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General Evolution of the Universe driven by Attraction and Four Levels of Biological Evolution as its Essential Part

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Abstract

A strict definition of the hierarchy of material systems is formulated. Based on this definition, the main hierarchical structure of the Universe was divided to 15 levels belonging to 2 branches. Process of the Universe evolution (megaevolution) is considered as hierarchogenesis, i.e., a process of new hierarchy levels formation. The main driver of the hierachogenesis is an attraction that takes different forms for different steps of the megaevolution. Duration and time of each this step on the Universe timeline were estimated using the data of the other investigators. Biological evolution is considered as essential part of the general megaevolution where symbiosis plays role of the hierarchogenetic attraction. Semantic consideration of the hierarchogenesis allowed to build a mathematical model of its dynamics. It appeared that this model describes general megaevolution of the Universe well enough to estimate time of macromolecules appearance, that is still unknown, and to predict when the next hierarchogenetic step will take a place.

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Hierarchogenesis as the Highest Level of Material Evolution

The evolution of our Universe never was smooth and consistent. It was full of inflection points, emergence of new functionalities, catastrophes, and so on. Events of so-called hierarchogenesis[1,2] were the rarest and the most important of them. Such events are characterized by the appearance of a new level of hierarchy. Because the notion of hierarchy has several quite different meanings starting from the original, churchly one, according which people or groups are ranked one above the other based on status or authority[3], I have to explicitly define what we mean by a hierarchogenetic event in a context of the evolution of the Universe.

An event can be considered as hierarchogenetic if it results in the appearance of a system that:

1. can exist by itself, not only as a part of a super-system on the upper hierarchical level;
2. consists of subsystems belonging to one or more lower hierarchical levels;
3. its subsystems are of several types that radically differ from one another;
4. interrelations between these subsystems lead to emergence of an entity that did not exist before, i.e., a novelty.

The first of the conditions above excludes such systems as free radicals, cell organelles, or organs (and systems of organs) of multicellular organisms. The second condition excludes hierarchical systems in their original social sense. For example, alpha male in a flock of monkeys that is the highest level of hierarchy doesn't consist of beta males, females, juveniles, etc). The third condition excludes systems that consist of the monotypic or almost monotypic subsystems like homopolymers, colonies, populations, or some multicellular prokaryotes[4]. And the fourth condition doesn't allow us to consider, for instance, each of the multiple emergences of multicellularity in different clades[5,6,7] as separate hierarchogenetic events, as opposed to eukaryotes that appeared in the history of life only once[8]. In this way, appearance of eukaryotes and multicellular organisms should be considered as only one hierarchogenetic event in each case.

Applying our definition to the whole history of the Universe, we find only 15 hierarchogenetic events with two branches. Their list with time of emergence, duration, and areas of science related to them is given in the Table 1.

Numbers in the 3rd column of Table 1 are approximate or average for interval values found in different sources while numbers in the 4th column were calculated based on them. Time of the Big Bang (as a zero point) was assumed equal to 13.8±0.02 Ga, i.e., billion years ago[9]. Appearance of quark-gluon plasma ("quark soup") and hadrons were estimated as 10^{-12} and 10^{-6} seconds after the Big Bang, respectively[10]. First nuclei appeared from 1 second till a few minutes of the Universe existence[11]. So, time from the Big Bang to each of these first three steps is equal practically to zero (in our gigayears time scale).

Appearance of the first atoms in Recombination Era is dated 380±50 thousand of years[12] after the Big Bang. First stars appeared 13.78 Ga (billion years ago), or more exactly - 175±75 million years after the zero point[13]. Time interval of appearance of the first galaxies was pretty wide: 150 My – 1 Gy after the beginning of the Universe[12]. And we originally chose for this step the middle value – 0.575±0.425 Gy. However in January of 2018, NASA[14] reported about finding one of the Universe's oldest galaxies, which formed only 500 million years after the Big Bang. So, we chose 0.49±0.01 Gy as the date of galaxies appearance. To find a value of the time when the first relatively complex (heteroatomic) molecules emerged was the most complicated task. We estimated it basing on the time of the interstellar dust appearance, i.e. as 1.1±0.3 Gy after the Big Bang[15].

