinction event. Wikipedia. https://en.wikipedia.org/wiki/Cretaceous

%E2%80%93Paleogene_extinction_event .

70. Galactic year. Wikipedia. https://en.wikipedia.org/wiki/Galactic_year .

71. Great Oxidation Event. Wikipedia. https://en.wikipedia.org/wiki/Great_Oxidation_Event .

72. Margulis Lynn, Sagan Dorion. Chapter 6. The Oxygen Holocaust. Microcosmos: Four Billion Years of Microbial Evolution (1986). California: University of California Press. p. 99. ISBN 9780520210646.

73. Lyons T. W., Reinhard C. T., Planavsky N. J. The rise of oxygen in Earth's early ocean and atmosphere. Nature. 2014, 506 (7488): 307 – 315. DOI: 10.1038/nature13068, https://doi.org/10.1038%2Fnature13068 . ISSN 0028-0836.

74. Sosa Torres, Martha E., Saucedo-Vázquez Juan P., Kroneck Peter M. H. (2015). Chapter 1, Section 2: The rise of dioxygen in the atmosphere. In Peter M.H. Kroneck and Martha E. Sosa Torres (ed.). Sustaining Life on Planet Earth: Metalloenzymes Mastering Dioxygen and Other Chewy Gases. Metal Ions in Life Sciences. 15. Springer. pp. 1–12. DOI: 10.1007/978-3-319-12415-5_1, https://doi.org/10.1007%2F978-3-319-12415-5_1 . ISBN 978-3-319-12414-8.

75. Holland, Heinrich D. The oxygenation of the atmosphere and oceans. Philosophical Transactions of the Royal Society: Biological Sciences. Vol. 361. 2006. pp. 903 – 915. http://rstb.royalsocietypublishing.org/content/361/1470/903.full.pdf .

76. Cambrian explosion. Wikipedia. https://en.wikipedia.org/wiki/Cambrian_explosion .

77. Sequoia sempervirens. Wikipedia. https://en.wikipedia.org/wiki/Sequoia_sempervirens .

78. Koch G. W., Sillett S. C., Jennings G. M., Davis S. D. The limits to tree height. Nature. 2004, vol. 428, 6985, pp. 851 — 854. DOI: 10.1038/nature02417, https://doi.org/10.1038/nature02417 .

79. Tjeerd van Andel. New Views on an Old Planet: A History of Global Change. Cambridge University Press, 1985, second edition 1994.

80. Hyde W. T., Crowley T. J., Baum S. K., Peltier W. R. Neoproterozoic 'snowball Earth' simulations with a coupled climate/ice-sheet model. Nature. 2000, vol. 405, 6785, pp. 425 — 429. DOI: 10.1038/35013005, https://dx.doi.org/10.1038%2F35013005 , http://earth.unh.edu/esci762-862/Hyde%20et%20al%202000.pdf .

81. Hoffman P. F. The break-up of Rodinia, birth of Gondwana, true polar wander and the snowball Earth. Journal of African Earth Sciences. 1999, vol. 28, 1, pp. 17 — 33.

82. Snowball Earth. Wikipedia. https://en.wikipedia.org/wiki/Snowball_Earth .

83. Bogdanova S. V., Pisarevsky S. A., Li Z. X. Assembly and Breakup of Rodinia (Some Results of IGCP Project 440). Stratigraphy and Geological Correlation. 2009, 17 (3): 259 – 274. DOI: 10.1134/S0869593809030022, https://www.researchgate.net/publication/255738849 , https://doi.org/10.1134%2FS0869593809030022 . ISSN 0869-5938.

84. Rodinia. Wikipedia. https://en.wikipedia.org/wiki/Rodinia#cite_note-mcmenamin-2 .

85. Haoshu Tang, Yanjing Chen. Global glaciations and atmospheric change at ca. 2.3 Ga. Geoscience Frontiers. 2013, 4 (5): 583 – 596. doi:10.1016/j.gsf.2013.02.003, https://doi.org/10.1016%2Fj.gsf.2013.02.003 .

86. Coleman A. P. A lower Huronian ice age. American Journal of Science. 1907, s. 4 - 23 (135): 187–192. DOI: 10.2475/ajs.s4-23.135.187, https://doi.org/10.2475%2Fajs.s4-23.135.187 . ISSN 0002-9599.

87. Bekker A. Huronian Glaciation. Encyclopedia of Astrobiology. 2014, pp. 1 – 8. DOI: 10.1007/978-3-642-27833-4_742-4, https://doi.org/10.1007%2F978-3-642-27833-4_742-4 . ISBN 978-3-642-27833-4.

88. Nicholas Eyles, Grant Young. Geodynamic controls on glaciation in Earth history, in Earth's Glacial Record (Deynoux M., Miller J. M. G., Domack E. W., Eyles N., Fairchild I. J., Young G. M. (eds.)). Cambridge: Cambridge University Press. 1994, pp. 3 – 5. ISBN 978-0-521-54803-8.

