Evolutionary Phases of Big History

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Abstract: The present article is devoted to the issue of unity of laws, patterns and mechanisms of evolution at all its stages and levels of Big History and megaevolution. Despite the enormous differences between cosmic, planetological, chemical, biological, and social evolutions, there are many similarities. There are a lot of important and insightful works on the development of complexity in our Universe and in the course of Big History. Unfortunately, much less studies are devoted to analysis of universal similarities, patterns and rules within Big History. Mostly such research is focused on a few laws of Big History which are usually connected with development of complexity. However, laws in terms of the typological similarity of many patterns and rules in star-galaxy, planetological, chemical, biological and social phases of Big History, are of great importance. In the present article we will consider a number of such important similarities, which, in our opinion, clearly demonstrate the systemic-structural and functional-evolutionary unity of the world at its different levels and in different areas. The understanding of these similarities deepens our perception about all stages of Big History and its regularities, and leads us away from the false idea that social evolution in all aspects is different from the evolution of previous levels. In the first section our key goal is to give our own definitions of evolution which would cover as many variants of evolutionary changes as possible. In the second section we will try to give a rather voluminous and dialectical picture of the unfolding universal evolution instead of a short scheme: cosmic – biological – social. The notions of main and transitional phases of Big History are introduced; and the importance of its planetary and chemical phases is shown. In the third section we will show that one can reveal a number of similarities at all levels and phases of megaevolution, which can be generalized in universal laws, rules, mechanisms, patterns and principles of evolution. One should note that in fact none of the important laws and principles, not any of the important rules of evolution, have been 'lost' in the process of transition from lower to higher levels. They were only modified and became more complicated, and there also appeared some new principles and rules (and in retrospect one can see their rudiments at the lowest levels of evolution). Some of these laws and rules are described in this section. In the fourth section we will try to present some evolutionary and philosophical ideas that explain the profound similarity in the laws and patterns of megaevolution at all its levels and phases. In the conclusion we will discuss evolutionary and non-evolutionary matters.

Keywords: Big History, evolution, universal evolution, megaevolution, pre-cosmic evolution, cosmic evolution, planetary evolution, chemical evolution, social evolution, phases of evolution, main phases, intermediate phases.

1 Introduction. The Similarities Between Different Types of Evolution

There are a lot of important and insightful works on the development of complexity in our Universe and in the course of Big History. Unfortunately, much less studies are devoted to analysis of universal similarities, patterns and rules within Big History. Mostly such research is focused on a few laws of Big History which are usually connected with development of complexity. (see Jantsch, 1980; Spier, 2010; Christian, 2018; Azarian, 2022; LePoire, 2020; LePoire & Chandrankunnel, 2020)). However, laws which can be found in terms of the typological similarity of many patterns and rules in star-galaxy, planetological, chemical, biological and social phases of Big History, are of great importance.

Evolution is a category whose definition provokes endless disputes. The matter is that 'evolution' (as well as 'progress', 'development', 'change', *etc.*) is among the terms with a broad meaning. Evolution is a process that started simultaneously with the emergence of our Universe (if there had ever been such a beginning). In any case, evolution can be considered as a form of matter existence. In the present article we will use the terms Big History, 'universal evolution' and 'megaevolution' as synonyms. We will use these terms for the process encompassing all evolutionary levels and lines from the Big Bang to contemporary phenomena; they are used simultaneously in two meanings, namely: the evolution of the Universe and evolution as a universal process.

Despite the enormous differences between cosmic, planetological, chemical, biological, and social evolutions, there are many similarities (for more details see Grinin, Markov, & Korotayev 2009, 2011; Grinin, Korotayev, & Markov 2011; Grinin *et al.* 2011; Grinin 2013, 2015, 2017, 2018, 2020; Grinin L. & Grinin A. 2019). Unfortunately, quite a few works are devoted to their identification. In the present article we will consider a number of such important similarities, which, in our opinion, clearly demonstrate the systemic-structural and functional-evolutionary unity of the world at its different levels and in different fields. The understanding of these similarities deepens our perception of every stage of evolution and its regularities, and leads us away from the false idea that social evolution in all aspects is different from the evolution of previous levels.

It seems undoubtedly fruitful to present all forms of evolution as a single and universal process, or as phases of *Big History*. By analyzing these phases, conventionally speaking, in the 'horizontal' dimension, as manifestations of evolutionary laws in different forms of matter, one can clearly figure out the general evolutionary similarities. However, we consider the transitions to a new level within the Big History framework already in the frame of 'vertical' dimension as qualitative breakthroughs in the framework of the Universe's development.

The 'vertical' view of Big History is generally accepted while the 'horizontal' approach is infrequently used. In the present article we tried to combine these two approaches. The first section will show the way to the elaboration of universal definitions of evolution, which will demonstrate profound similarities of all phases of evolution. In the second section, we will reconsider the vertical structure of Big History that had never been done before. In the third section, we will describe some of the universal evolutionary properties that manifest themselves at all phases of Universal evolution including social evolution which comes as one of the number of forms of evolution and then as an outcome of the preceding development. In the fourth section we will analyze at the profound (philosophic-evolutionary) level what defines the unity of evolutionary mechanisms and laws at all its phases and in all lines.

2 The Definition of Evolution

The concept of evolution was introduced into scientific discourse by Herbert Spencer, and it is important that he did it before Charles Darwin (who actually borrowed the term from Spencer), and that he attributed this definition to any type of evolution (for more details see Grinin *et al.* 2011: 5–6). Later on, biologists largely 'monopolized' the concept. Although Spencer's definition of evolution as a change 'from an indefinite incoherent homogeneity, to a definite, coherent heterogeneity' in the process of differentiation (Spencer 1972: 71) has retained its conceptual and even aesthetic appeal up to the present time, yet today it looks obviously narrow, covering only one, albeit very important line of evolutionary changes.

The attempt to expand the concept of evolution by including any change into it has led to definitions of evolution such as those given by Fred W. Voget (1975: 862) and Henri J. M. Claessen (for a more detailed analysis of this definition see Grinin and Korotayev 2009, 2020). Claessen bases his definition on Voget's approach and considers evolution as '*the process by which structural* *reorganization is affected through time, eventually producing a form or structure which is qualitatively different from the ancestral*' (Claessen, 2000a: 7; see also Claessen & van de Velde, 1982: 11ff.; 1985: 6ff.; 1987: 1; Claessen, 1989: 234, 2000b; Claessen & Oosten, 1996).