There are no data on a time of heteropolymers appearance. As for the appearance of protocells (the first extraterrestrial living systems), Alexei Sharov and Richard Gordon[16,17] based on an exponential increase of the life complexity over its history in accordance with Moore's Law, estimated this event at 9.7±0.3 Ga or 4.1±0.3 Gy after the Big Bang. We with R. Gordon[18] analyzed numerous data on the time when LUCA (the Last Universal Common Ancestor of all the terrestrial living creatures) and LECA (Last Eukaryotic Common Ancestor) were emerged. Finally, we got the following

Table 1. Hierarchogenetic branches and steps in material evolution of the Universe.

Hierarchogenetic branch	Hierarchogenetic step	Time after Big Bang (in years)	Duration	Related area(s) of science
Cosmic	1 - Appearance of the rest mass and light particles (quark-gluon plasma)	3.17E-20	3.17E-20	Elementary particle physics
	2 - Appearance of hadrons (heavy particles)	3.17E-14	3,17E-14	Physics of strong forces
	3 - Appearance of nuclei	3.17E-07	3.17E-07	Nuclear physics
	4 - Appearance of atoms	3.80E+05	3.80E+05	Quantum mechanics, Spectrometry
	5 - Appearance of stars	1.75E+08	1.75E+08	Astrophysics
	6 - Appearance of galaxies	5.75E+08	4.00E+08	Astrophysics
Substance	7 - Appearance of heteroatomic molecules (monomers)	1.10E+09	5.25E+08	Chemistry
	8 - Appearance of macromolecules (heteropolymers)	???	???	Biochemistry of RNA / protein worlds
	9 - Appearance of prebiotic protocells	4.10E+09	???	Biochemistry of RNA / protein worlds
	10 - Appearance of prokaryotic cells (LUCA – last universal common ancestor)	9.75E+09	5.65E+09	Microbiology
	11 - Appearance of eukaryotic cells with mitotic cycles (LECA – last eukaryotic common ancestor)	1.17E+10	1.95E+09	Protistology
	12 - Appearance of eukaryotic multicellular organisms with continuing differentiation (Gordon, 1999), and thus embryogenesis	1.30E+10	1.34E+09	Embryology
	13 - Appearance of artificial environment (agrocenoses), i.e. neolithic revolution	1.38E+10	7.65E+08	Anthropology, Agronomy, Veterinary
	14 - Appearance of nations and states with armies and governments	1.38E+10	8.90E+03	History, Economics, Politics
	15 - Appearance of noosphere	(1.38E+10)	???	Crowd Thinking, Social Networks, Politics

estimates for LUCA and LECA: 4.05±0.25 Ga and 2.1±0.6 Ga or 9.75±0.25 and 11.7±0.6 Gy of the Universe history, respectively.

The next step was appearance of eukaryotic multicellular organisms. This was happened 765±25 million years ago[19] or 13.035±0.025 Gy after the Big Bang. The two following steps (appearance of agrocenoses and states/nations) happened 14,000±4,000[20] and 5,100±100[21] years ago, respectively. But these points, as the very first ones, practically are not distinguishable (in our gigayears time scale), in this case, from present.

Then, the Table 1 includes two branches of main hierarchogenesis. The main one (Cosmic) lasted from the Big Bang and up to formation of galaxies. Possibly, it would be make sense to add there formation of clusters and superclasters of galaxies happened 3 and 5 Gy from the Big Bang, respectively. But there are no clear evidences that these types of objects meet our 3rd requirement for hierarchogenetic event and these clusters and superclusters are real novelties rather than just a kind of 'colonies" of galaxies. The second branch (Substance) moved away from the main one about 1-2 Gy of the Universe age. It started with appearance of substance as interstellar dust in a form of heteroatomic molecules. These molecules became more and more complex (presumably on the surface of the planets), combined into heteropolymers (macromoleculs) and then into the following hierarchical levels of protocells, prokaryotes, eukaryotes, etc. For time when each of these steps happened were chosen the best approximate estimation form the sources described above. The only exception is the time of macromolecules appearance that was not estimated, even approximately.

Of course, there were the other branches like interstellar dust ➔ planetesimals ➔ planets or living organisms ➔ ecosystems ➔ biosphere that developed in parallel with the principal direction of hierarchogenesis. But they do not belong to the mainstream of the Universe evolution, at least from our human prospective.

