Introduction

Evolution and Singularity*

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Many major transitions are currently underway in demography, energy use, environment, economic convergence, and global interdependence. With so much rapid change, often timescales for decisions are limited to about five years in the future. It is somewhat paradoxical then that this current rapid change is guiding us to look at very long time-scales. This motivation arises because one explanation of the current rapid change is that it is a continuation of a very long-term trend throughout Big History[1] (for standard accounts of the Big History see, *e.g.*, Christian 2004, 2018; Brown 2007; Christian *et al.* 2014; Spier 2010; Wood 2018; Grinin 2013, 2017, 2020; Grinin 2015, 2019; Rodrigue, Grinin, and Korotayev 2015, 2016, 2017; Grinin, Korotayev, and Rodri-

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[1] According to the definition of the International Big History Association, 'Big History seeks to understand the integrated history of the Cosmos, Earth, Life, and Humanity, using the best available empirical evidence and scholarly methods' (IBHA 2021).

gue 2011; Grinin *et al.* 2011). Only now when we observe the change trend within our lives do we fully appreciate the consequences and implications. But beyond just understanding, we attempt to articulate some of the potential issues and implications to help facilitate future scenario development and their considerations.

The rapid change leading to 'some essential singularity' was articulated early by John von Neumann in the 1950s. According to Ulam, von Neumann maintained, 'the ever-accelerating progress of technology and changes in the mode of human life… gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue' (Ulam 1958: 5). Later Carl Sagan (1977) popularized the cosmic calendar to demonstrate the relatively slow rates of change leading to humans and civilization. These realizations were only possible because of the scientific inquiries and tools necessary to measure the time of events. Often these included some aspects of radioactive decay which forms natural clocks on many timescales. The cosmological context was formed by combining the 20th century discoveries in physics with the astronomical measurements of the cosmic background microwave radiations and the expansion of the Universe seen in the cosmic redshift of galaxies (see, *e.g.*, Bryson 2003). While the timescale is somewhat known, some of the major questions in this history are not fully understood such as the nature of the Big Bang (see Guth 1997, 2002, 2004; Grinin 2019), the (dark) substance of the Universe (about dark energy see Gorbunov and Rubakov 2010, 2012; May *et al.* 2008: 38–39; Spier 2011; Siegfried Kutter 2011), the origin of life (Cherepashchyuk and Chernin 2004; Fedonkin 2003; Zavarzin 2003; Zaguskin 2014; Martin 1999; Woese 2000; Grinin 2020), the meaning of consciousness, the sustainability of technological civilization (Grinin L. and Grinin A. 2021; see Grinin L., Grinin A., and Korotayev A. in this volume) as well as the future influence on the human biological nature (see Grinin A. and Grinin L. in this volume).

It is important to explore these topics and trends, not just to further understand our origin, but also to put into context our possible future scenarios, to interpret trends and help guide decisions by identifying options and possible consequences. Often civilizations at a smaller scale have failed to be sustainable because of their belief in the continuing expanding trends without regard to their marginal benefits (Tainter 1996). For example, the Easter Islanders, in their very limited island, continued the competition to construct the stone statues along the coast by using a seemingly unlimited supply of trees which were needed to move the stones. This worked well until the trees were depleted leading to diminished ecological conditions with consequent lower sustainable population (Diamond 2005).

So, we approach this topic, understanding the limitations of data, interpretation, and trend extrapolation. It is important to remember that the megatrend towards a singularity does not mean that the singularity will happen but instead there might be some limitations and changes in the trend.

To place the accelerating trend of complexity in the context of Big History, we need to distinguish the two forms (arms) of megaevolution so far in the Universe. The first arm of megaevolution is the decelerating development of physical matter and energy into galaxies, stars, and planets from the initial Big Bang (see Fig. 1). The second arm of megaevolution is the accelerating rate of complexity evolution in the form of life, humans, and civilizations (see Fig. 2). This increasing complexity requires additional information to overcome the second law of thermodynamics tendency towards thermal equilibrium (death). Instead it marches further from this natural equilibrium towards a stable disequilibrium (Nazaretyan 2001, 2005) maintained by a constant flow of energy under information control. This concept of complexity correlates with various definitions of complexity in mathematics, such as the minimum length of the text describing its structure. Of course, the scheme of megaevolution can be presented in different versions and projections (see Fig. 1).