This definition has undeniable advantages because the structural reorganization is a crucial point for many processes, it also shows a complex and long-term character of changes, and focuses on a new form or structure which is *qualitatively different* from the ancestral one. However, it also has serious drawbacks that generally complicate further evolution research. The main thing is that this definition is intended, most likely, to describe the changes within one evolutionary phase (in fact, it was intended for social evolution). Although it points out qualitative differences, it does not pay sufficient attention to the most important process of formation of the fundamentally new that has not yet happened and that may lead to a new level of evolution, level of complexity. In other words we mean the lack of attention to the aromorphic evolution (about aromorphic evolution see Grinin, Markov, and Korotayev 2009, 2011), to the line of complexity rise. Besides, the word 'reorganization' is not precise enough. It implies that an already existing object is evolving and its structure is changing while the process can be described: a) as self-organization, *i.e.*, creation of a new structure from an unstructured mass, or b) as an emergence of a new structure via combining of smaller structures (cells, societies, *etc.*), or c) in another way.

Therefore, in evolution one should distinguish: a) reorganization; b) emergence of a new structure as a result of self-organization or association; c) division; d) complication; and e) other. In addition, evolution may not at all be related to the changes in structure only. It may be a change of function, productivity, adaptability, appearance of new lines, divergence and convergence of existing species, lines, *etc.*, in other words, everything that promotes positive changes. Or to be more exact, with *a positive balance of changes* since the positive and negative changes always go side-by-side, in other words if something is gained then something is lost. The general balance and outcome are important.

Positive changes can be widely presented as: complication; increasing ability to self-regulate along with growing variability and diversity; increased sustainability; better adaptation to changes and environment; formation of new elements or complexity, optimization of existing properties and functions, *etc.*

It is necessary to distinguish between *narrow* evolution (*i.e.* within individual systems and taxa) and *broad* evolution (within the Universe or phases of megaevolution). Within the division into narrow and broad evolution, it becomes even a more nontrivial task to determine what a positive balance of changes is. The fact is that positive changes for certain objects or sets may mean negative changes for other objects, systems or amalgamations that have, for example, been swept away by selection, absorbed or restructured, as well as within individual subsystems of a system. Thus, certain evolutionary success can be provided by other failures, which we have formulated as *a rule of payment for aromorphic progress*[1] (Grinin, Markov, and Korotayev 2008: 80–81; see also below). This rule means that the emergence (strengthening) of positive qualities implies a simultaneous disappearance of some organs, subsystems, functions and qualities antecedent to evolutionary changes. But as a result, some evolutionary success ensures the movement of a large set of systems in a certain direction, since the acquisition of features equally suitable for a wide set of environments is carried out, in general, to 'master' the environment and to increase the number of relations with it (Timofeev-Resovskij *et al.,* 1969: 282).

Our key goal is to give our own definition of evolution which would cover as many variants of evolutionary changes as possible. One should present evolution both as a) progressive evolution, *i.e.* a movement from a lower stage to a higher one, and b) as transformations within a single stage or sideward movement, which often contribute to the formation of large areas of reality (the scheme of Universal evolution clearly shows all of them).

Taking this into account, *one can denote evolution as the process of changes through time of forms, structures, functions, properties and other aspects of objects, systems, subsystems, natural groups and complexes of different size systems and objects, due to which there appear qualitative changes in comparison with the previous state (up to the formation of new areas or development levels)*[2]*. At the same time, the overall balance of such changes should be generally positive (taking into account the level of generalization). In other words, the sum of changes should be positive and appear immediately or in a more distant period. The positive balance can be manifested in relation to* *individual systems (objects) and/or to their narrow or wide set.*

So if the general balance of changes is positive, we deal with evolution; if it is negative, we speak about devolution or involution.

3 Big History, Its Main and Transitional Phases

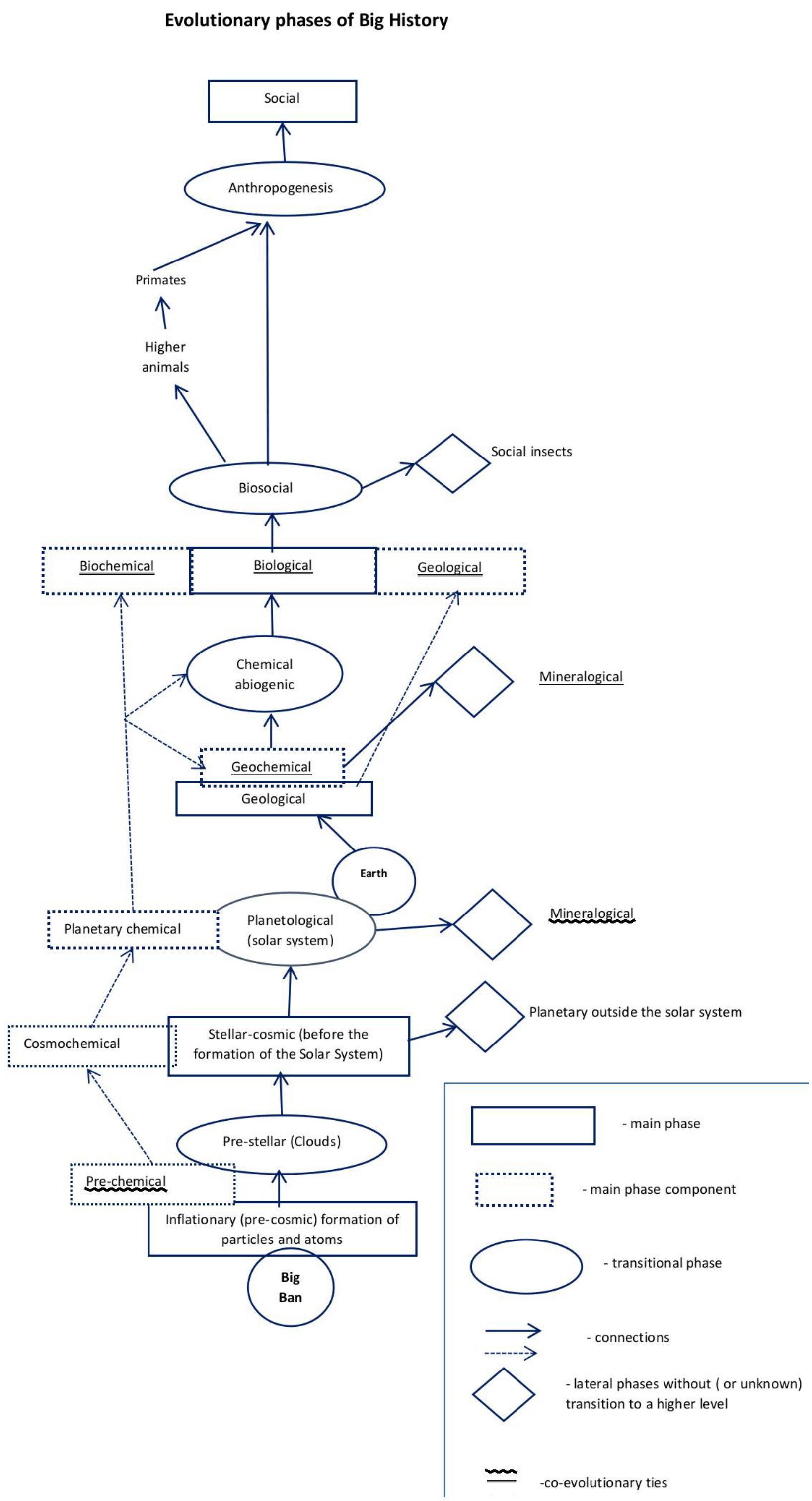
Let us consider our scheme of megaevolution movement which in comparison with usual schemes is much more complete and relevant. As has been mentioned above, here we reconsider the vertical structure of Big History. Such a full picture of Big History has never been created before. We tried to give a rather voluminous and dialectical portrait of the unfolding evolution instead of a short scheme: cosmic – biological – social/cultural. However, even this scheme does not fully reflect the complexity of Big History lines and phases.