The fifteenth step in Table 1 is a possible candidate for the next hierarchogenetic event: noosphere as the sphere of human thoughts. It is hard to predict in which particular form it will be realized as the next hierarchogenetic step because the evolution after a bifurcation point cannot be predicted just before it, where we obviously are now. Yet we already can observe some essential signs of the noosphere appearance: globalization, the Internet, social media, crowd thinking, etc.

Of course, this list of 15 hierarchogenetic events could be slightly modified, expanded, or narrowed[1]. But it gives us an approximation to the number of hierarchogenetic events and general picture of the hierarchogenesis as the main staircase of material evolution. And the main driver of this evolution is a kind of attraction that takes different forms for different hierarchogenetic steps. For biological systems, such attraction took the form of symbiosis that we consider in the next section.

Four Levels of the Biological Evolution

As one can see from Table 1, the biological evolution is the longest and probably the most important (at least from our, Earth's habitants prospective) part of the general evolution of the Universe. It reveals itself at four different levels and each of them has its own specific time scale. These levels are:

- microevolution - evolution inside species that is experimentally investigable and based on natural selection and intraspecies struggle for life (with time scale from hours to thousands of years)
- evolution as itself - evolution in Darwinian sense, i.e., origin of species, based on natural selection and interspecies struggle for life (with time scale from thousands to millions of years)
- macroevolution – evolution in Cuvieres sense, i.e., appearance of macro taxa due to global events and catastrophes, often involving adaptive radiation (with time scale from tens to a few hundreds of millions of years)
- megaevolution - based on symbiosis (with time scale from many hundreds of millions to billions of years).

From all these levels of biological evolution, only megaevolution represents steps of the main staircase of hierarchogenesis and can be considered as part of megaevolution of the Universe. And this general megaevolution has only 3 purely biological steps:

protocells → prokaryotic cells

prokaryotic cells → eukaryotic ones

eukaryotic cells → multicellular organisms

These steps took totally more than 9 billion years (Table 1), i.e., about two thirds of all the Universe existence, and were the longest ones of all the main hierarchogenetic steps. Another specific feature of this biological megaevolution is symbiosis that means coexistence of two and more living organisms and includes mutualism (coexistence to a mutual benefit), commensalism (when one organism lives with, on, or in the other one without damage to either), amensalism (when one organism adversely affect the other) or parasitism (when one species parasitizes on the other). Wherein, symbiosis in general is a particular biological kind of general attraction that is the main driver of hierarchogenesis.

The embryologist Paul Weiss[22] wrote, explaining the role of symbiosis in (mega) evolution in the last point of his "canon":

"12. Although I have emphasized for didactic reasons the relatively conservative features of systems, the unidirectional change of systems must not be overlooked. We find it expressed, for instance, in the mutability of systemic patterns in evolution, ontogeny, maturation, learning, etc., as well as in the capacity to combine systems into what then appear as super-systems with the emerging properties of novelty and creativity".

This citation highlights the inextricable connection between the emergence of real novelties and combining systems into a kind of super-system. In other words, the appearance of a new hierarchical level is a result of conjunction of elements on the previous level, i.e., symbiosis.

The very term "symbiosis" was proposed almost 150 years ago by Heinrich Anton de Bary [23,24]. Then, after a quarter of a century, Petr Kropotkin[25] came to the conclusion that mutual aid in addition to competition plays an essential role in the evolution. Symbiosis obviously includes such mutual aid. Kropotkin's ideas were further developed in the context of symbiosis by Konstantin Mereschkowsky, Boris Kozo-Polyansky, and Andrey S. Famitsin[26,27,28]. In addition, I formulated the law of congruous attraction[29] according which species tend to maximum overlapping of projections of their ecological niches to axes of multidimensional space of factors where it doesn't lead to competition. This law, together with the law of competitive exclusion[30], determines the main forces that form structure of ecosystems.

Besides, Mereschkowsky[31] from the very beginning formulated a theory of symbiogenesis, according which eukaryotes appeared as a result of a symbiosis of different prokaryotes. His ideas were developed further by Kozo-Polyansky[32] and Ivan Wallin[33] presented his endosymbiotic theory that was very close to the concept by Mereschkowsky. It was Wallin who first provided the experimental foundations of the idea that eukaryotic organelles originated from prokaryotic bacteria.