89. Huronian glaciation. Wikipedia. https://en.wikipedia.org/wiki/Huronian_glaciation#cite_note-1 .

90. Zegers T. E., de Wit M. J., White S. H. Vaalbara, Earth's oldest assembled continent? A combined. structural, geochronological, and palaeomagnetic test. Terra Nova. 1998, 10 (5): 250 – 259. DOI: 10.1046/j.1365-3121.1998.00199.x, https://doi.org/10.1046%2Fj.1365-3121.1998.00199.x , http://www.geo.uu.nl/Research/Paleomagnetism/publications/Zegers98b.pdf .

91. Vaalbara. Wikipedia. https://en.wikipedia.org/wiki/Vaalbara#cite_note-Zegers-etal-1998-Abst-1

92. Triple point. Wikipedia. https://en.wikipedia.org/wiki/Triple_point .

93. Section 8: Example 1—A Phase Diagram for Water. Unit 2: The Behavior of Atoms—Phases of Matter and the Properties of Gases. Chemistry. Annenberg Learner. https://www.learner.org/courses/chemistry/text/text.html?dis=U&num=Ym5WdElUQS9NeW89&sec=YzJWaklUQS9PQ289 .

94. Peptidoglycan. Wikipedia. https://en.wikipedia.org/wiki/Peptidoglycan .

95. Cell wall. Wikipedia. https://en.wikipedia.org/wiki/Cell_wall .

96. Cell nucleus. Wikipedia. https://en.wikipedia.org/wiki/Cell_nucleus .

97. Knoll A. H., Javaux E. J., Hewitt D., Cohen P. Eukaryotic organisms in Proterozoic oceans. Philosophical Transactions of the Royal Society B. 2006, vol. 361, 1470, pp. 1023 — 1038. DOI: 10.1098/rstb.2006.1843, https://dx.doi.org/10.1098%2Frstb.2006.1843 .

98. Multicellular organism. Wikipedia. https://en.wikipedia.org/wiki/Multicellular_organism .

99. Skulachev V. P. Oxygen in a living cell: good and evil. Soros educational journal. 1996, 3, p. 5, http://www.pereplet.ru/nauka/Soros/pdf/9603_004.pdf .

100. Volvox. Wikipedia. https://en.wikipedia.org/wiki/Volvox .

101. List of distinct cell types in the adult human body. Wikipedia. https://en.wikipedia.org/wiki/List_of_distinct_cell_types_in_the_adult_human_body .

102. George Royston-Bishop, Martin J. Siegert, John Woodward. Antarctic Subglacial Lake Vostok. Encyclopedia of Lakes and Reservoirs. DOI: https://doi.org/10.1007/978-1-4020-4410-6_41 .

103. Lake Vostok. Wikipedia. https://en.wikipedia.org/wiki/Lake_Vostok .

104. Kapitsa A. P., Robin G. Q., de Ridley J. K., Zotikov I. A. A Large Deep Freshwater Lake Between the Ice Sheet. Nature. 1996, vol. 381, 6584, pp. 684 – 686. https://www.nature.com/articles/381684a0 .

105. Robin, Gordon de Quetteville (1921 – 2004). Encyclopedia of Australian Science. http://www.eoas.info/biogs/P004576b.htm .

106. Moskvitch K. Lake Vostok drilling in Antarctic 'running out of time'. BBC News (27 January 2011). https://www.bbc.co.uk/news/science-environment-12275979 .

107. Casey Kazan. Secrets of Antarctica's 15-Million Year-Old Lake -A Galaxy Classic. The Daily Galaxy (5 December 2007).

108. Studinger M. Subglacial Lake Vostok. Columbia University (2008).

109. Ekaykin A. A., Lipenkov V. Y., Petit J. R., Johnsen S., et al. Insights into hydrological regime of Lake Vostok from differential behavior of deuterium and oxygen-18 in accreted ice. Journal of Geophysical Research. 2010. DOI: 10.1029/2009JC005329.

110. Bulat S. A., Alekhina I. A., Marie D., Martins J., et al. Searching for life in extreme environments relevant to Jovian's Europa: Lessons from subglacial ice studies at Lake Vostok (East Antarctica). Advances in Space Research. 2010, 48 (4): 697 – 701. DOI: 10.1016/j.asr.2010.11.024.

111. Burton K. Researchers find antarctic lake water will fizz like a soda. NASA (11 August 2003).

112. The Earth Institute at Columbia University (21 March 2002). News Archive - The Earth Institute - Columbia University .

113. Ediacaran biota. Wikipedia. https://en.wikipedia.org/wiki/Ediacaran_biota .

114. Rothman D. H., Hayes J. M., Summons R. E. Dynamics of the Neoproterozoic carbon cycle. PNAS. 2003, vol. 100, 14, pp. 8124—8129. https://doi.org/10.1073/pnas.0832439100 .