Let us take a closer look at this scheme: what is new?

1. Big History is presented starting from the Big Bang as consisting of ten phases and not of three or four as is common.

2. In addition to the main phases, we have introduced intermediate or transitional phases of evolution. These are: a planetary phase within the Solar system, the abiogenic chemical phase, biosocial phase and anthropogenesis.[3] It would be fruitful to consider the planetary evolution within the Solar System as a special level of evolution which is transitional between the cosmic evolution and evolution of the Earth. In a way, this is a new idea in evolutionary studies (for more details see Grinin 2020). The division into main and intermediate phases: a) reduces the qualitative gap between the main phases of megaevolution; b) shows the mechanisms of evolutionary development and the mechanisms of its transition to a higher level; c) reflects previously failed attempts of evolution to find the way to a higher level. For example, biosocial evolution paved the way to social one at different times through different directions, including

Figure 1. Phases and lines of Big History



social insects, until it became possible to make this breakthrough through primates.

3. Thus, *Big History appears as an alternation of five main and five transitional phases.*

4. We have introduced pre-cosmic evolution (see Grinin, 2013, 2014, 2015), which is called inflationary here. Its introduction makes sense since this evolutionary phase was associated with the formation of conditions for the origin of the Universe and its certain order. This phase was characterized by: a) fast and rapid changes of parameters due to temperature drop and expansion (inflation) of the Universe; b) formation of primary structures of the microworld (protons, neutrons, electrons and other particles) and then of atomic nuclei and atoms of the first elements. In other words, it was simultaneously pre-chemical evolution (which is distinguished separately). During this phase the evolutionary processes were very specific, since this was actually the process of self-organization of both the Universe in general and of its macrostructures[4].

5. We have also introduced the idea of continuous lines of evolution, one of them is the chemical evolution in the Figure 1. It is easy to notice that the latter appears to be a component of larger types of evolution at each phase of megaevolution, forming a lateral but necessary part of the latter. Only in the phase of abiogenous chemical evolution does the role of chemical evolution rapidly increase to the level of a transitional phase. Then it again becomes a part of a larger phase, the biological. In the scheme, we do not trace a further development of chemical evolution, but one should remember that it has also become an important component of social evolution, which could be called sociochemical. At the same time, its results begin to appear already in the phase of anthropogenesis, from the moment when humans learned how to control fire.

6. Some lines are singled out as lateral or dead-end. The dead-end lines may be defined when development has almost or completely stopped. For example, this is the case with mineralogical evolution on some planets and satellites like Mercury or the Moon, where it stopped billions of years ago (see Grinin, 2020). The lateral lines are by no means insignificant. They just did not 'go' further, *i.e.* they did not become a starting point for transition to a higher level. And still they have created new evolutionary domains in which development continues. This refers, for example, to social insect species numbering many thousands species. Among the lateral lines, it is worth noting the planetary evolution within the framework of the space-stellar evolution prior to the formation of the Solar system. It is mentioned as a dead-end line because we do not know exactly how and where the evolution took place on the myriad planets in the Universe. But it is very likely that there occurred transitions to some new levels. Such dead-end lines show that any transition to a higher phase was preceded by several dead-end lines which reflect the complex process of finding the ways to higher levels, the need for a number of attempts to do this in different directions (according to the rules of evolutionary preparation and payment for evolutionary progress; see below).

7. One of the most important ideas is the idea of co-evolutionism, when two or three (or even more) directions of evolution become inseparable. Co-evolutionism implies an increasing rate of development due to a synergistic effect, and increasing complexity and development of opportunities for a breakthrough. Co-evolution may have different scales and manifestations. For example, it may comprise minor but very important lines within a larger phase (line), like in case with biochemical evolution in the framework of biological one. Geological evolution is in co-evolution with the latter (more precisely, its part which is related to the influence of life on changes in the Earth's outer shells, including the atmosphere).

4 Some General Evolutionary Laws and Patterns

As already mentioned, in different areas of the Universe, at all levels and phases of megaevolution, one can reveal a number of similarities both in the ways and principles of construction and functioning of objects (systems) and in their change and development, which can be generalized in universal laws, rules, mechanisms, patterns and principles of evolution. One should note that in fact *none of the important laws and principles, not any of the important rules of evolution, have been 'lost' in the process of moving from lower to higher levels*. They were only modified and became more complicated, and there also appeared some new principles and rules (and in retrospect one can see their rudiments at the lowest levels of evolution). Some of these laws and rules are described in this section (see also Grinin 2017, 2018, 2020; Grinin L. & Grinin A., 2019, 2020b).

4.1 The Law of the Age Stages/Phases of Objects' Life

Oswald Spengler (1991) and Arnold Toynbee (1962–1963) became renowned for their theories of civilization according to which every civilization passes through certain stages of life (birth, youth, maturity, and decline) before the collapse. This approach still arouses discussions but nevertheless, the idea of certain phases of social organisms' life is rather reasonable. But while in social life a society can prolong its life and retrieve its dynamism at the expense of innovations and reformations, in the case of evolution we clearly observe that all material objects and systems have a certain lifespan and pass certain phases. It is quite obvious with respect to biological organisms and even species. Stars also have certain life phases. After the phase of ordinary thermonuclear reactions, which is called the main sequence phase, depending on the size, a star transforms either into a white dwarf (after passing the red giant stage) or (if having a large mass) into a neutron star. One can find certain phases within the life span of many other objects as well.