However, these ideas were not included into the scientific mainstream for almost all of the 20th century. Only during the last few decades, it became more and more obvious that symbiosis, as a kind of win-win strategy, is one of the important factors of the evolution[34,35,36] particularly reticulate evolution[24]. At the same time, while numerous symbiotic interrelations occurred throughout the evolution after the emergence of multicellular eukaryotes[37,38], they never created a new hierarchical level by our definition of hierarchy.

As for endosymbiosis, it was passed more than 40 years before ideas by Mereschkowsky, Kozo-Polyansky and Wallin became well-known after Lynn Margulis published her famous book "Origin of Eukaryotic Cells" that gave endosymbiotic theory new life[39]. Only in the 1970s endosymbiotic theory gained at last its wide recognition, and symbiosis as a biological kind of attraction, was recognized as one of the main factors of biological evolution and the leading driver of biological hierarchogenesis.

But biological steps of the general megaevolution has another specific difference from the other pre- and post-biological steps. As we can see from Table 1, these steps lasted hundreds of millions and billions years and were drastically longer than any other steps of the main hierarchogenesis.

The natural question is: why it took so long?

We with Richard Gordon tried to find an answer to this question applied to prokaryotes eukaryotes step but could find it neither among the physical and chemical events happened on the Earth when prokaryotes were its only habitants nor among biological waiting for appearing of introns or sex reproduction[18]. Finally, we offer a possible answer to the question based on completely new approach.

Semantic Consideration of Hierarchogenesis

This answer relates mostly to internal rather than external system factors that could play their own role. To estimate the essentiality of this role, let us consider the following model situation.

In a well-known thought experiment[40], a monkey eventually types the text of Shakespeare's works (e.g., Hamlet) by randomly hitting the keys of a typewriter. But then it was evaluated that such a process would take far more time than the age of our Universe[41]. However, if we change experimental conditions and place behind a single monkey a reciter who knows the Hamlet text by heart and erases in some way all the incorrect monkey's hits, the time would be incredibly reduced. The text of Hamlet contains 132680 alphabetical letters and 199749 characters overall. If we estimate the monkey's typing speed as 4 hits per second, we will need about 40 hits (including spaces and punctuation marks) or 10 seconds (in the worst case scenario) per correct character. In average, it will be about 5 seconds. This gives for a whole text of Hamlet:

(199749 characters x 5 sec)/3600 sec per hr/24 hrs per day = 11.56 days (1.65 weeks)

Let's extend this thought experiment by replacing the typewriter with a computer keyboard and the Shakespeare reciter with an AI (artificial intelligence) program that estimates meaning of new typing by comparing it with already existing texts. This program eliminates the next character if the set of characters after the last space cannot belong to any word; the next word if its combination with the previous one in a phrase doesn't make any sense, i.e., doesn't have at least approximate analogs among the existing texts; and the next phrase if it completely drops out of the context. Of course, the monkey could be also replaced with a generator of random characters. Such a program would be able to create essentially new texts (novelties) that are meaningful and at the same time completely unpredictable.

It seems obvious that the longer the text (and respectively the richer the context and vocabulary) the less probability of the next phrase being acceptable and accordingly the more time will be needed for its random creation. However, let us suppose that the AI program is more sophisticated and, after accumulation of a rich enough vocabulary and context, would operate with randomly chosen words from this vocabulary and phrases compared with this context rather than choosing the words from complete dictionary and comparing phrases with full set of texts. In such case, new phrases will be creating essentially faster after approximately the middle of the text generation process. As a result, a curve with a single minimum at its midpoint should roughly approximate the rate of text creation.

We can build a simple, rough mathematical model here. The curve for rate of novelties on Fig. 1 can be described by a sort of parabola:

$$R_t = kt^2 + R_{min}$$

where R_t is a rate of the text creation in moment t, k – constant, R_{min} is the minimal rate when AI program switches from creating words from random letters to creating phrases from random words taken from the vocabulary first and only then, if necessary, from dictionary, and t – time measured from t= 0 that corresponds R_{min}. This dependence shows that rate of the creation decreases before the switch (t = 0) and increases afterwards not linearly but with acceleration. This reflects a quite obvious idea that the emergence of innovations does not prevent the appearance the other innovations but, on the contrary, facilitates them (see differential equation below) due to enrichment of the created context.