Both arms proceed from combining two existing structures to form a new emergent structure. This process is known as aromorphosis (Galimov 2001; Grinin *et al.* 2009, 2011). Between these jumps of structure, there is a rather smooth evolutionary process. A complex system cannot arise 'from scratch'; such a system is always the result of combinations of systems of the previous level of evolution. Evolution is not engaged in strategic planning and preliminary calculation of its aromorphoses, it works only with the material that it already has at hand and can immediately use.[2]

[2] Therefore, not all of the most important evolutionary solutions appear to be optimal. An amusing example is the structure of the eye of vertebrates where the optic nerve attaches to the retina from the outside, creating a blind spot. This makes absolutely no sense, as evidenced by the structure of the eye of cephalopod mollusks. It is arranged in the same way as in vertebrates, but the nerve is attached on the back of the retina, so there is no blind spot. Why is the eye of vertebrates so ridiculous? Apparently, the first direct ancestor of vertebrates purely by chance had an eye of such a structure, and evolution had no choice but to begin the development of the type of vertebrates, starting with what it is. Such evolutionary omissions (there are many other examples) constitute the most important confirmation of the conservatism of evolution in biology.

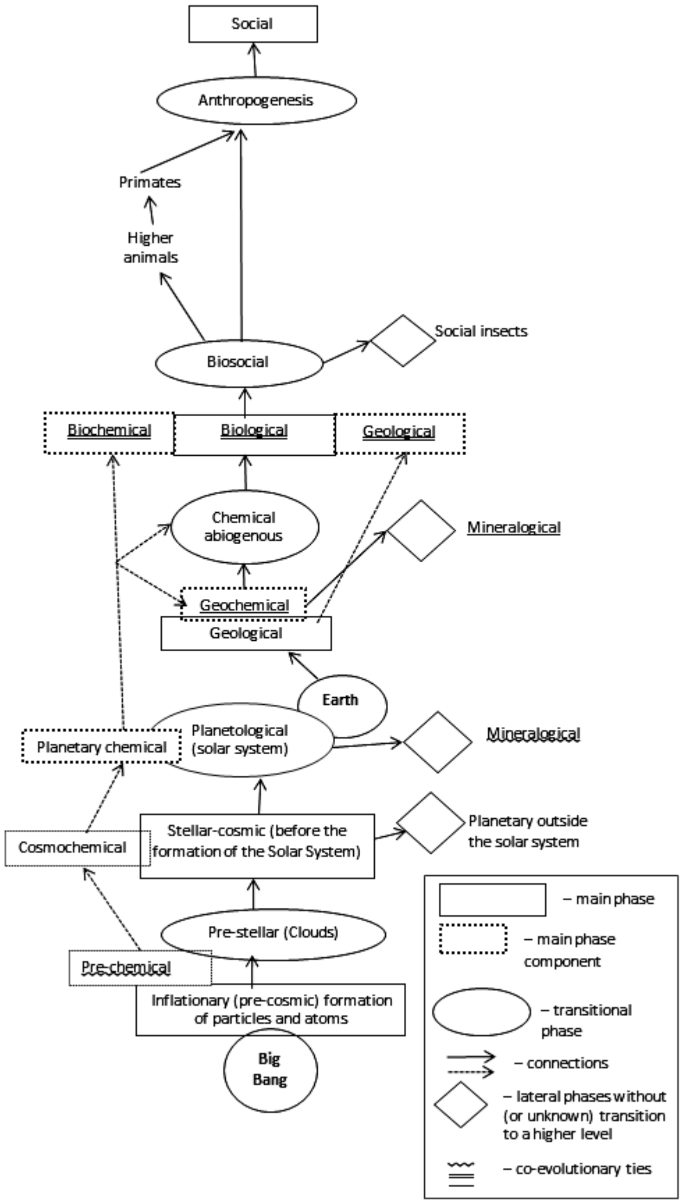

Fig. 1. Phases and lines of megaevolution (Grinin L. and Grinin A. 2020a, 2020b)