4.2 The Rule of 'Block Assemblage' in Evolution

We formulated this rule (see Grinin, Markov, & Korotayev, 2008; Grinin *et al,.* 2009) for the analysis of similarities between biological and social phases of Big History. However, it is quite relevant for its cosmic, chemical and geological phases as well. The essence of this rule is that in the course of evolution there emerge some elementary or more complex units, systems and constructions which are used in different variations. The elementary particles are the units which form atoms. With the emergence of atoms there also emerge stellar systems, and in the stellar interior new types of atoms including heavy elements are formed from additional elementary particles. Due to the diversity of emerging atoms one can speak about chemical evolution. Atoms are the universal units and components for the formation of various molecules and this marks the beginning of planetary and geological evolution. Thousands of different minerals, materials and substances are formed from molecules. Then a complex molecular organic evolution leading to life. The cells become 'bricks' for the formation of living organisms; there progressively emerge whole blocks of organs and systems which are surprisingly similar in different classes and even types of living organisms. One can recall genes and chromosomes as standard components and blocks of biological systems. One can insert a gene of a mouse into an elephant DNA, and the gene of a dog – into the human DNA! Thus, there is a striking standardization of elements and 'components' at all evolutionary levels; and since entirely new objects within evolution are created for 90–99 % from the already existing components, the speed of evolution increases dramatically. Let us also add that in human society borrowing occurs rather frequently: societies borrow (sometimes to the full extent) religions, legal, political and technological systems. Thus, 'block assemblage' allows modernization of societies.

4.3 The Circulation of Matter in Nature and Increasing Diversity in Evolution

The circulation of matter, energy and information occurs at any level. At the same time, together with circulation of matter and energy, there also occurs a circulation of states of objects. This process provides a huge potential for the search of new options. The more new objects are created to replace the old ones, the more diverse they are. Nature's workshop is based not only on the selection from the diversity but also on a constant remaking of objects. Every object has its own lifespan (see above), therefore its decaying substance is involved in the circulation and formation of new objects. New stars are formed from exploded stars but they differ from their predecessors and this brings about an increasing diversity and enhances chances of the emergence of something brand new. Decayed biomass is a source of nutrients to support the reproduction and life of other living creatures. The debris of a destroyed empire gives rise to a new power. *Thus, the decay and revival (in different ways) of objects (organisms) is a general law of evolution/Universe*. We speak about the Universe since these processes ensure the continuity and laws of perdurability of matter and energy. We speak about evolution because these processes allow some constant testing of new variants (in biology they also include mutations, and in human society – deliberate changes which accelerate the given process).

Thus, the collapse of one object implies to some extent the origin of the other one. This provides an opportunity to reap the benefits of long processes. For example, a supernova explosion results in accumulation of heavy elements that played an important role in the formation of the Solar system (*e.g*., Bizzarro *et al.,* 2007). To an even greater extent, this manifests itself in biological evolution with its myriads of trophic chains. And to a great extent this also refers to social evolution, in which, for example, the invaders' societies inherit the culture of the invaded. Here we deal with a 'creative destruction' when the new is created at the expense of destruction or elimination of the old (see below). At the same time, the new is already somewhat different from the old, and sometimes to a significant degree, and this provides continuity and space for advancement to the new. Thus, the change of the ruler does not necessarily lead to fundamental changes in society, but every new ruler is somewhat different from the predecessors, he acts in a somewhat different manner; and thus, historical experience is accumulated (Grinin, 2013: 140).

4.4 The Typical and the Unique Objects

On the one hand, one cannot help wondering at the natural 'production-line' capable of creating millions and billions of exceptionally similar copies of the same objects. But, on the other hand, the variability among similar objects is unquestionable. In fact, every star is very different from another even if it belongs to a narrow classification group (and there are lots of such groups). And even if stars are formed (like enzygotic twins) from one gas-dust cluster (as a result of a single outburst of supernova, *etc.*), still they differ in mass, chemical composition, the presence or absence of planetary system (and in the planetary system types), brightness, characteristics of reactions, and position, *etc.* Not a single biological individual is identical with another. The same refers to human beings (various papillary patterns on the fingers, unique genetic code, *etc.*). Not so long ago we believed that animals act like mechanisms guided only by their genetically determined instincts. But at present, ethology has identified a large range of individuality among animals as well as among insects (see, *e.g.*, Reznikova & Panteleyeva, 2012). Thus, typical and unique (individual) characteristics are peculiar to all macro-objects in nature. Individuality has been also discovered in the microworld. But it is quite possible that molecules, atoms and even elementary particles might also have something like individual features. Thus, such features as, for example, uniqueness which seems typical only of humans may appear also inherent to all natural objects. The variability of typical objects (belonging to one class, species, group, *etc.*) is the most valuable tool of evolution which allows selecting variations of attributes (as well as their concentration, *etc.*) which are the most appropriate for a number of tasks. A qualitative breakthrough can occur only as a result of the emerging unique circumstances (whose possible occurrence is significantly increased through variability). Finally, only the endless variety of stars, planetary systems, planets and preceding events could be a trigger of emergence of life on the Earth. But one should remember that individuality increases as evolution develops. The number of attributes of variability increases together with the complication of systems (*e.g.*, in human society, language, social position, nationality, *etc.* are added).

4.5 Selection and Struggle for Resources

Social evolution is largely a struggle for resources and for living space (and not only at its initial phases). The same refers to biological evolution. However, the study shows (Grinin, 2018, 2020; Grinin L. & Grinin A., 2019) that the struggle for resources is a common selection mechanism at all levels of evolution, including cosmic evolution. Therefore, it can be defined as a law of evolution which is unfair from the moral point of view but very effective from the point of view of evolution. Only at higher phases of social evolution are there attempts at eliminating the most acute forms of injustice. The struggle for resources is connected with evolutionary selection, which can be traced at all levels of evolution, including the cosmic one. Thus, during the formation of the planetary system within the Solar system those planetesimals were selected that eventually formed the protoplanets, while many of the other planetesimals and asteroids became asteroids and small planets (Grinin, 2017, 2018; see also Bottke *et al*., 2012).[5] Moreover, certain advantages, including random ones, which may play a role in the selection process, become very important. This method of trying out different variants and constructions is a mechanism by means of which evolution performs 'creative destruction'. The selection simultaneously increases and decreases diversity by creating new options and destroying old ones. Evolutionary selection is also the most important tool for regulation of processes. The environmental influence on selection can be traced in most types of selection. However, in the pre-biological world, the selection mechanisms were different from Darwin's selection (Grinin, 2020).

It is evident that the role of selection in biological and social evolution is more significant. Therefore, it would be interesting to consider similarities and differences in their selection mechanisms. The similarities lie in the fact that in both cases selection contributes to growing adaptation, emergence of new elements and functions, disappearance of less successful organisms and forms, greater adjustment between an organism and environment, *etc.* In short, the selection drives the evolutionary process. But at the same time, the selection mechanisms in social and biological evolution are significantly different. The reasons for this are the following. In the biological world, the main source of stable and heritable innovations is mutational and recombinational variations which are characterized by a high degree of randomness and unpredictability. In this situation, 'the post factum selection', the selection among the already emerging deviations that find their realization in the phenotype, becomes the only way to give the process certain direction (in this case – to secure the adaptive character of changes). In the social world the main source of heritable innovations are not random errors of copying and reproduction but conscious and purposeful changes (and over the last centuries and decades this awareness and purposefulness tend to increase). At the same time, people are certainly unable to foresee many consequences of changes, that is why purposeful actions may sometimes seem stochastic and random in the short term while from another point of view they may seem quite rigid and quite a strong trend, not perceived by people.