Application of this model to megaevolution leads to its great simplification at least because a text has only four not fifteen levels of hierarchy: character, word, phrase, and the text itself. Nonetheless, it pretty well describes not only biological megaevolution but the pattern of the general megaevolution of the Universe, as well. In the last few hundreds of millions of years and in

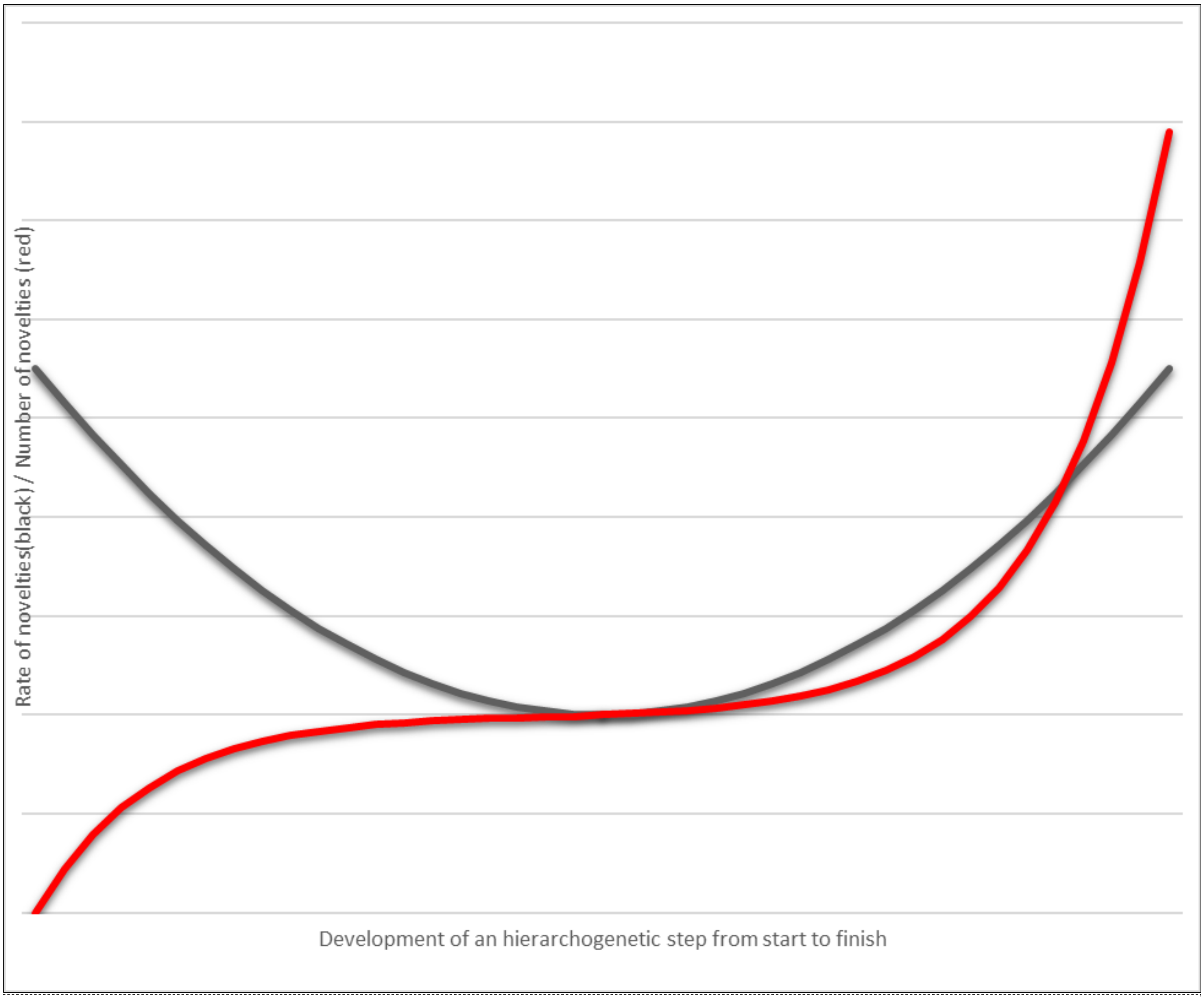

Figure 1. Rate of emergence of novelties (black curve) and number of novelties (red one) at any given moment as a function of a time. Zero of time relates to the minimal value of the rate (bottom of the black curve).

the very beginning of the Universe history, novelties were appeared at an amazing high rate while between 12 and let us say 2 billions of years ago everything developed far slower.