Another important aspect of selection, which is absent in biological evolution, is the struggle for the selection of a certain model (model of reforms, model of unification, ideological model) at the level of individual societies, as well as at the inter-societal level because in social life from time to time there occur aromorphoses associated with integration, including the violent one. For example, independent communities (sometimes voluntarily, but more often forcibly) are unified into a multi-communal chiefdom, polis communities (or the polity of another type). And accordingly, it is the most 'successful' community (no matter what was the reason for its 'success') that becomes the center, quite often some peculiarities that determine advantages of the successful societies show up incidentally. The same can be said about the struggle for the main dialect of the language, for religion, god, myth, city, for unification of tribes and chiefdoms into a confederation, or of principalities into a large state, *etc.* Selection can be seen everywhere, for example, selection of a leader, model, course, central position. At the same time, the decisive advantage may vary: from the size to the leader's genius, from geographical position to a happy coincidence (a successful fight between representatives of two armies, an eclipse at the right time, rumor, *etc.*).

4.6 Discontinuity and Catastrophes

Within evolution, the periods of slow changes (accumulations), that is of an evolution in its narrow sense, are alternated by rapid metamorphoses and qualitative transformations (which sometimes look like revolutions) and the periods of explosive growth are followed by catastrophes. Thus unevenness, discontinuity are a very important characteristic of evolution, which rate, smoothness or abruptness, tempo, etc. is changing constantly. In geology and paleontology there were hot debates between proponents of catastrophism (the school of the famous paleontologist George Cuvier) and adherents of gradual changes (the outstanding geologist Charles Lyell and his followers). The victory of the latter was a progress; however, later it became clear that it was very difficult to explain many things only by slow and insignificant changes. Thus, evolutionary theory was enriched by the ideas of leaps, revolutions, and catastrophes enabling us to understand how and why the world kept changing. It is important to note that catastrophism is an essential part of evolution at all its stages. The idea of 'Big Bang', the biggest 'catastrophe' in the history of the Universe, underlies its origin (about Big Bang, see Guth, 1997, 2002, 2004; Diemand *et al.,* 2008; Gorbunov & Rubakov, 2011; Grinin, 2019).

However, it would be more correct to speak about *the principle of synthesis of gradualism and catastrophism*. The combination of both principles in evolution is obvious. But, in our opinion, at any other levels of evolution they are not so naturally combined as in cosmic evolution, for example, in destinies of individual stars. The main sequence of stars, during which there is a very long process of hydrogen burning – an obligatory stage for any star – demonstrates the gradual character and importance of slow and long processes. However, disasters of this or that scale may take place during the lifetime of stars. This leads us to the formulation of the *rule of cyclical alternation of abrupt and gradual changes*. It consists in the fact that evolution naturally combines the processes of slow and almost imperceptible growth with explosive one and consequently, the periods of slow accumulation of changes with periods of rapid transformations, often associated with destruction or even collapses. This may finally lead to the formation of objects with qualitatively new characteristics. So the order can again be replaced by disorder.

Thus, catastrophes appear to inevitably accompany development and evolution, to be a kind of compensation for the development and rapid growth (and at certain evolutionary stages – a compensation for progress).[6] In cosmic life, catastrophes are an inevitable result of the long life of stars which, after having depleted their energy reserves, turn into the white dwarfs or red giants and sometimes they produce extremely bright outbursts of light – the outbursts of supernovae. In biology, catastrophes are the great extinctions which freed space for new progressive species to appear and flourish. It should be noted that it is just catastrophes that provide abundant data for the scientific reconstruction of past events. Thus, as a result of the study of supernova's outbursts, the spectrum shift analysis served a firm foundation for the discovery of antigravitation of cosmic vacuum (the so-called dark energy which constitutes the vast majority of the total mass of the Universe; about dark energy and matter see Guth, 1997, 2002, 2004; see also Grinin, 2013).

In general, one can talk about the pattern of *catastrophes as one of the main selection mechanisms at all phases of Big History*, including social one, and not only at its early phases, when catastrophes could have a huge impact on the direction of future development (suffice it to recall the great plague epidemic – the Black Death – in the 14th century [McNeill, 1998] and Covid-19). Thus, dramatism is characteristic of evolution at all its levels. The pattern of catastrophes is closely connected with *the cycles of alternating order and chaos.* The order from chaos is one of the main patterns of evolution (Prigogine & Stengers, 1984). The alternation of order and chaos, the transitional from the latter into an order, and the break of order again before moving to a new level make an inevitable sequence of many processes. The creation of a stable order often requires elimination of many 'superfluous' objects. Such elimination in evolution often takes the form of mass extinctions or other catastrophic events.

4.7 The Principle of Creative Destruction

By studying the relationship between catastrophes and evolution, one can formulate the *principle of creative destruction* for phase transitions, transformations and expansion of diversity if to use Joseph Schumpeter's expression (1994 [1942]). 'Creative destruction' is the creation of a new one by destroying or removing the old one from active operation. At the same time, the new is already essential and different from the old. As already mentioned, this provides both continuity and space for moving towards the new. However, the destruction itself cannot be creative. It turns out this way only after a great amount of preparatory work. At the same time, first this often leads to regress and only then (*i.e*. much later) evolution, as if taken a run-up, starts a new movement forward. In social evolution, one can find many such cases. The most famous examples are the barbarization of Europe after the fall of the Western Roman Empire after the German invasion and destruction of prosperous countries resulting from the Mongol invasion. Both catastrophes would launch a rise based on a new synthesis which, however, would take much time. Therefore, one can speak about *the rule of preparatory work of evolution*. It means that an evolutionary breakthrough resulting from unique circumstances is never a coincidence, but it is always prepared by a huge and longtime 'work' of evolution to advance changes in a certain direction. However, the emergence of unique circumstances in the right place at the right time often depends on chance. At the same time, a phase transition or transformation of an object often needs an impetus or a trigger to start. On the one hand, of course, the latter will not work without the internal readiness of the system; but on the other hand, even a high level of internal readiness by itself cannot launch the transformation process like the gunpowder cannot explode without fire. Without a trigger, a system may remain in a state of potential readiness for transformations for a long time. In this case, the analogues of evolutionary typical/recognized systems are formed (about the analogues in social evolution see Grinin 2003, 2004; on analogues in cosmic evolution see Grinin 2013, 2017, 2018; Grinin L. and Grinin A. 2019).

5 Why Do We Observe Unity and Similarity in the Mechanisms and Patterns at Different Levels of Big History?

In this section we will try to present some evolutionary and philosophical ideas that explain the profound similarity in the laws and patterns of evolution at all its levels and phases.

What defines this unity? This is one of the most important questions, the answer to which can significantly change our approach to the study of evolution. But it can only be provided by a long and diverse work on the development of *evolutionary studies*. As far as we know, almost no one has performed such work in a consistent manner, although a number of researchers left very insightful ideas and assumptions. In this section we would like to demonstrate some opportunities and dimensions of such research.

5.1 The Causes of Evolution

First of all, let us speculate why evolution is possible at all? Some general reasons are: 1) the gradually changing conditions which make it necessary to adjust structure, functions, *etc.* to the changed conditions; the aspiration for the most harmonious congruence with external environment is caused by *the pursuit to the most favorable energy state*, but the process of this adjustment sometimes leads to an unusual result that can provide some advantages; 2) competition due to limited resources; 3) the desire for self-preservation; and 4) the circulation of matter (see above). But, as already mentioned, in every cycle this circulation has some differences which tend to accumulate.

It would be safe to assume that the unity of processes is determined by the following causes and factors:

- all processes unfold in a unified system, that is, in the Universe. It is clear that a common system to some extent defines common means and principles. In fact, since everything happens within one system and one Universe, it would be strange if each line of evolution had its own peculiar laws and patterns;
- during the formation of this unified system there was imbedded some common unity;
- all processes and systems have a common base of elementary particles and lower structural units (atoms and molecules), which canalizes the processes and development to a certain limit. Although *the law of emergence* states that the sum of properties of the parts is not equal to the sum of properties of the whole; nevertheless, there is undoubtedly some meaningful dependence on the sum of properties of the smallest parts;
- the fundamental laws of the material world always work. These are the laws of conservation, the law of gravitation, the basic forces of physical nature, the reaction of bodies and particles to changes in external parameters, *etc.*;
- the mass-energy unity. If mass and energy form two poles of the state of matter, the ratio between mass and energy must be traced at all levels.

5.2 The Systemic Character, Environment, and the Laws of High Abstraction

There are also quite obvious situations, laws and patterns that are present at all levels and in all systems.

1) For example, objects or systems exist in the environment and there should be some interaction between them. Despite the variety of environments and situations, there are quite a few basic interaction models; so, they can be quite similar at different levels. 2) The systemic character by itself leads to certain similarities; this was established back in the 1950s and with respect to a number of relations even earlier. 3) The laws of dialectics, formulated by Georg Wilhelm Friedrich Hegel, also have in their abstract form a rather clear mechanism. For example, the law of transition from quantitative to qualitative changes manifests itself because any forces have limits beyond which their impact declines and becomes insignificant, so when the quantitative accumulation reaches this limit, the former structure (order, *etc.*) must inevitably transform. The law of the unity and struggle of opposites as a part of an even broader pattern of binary (duality, dichotomy) is determined by the fact that any structure or change requires at least a couple of opposing forces, elements, *etc*. 4) The binary is also related to the universal symmetry, which determines the opposite parts or paired relationship between elements (*e.g*., of the positively and negatively charged).

5.3 Parsimony of Evolution

The presence of common laws and patterns is logically explained by the fact that in all aspects it is more advantageous to have a few universal rules than a set of special ones for each case. Here, it is worth mentioning *the rule of rarity of new evolutionary rules*. According to this rule, evolution is wasteful in its 'experiments,' but rather stingy with respect to mechanisms and patterns and 'prefers' to use the already available rather than to invent new ones. Each new rule (or pattern) is related either to the peculiarities of filling evolutionary niches or to the emergence of some new sub-levels, levels or blocks. This perspective allows us to hope that in the future it will be possible to identify a group of primary (basic) rules and laws of evolution that have already manifested themselves in the first hundreds of millions of years, and then new ones that would appear later. In addition, self-organization does not require a large amount of forces or rules, their quite a limited number would suffice (Grinin, 2017). One should remember that the diversity of manifestations is based on a limited number of basic rules.

5.4 More Specific Mechanisms

Much is canalized by rather rigid constraints: energy, efficiency, and previous development. Thus, the choice of the most energetically advantageous regime can occur at different levels; the same concerns, respectively, the choice of forms and other things. But, of course, revealing the specific mechanisms united by a common law or rule of Universal evolution is of special value. Thus, some things are determined by *the rule of minimization of evolutionary efforts*, when the ready-made solutions are used, and also by the above-described *rule of 'block assemblage'*. So, the increasing complexity of structure at all levels – from atom to society – is often carried out, conventionally speaking, by *polymerization*, that is by assembling standard 'details'. All chemical elements of Mendeleev's periodic table can be represented as gradual complication of the structure of their atoms through adding an atom of hydrogen. The same can be said about complex molecules, multicellular organisms, expansion of the society by adding small structures (like a family, community, *etc*.).

5.5 Differences and Similarities Are Two Sides of the Same Coin

We would like to present the following methodological idea. To show the path of evolution, how it became more complicated and moved to new levels, it is crucial to investigate, figuratively speaking, its vertical development (from simple to complex). But if we study it from the general point of view, it is logical to present different levels as different manifestations of changes in the horizontal dimension, in other words, as a multi-line manifestation of general development. In fact, we are talking about changes, transformations in different parts or spheres of the *single* Universe: stars, planets, minerals, molecules, living beings, *etc.* At the same time, it is important to keep in mind that the developing higher forms are a part of a broader evolution. Thus, abiogenic chemical evolution was actually a lateral line of geochemical evolution, and the latter, in its turn, was a part of geological evolution. And this mere fact determines the similarities. In addition, some types of evolution develop in co-evolution which imply mutual influence, transformation and support (see above). Such an approach allows understanding that there are some basic patterns which are differentiated and acquire specific forms related to the peculiarities of the form of matter in which they manifest themselves. It is quite possible to distinguish these common patterns. The more so in the case of evolution on the Earth, where all its forms and levels are very closely connected by a common place of development. Thus, if we consider megaevolution horizontally, that is in terms of emerging new lines, then we reveal a common basis and if we consider megaevolution vertically as a tree, then we find 'genetic' relationship. As we have already mentioned, this 'genetic' relationship to a great extent determines not only the direction of evolution and its canalization, but also similarities in mechanisms and patterns of different levels and lines.

The rule of evolutionary inertia (formulated by Ludwig Doderlein and Othenio Abel for biological evolution) can be used for predetermined character of evolution. It deals with the general dependence of subsequent evolution on the previous one, when the past largely determines not only the present but also the future. This is reflected in the significant dependence of subsequent phylogenetic events on the preceding ones, which is interpreted as evidence of the inertial influence of the past evolution on its future. The inertia manifests both in the similarity of development mechanisms and in the fact that every transition to a higher level more and more channels the direction of development. Meanwhile, we are too accustomed to seeing an insurmountable barrier between higher and lower levels of evolution, absolutizing the differences between living and non-living, human and animal. *But one should rather be surprised not by the similarities, but by the differences. The similarities between the levels are more natural, since the birth of a new one does not mean the rejection of the old one.* Until recently, evolution has been mainly additive in nature, so the new did not reject the old, but added to it: elementary particles did not disappear with the emergence of atoms, and the latter – with the emergence of molecules; inorganic molecules remained, but organic molecules were added to them, *etc.* Therefore, the old has a continuous effect on the new, but the new also affects the old where possible. A number of evolutionary rules, namely: localization of evolutionary breakthrough; preparatory work of evolution; necessity of preadaptation for the transition to a new level (direction) of evolution; necessary heterogeneity of components in the system; continuum of evolutionary states and characteristics; dependence of the evolution rate on its narrowing scope (see Grinin, 2017, 2020) show that the new is not only different from the old, but also related to it, and that it breaks through only in certain directions (in fact, where the old allows it to break through), and that it is formed not in all, but only in some aspects.