Coming back to our mathematical model, let n(t) be the number of innovations at time t > 0. Then:

$$\frac{dn}{dt} = En$$

on integrating: $n(t) = n(0)e^{Et}$

where E is a constant, if conditions are constant. Time t=0 is taken as R_{min} again, i.e., relates to the bottom of the curve in Fig. 1.

For the first part of the process (until the switch at the bottom where $R = R_{min}$), $E < 0$ while for the second part it is positive (see Fig, 1).

This model allows us to look at the evolution as at a semiotic process[42,43] where the role of the AI program in selecting meaningful words and phrases is played by the selection carried out by the environment. This mechanism is akin to natural selection in biological evolution, but much simpler and more primitive. Such selection rather rejects "bad" variants than selects "good" ones[44].

At the same time, there is one principal difference between our model and megaevolution of the Universe: if the program compares random words and phrases with ones that already exist in knowledge bases in a form of vocabularies, contexts, dictionaries, and collections of texts; the Universe has not had such knowledge bases, and have used laws of nature that, in a given condition, select only sustained particles, nuclei, atoms, molecules etc. Respectively, the leading direction of the megaevolution has been determined by nothing else than the laws of nature in a given environment that discard all the incompetent variants.

In addition, the last version of the thought experiment, described above, helps to understand what could be an internal factor of hierarchogenesis. If we drop timestamps related to all the hierarchogenetic steps (see 3rd column in Table 1) onto the existing timeline from the Big Bang till now (and a little bit in the future) we will get a curve (Fig. 2) that is very similar to the curve calculated by the model (Fig. 1).

Unfortunately, we don't know when the first heteropolymers or macromolecules (e.g., proteins or nucleic acids) emerged although this definitely happened after formation of monomers and before emergence of protocells that took place, accordingly to Sharov and Gordon[17], 9.7 ± 3.0 Ga. As a result, the line on Fig. 2 has a gap between 1.1 and 4.1 Gy since the Big Band. But all the other points almost ideally lie on a smooth curve, and this allows to assume the most probable position of the missed point and respectively to estimate appearance of macromolecules about 2.4 ± 0.1 Gy after the beginning of the Universe.

At the same time, the curve on Fig. 2 corresponds well to the red model curve on Fig. 1. In other words, the dynamics of the main Universe's hierarchogenesis not only quite regular rather than random, but our model describes it very adequately.

Discussion

As we saw in Section 1, the main driver of the general megaevolution has been this or that kind of attraction among the systems. Without such attraction, these systems couldn't obviously originate a super-system that belongs to next, new level of the main hierarchy. But physical, chemical, biological, anthropological, political or economic implementations of this attraction on the fifteen different levels of main hierarchy are quite different.

For quarks in hadrons and hadrons in nuclei, it is strong forces; for nuclei and electrons in atoms – electromagnetic forces; for ionized atoms in stars and stars in galaxies – gravity; for atoms in molecules (monomers) and monomers in heteropolymers – ionic, covalent, and hydrogen chemical bonds. Attraction in biological system takes the form of symbiosis that we considered in the details in Section 2. For agrocenoses, this attraction, on the contrary to all the other cases, appeared itself asymmetrically and took the form of selection by ancient humans plant and animal species that could be reliable and replenished source of food whereas all these species didn't show, at least at the beginning, any attraction to the humans. For states – it was attraction between these agrocenoses, or more exactly farmers, i.e., families and Neolithic tribes, in the face of an external threats in the form of raids by nomads and other less civilized tribes. And finally,