5.6 Evolutionary Memory

One can also make some assumptions that development (evolution) has some kind of a code and memory, which are fixed with the help of some imprints, and also function on the basis of *the rule of minimization of evolution efforts* (see above). Of course, it remains unclear how this memory becomes fixed but there is no doubt that it is based on some rather material things.

For example, everybody knows about the so-called golden ratio. But why does this ratio have such proportion?[7] Why do some patterns become common at all? Probably, because some discoveries of nature and evolution reveal a certain code, a set of ancient and longstanding solutions and combinations, thanks to which, on the one hand, the already available solutions are used to create a new one, while on the other hand, the evolution related to those solutions is canalized and becomes autoevolution, according to Antonio Lima-de-Faria (1988).[8] But this defines certain limits, since the fundamentally new solutions are already made far from easily and only as a result of some rarely occurring breakthrough created by peculiar circumstances.

It is still impossible to reveal how these universal solutions and patterns are encoded, but there probably exists some mechanism. However, if we speak about the 'genetic' connection between higher and lower levels of evolution (see above), why should we deny the possibility of 'genetic' memory and 'genetic' code of evolution? Even relatively simple structures have memory. A kind of 'memory' can be observed in self-organization and the activation of this 'memory' is promoted by the fact that order often turns out to be energetically beneficial. Another aspect of this assumption is the universal character of information. We learn more and more about different kinds of information, in particular, about chemical signals which even the simplest organisms (bacteria) appear to be able to perceive; probably, viruses also exchange some information (Solé & Elena, 2018). In fact, one can observe information already at the level of elementary particles, where it seems to be syncretic with the energy form. But, in any case, it is important that the information interaction can occur only if the properties of objects correspond to each other (Yankovsky, 2000). Also the electromagnetic and other interactions provide adjustment, as a result of which, for example, negatively and positively charged particles 'recognize' each other. In fact, they exchange 'codes' and turn out to be complementary, and therefore can create stable structures. It bears repeating that at this level the energy and information aspects are inseparable but still different. A greater difference between the energy and information aspects can be observed in catalytic interaction (*Ibid*.) when one substance-catalyst changes the rate of chemical reaction between other substances, which are reactive chemicals in this case. Without information that activates the reactive chemicals, the reaction would be much slower or could not take place at all under existing conditions. In other words, information is mostly separated from energy processes so the catalyzers can only impact the speed but not participate in chemical reactions. But the condition that information between objects is transferred by means of substance or energy exchange is fully fulfilled. In the general theory of information, the law of information preservation is also formulated: the latter *keeps its significance unchanged as long as the information carrier – memory – remains unchanged*. The information exchange at the lowest levels, already in the micro-world, evidences the existence of memory (in particular, in the form of recognition). It seems that preservation and transfer of information at different levels and in different systems is not only one of the foundations of interaction between different objects, from particles to galaxies, but also a way to react to environmental changes, and most rules, laws and patterns manifest themselves just in the interaction with the environment.

Thus, there is a common base, a 'common denominator' in the continuity of motion and energy processes, in interactions involving information exchanges, in destruction and new assemblage, and other aspects so that the common may manifest itself in the behavior of different objects. At the same time, it should be implemented not only in standard but also in unusual conditions which are the most interesting for evolutionary studies because it is just the unusual responses to unusual challenges that may give rise to fundamentally new things.

We have already mentioned above the circulation of matter, energy and information. However, such circulation could not take place without some kind of memory which made possible the new assemblages and new processes of self-organization. Hence, we inevitably return to the fact that there must be some mechanisms of coding, some organizational and system-forming memory. *However, similar to non-specialized stem cells, which can* *differentiate into different cell types and organs, the matter with such memory in different situations can transform into different types and forms of matter.*

6 The Capacity for Development, Self-Preservation and Self-Organization

Evolution, that is the changes of objects, actually means the destruction of their stability and identification. From this point of view, at any stage and in any sphere of evolution the matter can be divided into two types: the one that is capable of self-preservation and the one that is capable of self-transformation (of course, these characteristics are manifested in different objects and systems in different proportions). In other words, one may speak about *evolutionary and non-evolutionary matters*. Within human society there also exist rather conservative elements and there still exist societies which are not quite prone to changes, and this phenomenon was even more strongly pronounced in the previous epochs. An average lifespan of a biological species is less than 10 million years. At the same time there are species which have endured for 200–300 million years. Thus, the presumable age of blue-green algae is several billions years, and they have not changed significantly since the Archean Eon. Thus, in biology one can observe species that have existed for hundreds of millions of years without radical changes as well as species that have given impetus to powerful typogenesis (*i.e.,* the formation of new taxa), or species that are disappearing rapidly in biological terms within hundreds of thousands of years. One of the most important discoveries of the second half of the 20th century was the discovery of the so-called dark matter whose abundance in the Universe far exceeds by mass the visible (or baryonic) matter visible to us. But at the same time, it seems that dark matter is hardly able to evolve in comparison with light matter.

At any phase, the evolving matter makes up the minority; thus, the light (baryonic, stellar) matter according to some current views amounts for only 3–5 % of the total mass of the Universe. It is amazing that this proportion is relevant even to human society in which, according to some reports, the number of innovators is also 3–5 %. Actually, any object, system or any form of matter can evolve, but this ability differs so much among various types and objects that it is reasonable to talk about the evolutionary rule *of inability of some objects to evolutionary changes.* In addition, evolutionary changes require a certain time rate of change of external conditions (or special conditions), which is far from always available. At the same time the inability to evolve means the ability of the matter to self-preservation. And in some cases this turns into a clear advantage, while in others it becomes a disadvantage. Thus, one can see that the diversity of forms of existence (and development) in our Universe is also manifested in a hugely varying ability of different objects and forms of matter to change and evolve.[9] In short, existence fluctuates between stability and variability over a huge continuum.

Both characteristics – stability and variability – have great advantages, as well as disadvantages; they are both necessary for the existence of objects, species and the world in general. This can also be observed in social evolution. There are more stable institutions which remain fundamentally unchanged when undergoing transformations; there are nations that have adapted to their way of life, so that they can exist without radical changes for a long time (millennia); and in some societies and situations the evident rapid changes lead to considerable qualitative transformations. We believe that such an inability is not genetic or race-related (although for the period of anthropogenesis it is quite possible), but depends on the certain societies' circumstances including natural and social environment, the role of factors, like the emergence of outstanding personalities, *etc*.

A Short Addendum: As we above mentioned, even our scheme (Fig.1) does not fully reflect the complexity of Big History lines and phases. We suppose that we can discuss some more transitional, lateral or, even may be, main phases of megaevolution. On the Fig. 2 we show the way of Big History since its biological phase with possible addition: the virus' kingdom transitional phase and the hypothetical posthuman phase (about the latter see Grinin L & Grinin A., 2015: Introduction; 2016: Introduction; 2020a; 2021). Both of them are demanded a special discussion which, we hope, will be possible in the future.

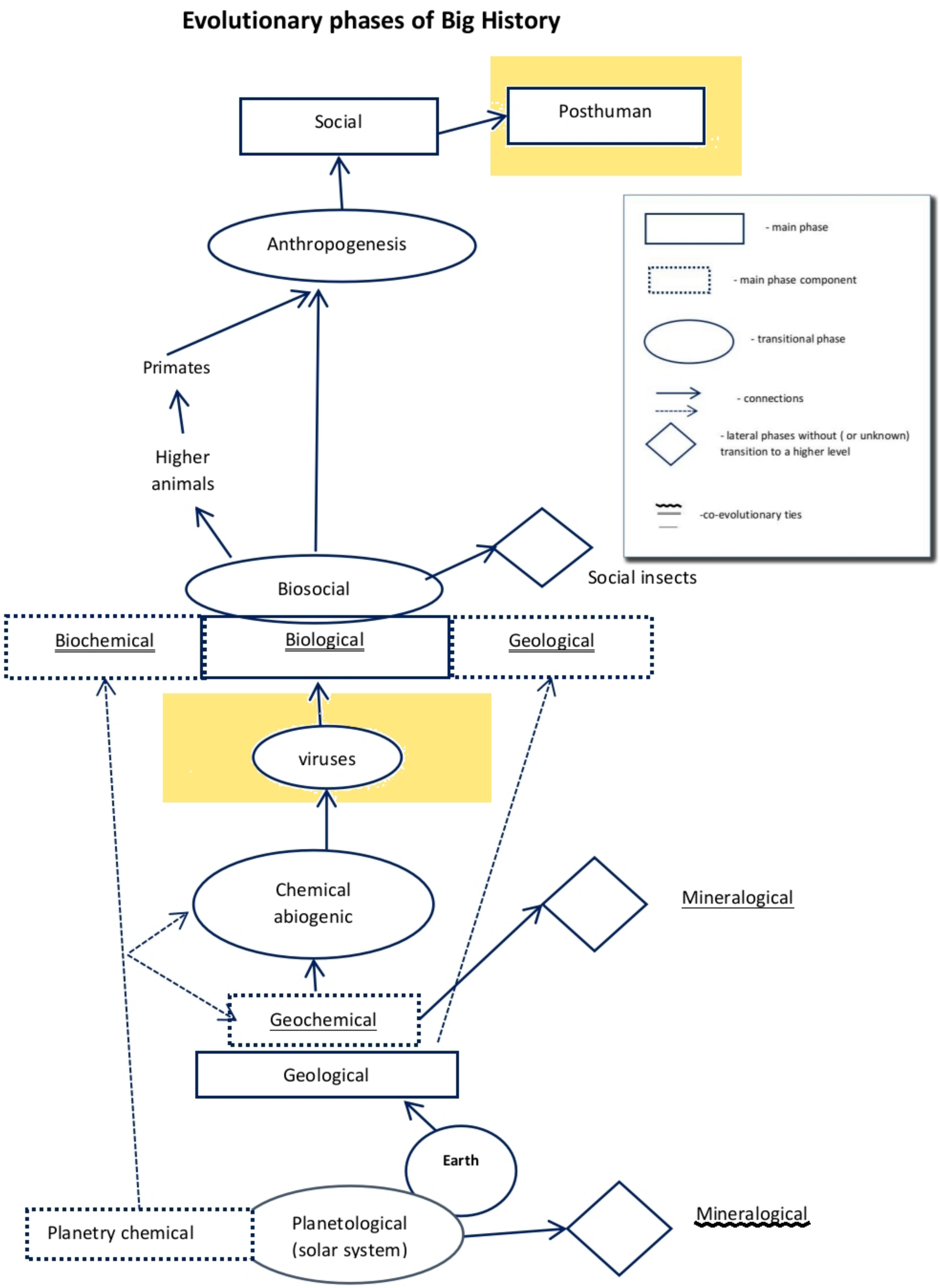


Figure 2. Phases and lines of Big History with virus and posthuman phases

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Endnotes

1 The term is connected with the biological concept of aromorphosis which is "an increase in the organization level that makes it possible for aromorphic organisms to exist in more diverse environments in comparison with their ancestors; this makes it possible for an aromorphic taxon to expand its adaptive zone' (Severtsov A. S. 2007: 30–31). It is worth to add one more definition 'Aromorphosis is an expansion of living conditions connected with an increase in complexity of organization and vital functions' (Severtsov A. N. 1967).

2 For the social evolution definition it is worth adding after 'with the previous state' 'and also the ability to accumulate such changes, including their purposeful usage and training in activities that lead to such changes'.

3 The planetary evolution outside the Solar system is distinguished separately (see below).

4 The concept of inflation phase in the early Universe, of course, covers more than the traditional accepted phase introduced by Guth (1997, 2002, 2004).However this subject is beyond the scope of this article. For detail see Grinin 2019.

5 The struggle for resources among stars and galaxies may proceed in the form of weakening of another object or its destruction (*e.g.*, through a direct transfer of energy and matter from one body to another), in the form of 'incorporation', 'capturing', *i.e.* 'annexation' of stars and star clusters by larger groups (*e.g.*, Gibson *et al*. 2007). Another example connected with Jupiter and other gas giants were probably the first planets to form and take almost all gas, while the Earth-type planets got quite a few resources (Lin 2008; Batygin *et al*. 2016; Batygin and Brown 2016).

6 In his book *A Choice of Catastrophes* Isaac Asimov (1981) analyzed all possible types of catastrophes (real and possible) starting from the Big Bang, the supernova explosions, possible collapse of the Sun to glaciations, continental drift, seismic sea, biological and social catastrophes and made some predictions.

7 Let us remember that in the rounded percentage value the golden ratio describes the relationship between two proportions which is 62 % to 38 %. This ratio equals 1:1.62 (a common proportion in the construction of objects).

8 That is in the most general form, the mechanism is similar to that in the genome of living beings, in the form of so-called genomic ballast combinations of genes of which are used only in extreme cases.

9 One can assume that dark matter is not completely devoid of the ability to change, it only requires much more time than the light matter for such changes. The stars also used to seem unchanged.