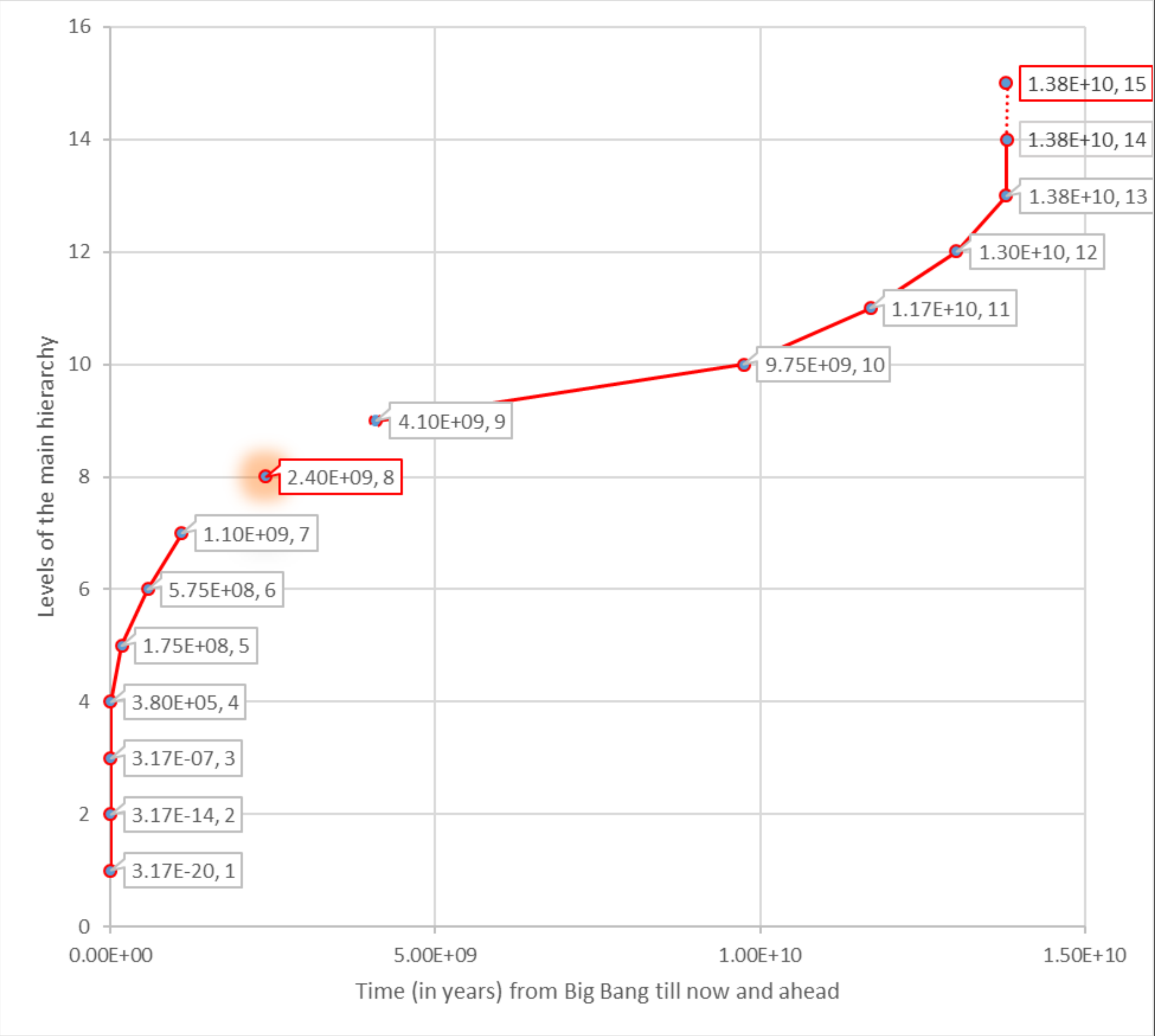

Figure 2. Dynamic of successive steps of the main hierarchogenesis or megaevolution of the Universe (see Table 1) since the Big Bang. Points: 1 – quarks, 2 – hadrons, 3 – nuclei, 4 – atoms, 5 – stars, 6 – galaxies, 7 – heteroatomic molecules, 9 – protocells, 10 – LUCA (last universal common ancestor), 11 – LECA (last eukaryotic common ancestor), 12 - multicellular organisms, 13 – agrocenoses, 14 – nations/ states, 15 – noosphere. Gap between points 7 and 9 relates to step 8 (macromolecules) that cannot be confidently dated. So, the label of the point 8 is an interpolation. Point 15 (noosphere) relates to the future, and the dotted line between points 14 and 15 describes probable prediction.

noosphrere can be understood as a successful completion of globalization. It will be able to emerge only as a result of an attraction between states and nations for solving global problems that threatens the very existence of the humanity. Hopefully, we will make this next hierarchogenetic step before it will be too late.

At the same time, each of these types of attraction meets some sort of repulsion that doesn't allow the systems just to merge into the one instead of formation a new level of hierarchy. The primary and the most important repulsion was the Big Bang that started enlargement of the Universe itself and made attraction (that has been acted in opposite direction) the main driver of the evolution. The other, more particular kinds of repulsions also have different nature for different hierarchical levels. For hadrons in nuclei, it is electrical charges repulsion. For the stars, it is energy of thermonuclear synthesis that doesn't allow stars to collapse into a black hole until thermonuclear fuel, first of all hydrogen, is not exhausted. For galaxies – it is centrifugal force of their rotation that doesn't allow the galaxy stars to fall into the black hole that is usually located in the centers of galaxies.

For atoms in monomers and monomers in heteropolymers – it is the Pauli exclusion principle that doesn't allow two or more identical fermions, including electrons, occupy the same quantum state within any quantum system including molecules. As a result, atomic nuclei in each molecule are separated by electronic clouds populated by not more than 2 electrons with opposite spins at each energy level. This, on the one hand, compensates the electric repulsion between positively charged nuclei and, on the other hand, doesn't allow them to get essentially closer than a sum of atomic electron clouds radii.

For prokaryotic, eukaryotic, and multicellular biological organisms, it is law of competitive exclusion formulated by Georgy Gause[30] according which two species competing for the same limiting resource cannot coexist. In other words, they cannot occupy the same ecological niche that makes Gause's principle directly opposed yet complementary to the law of the congruous attraction[29] mentioned above.

For agrocenoses, it is resistance of animal species to domestication and instability of one-crop agricultural systems. Respectively, the ancient humans had to graze cattle, to build fences, to weed the fields from weeds, i.e, "by the sweat of their faces they ate bread". For states and countries, it is natural contradictions, always arising between neighbors, be they families or tribes. And finally for noosphere, we see with our own eyes all the political, economic, cultural, and religious obstacles that stand in the way of the integration of all the humanity into the one super-system that will hopefully be the next step of the hierarchogenesis and megaevolution.

This permanent counteraction and balance of attraction and repulsion doesn't allow to stop the process by some kind of complete unification. On the contrary, the unification at the each step of the megaevolution is not, due to repulsion, perfect and opens a possibility for the further evolution. Such megaevolution, as we saw, pretty well matches to the simple model described in the previous section. Although this model uses semantic analogy, it doesn't necessary mean that the evolution of the Universe is semantic in its nature. This could be just a result of external similarity of the both processes.

Our sematic model supposes that at the very beginning of the process, new words and phrases are accepted easily and quickly because they don't contradict existed context that is very poor due to the shortness of already created text. Then, when the created text becomes longer, and the context - richer, the choosing acceptable words, and especially phrases, that not contradict the context becomes less and less probable and events - more and more rare. In the same way, at the very beginning of the megaevolution, the different options for elementary particles, nuclei, atoms, or simple molecules were pretty limited while environment diversity (that can be considered as analog of the context) was poor, and this led to quick and often hierarchogenetic events. Afterwards, number of variants for heteropolymers and more complex systems became truly immense while molecular environment – more and more diverse, and time intervals between hierarchogenetic steps – longer and longer.

As for accelerating the process closer to the end, this is the result of the development along channeled trajectory, which led to a secondary restriction of possible new variants, and transition in our model from "dictionary" to "vocabulary" (where the number of options is much less than in the "dictionary") speeds up the process of megaevolution. In addition, these steps of hierarchogenesis happened in human society, where the semantic component (the already created plot dictates subsequent events) can play its important role.

In any case, the proposed model, which describes the general evolution of the Universe quite well, allows us to predict that the next hierarchical step (noosphere or, perhaps, something else) will come through a hundred years, if not in a couple of decades.

Conclusion

We provided the strict definition of the hierarchy of material systems. Such definition allowed to describe an emergence of each level of the hierarchy as a step of hierarchogenesis that can be considered as the general evolution of the Universe or megaevolution. This megaevolution is divided to 15 steps, and each of them is characterized by separate hierarchogenetic event, i.e., by appearance of the new level of hierarchy. Biological steps of this megaevolution can be detailed using three additional time scales: macroevolution, Darwinian evolution, and microevolution. The main driver of the 15-steps megaevolution is an attraction that takes the different forms on the different steps. At the same time, this or that type of repulsion counterbalances, up to some degree, this attraction at each the step. The general evolution of the Universe is well described by a simple mathematical model based on semantic considerations. This model allows us to estimate the time of appearance of macromolecules (11.4 billion years ago) and to predict the next hierarchogenetic step in the next a few dozen years.

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