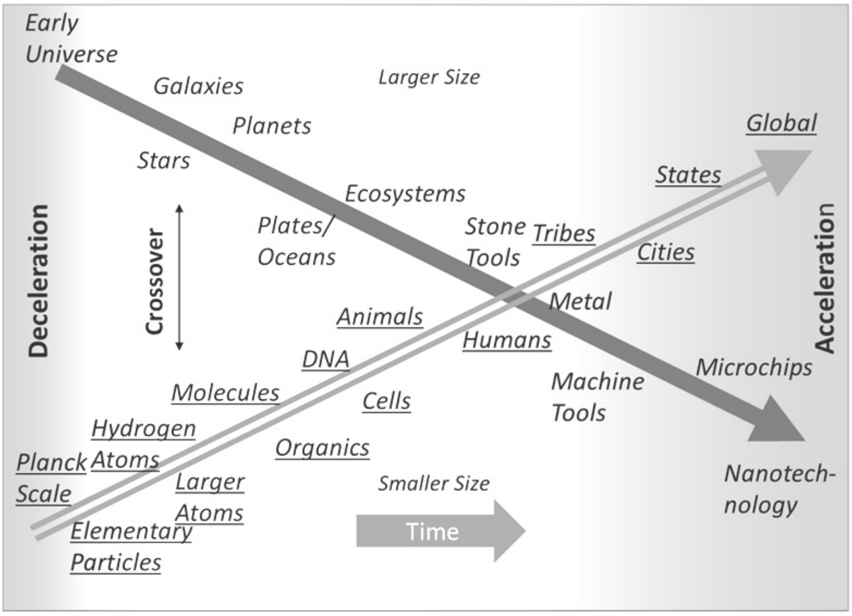

Fig. 2. Megaevolutionary processes in the Big History perspective (LePoire 2004)

We tried to give a rather voluminous and dialectical picture of the unfolding evolution instead of a primitive scheme: cosmic – biological – social. We have introduced pre-cosmic evolution (see Grinin 2013), which is called here inflationary. In addition to the main phases, we have introduced intermediate or transitional phases of evolution. We have also introduced the idea of continuous lines of evolution, one of them is the chemical evolution.

Megaevolution is presented as an alternation of main and transitional phases. Some lines are singled out as lateral or dead-end. The idea of co-evolution is highlighted.

It is useful to explore some of the events in the first arm which starts with the Big Bang with many events happening (although at a decelerating rate) in the first three minutes (Weinberg 1977), followed by a much slower condensation into galaxies. This process mostly occurs through cooling of the Universe by expansion. It is important to note that while some processes reach their thermal equilibrium, others (such as the fusion of protons and nuclides) do not. This is important since it leaves much energy later to support the second arm of life through the energy production in stars.

After an imperceptible fraction of a second after the Big Bang, matter existed in the form of plasma consisting of free quarks, leptons, photons and other particles, which are considered elementary, structureless in quantum field theory (called a quark-gluon plasma). The Universe had a very simple description: it was, in fact, only a list of types of particles and fields plus temperature, which uniquely determined the density and all other properties of the medium. After a certain decrease in the temperature due to the expansion of the Universe, quarks were bound by gluons (carriers of strong interaction) into composite particles – hadrons (neutrons, protons, and others) – the first stable structural formations. The structure of matter was spontaneously complicated, and the basis for a new level of organization of matter were the elements of the previous level. Objects of a new level of organization of matter consisted of objects of the previous level. Some other particles, such as electrons, were still free. After some additional cooling of the Universe, the primary protons – the composite objects of the previous level of evolution – were connected with electrons (the process of recombination of electrons). A higher level structure was formed – a hydrogen atom, which included, as a substructure, the products of self-organization of previous levels: protons and electrons. The previous pattern of evolution was repeated.

At some phase of the evolution of inorganic matter in the Universe, the first stars were formed – also composite objects, which were formed mainly from hydrogen and helium atoms (Chaisson 2014). During the evolution of stars, heavy chemical elements are produced in quantities sufficient to form earth-like planets. Heavy elements are thrown into space in the process of supernova explosions. Here we are dealing with another type of conservatism: heavy elements could not appear without stars, and the existence of stars is a necessary prerequisite for the appearance of heavy elements, but the stars themselves are not included, obviously, in the composition of heavy chemical elements. In its future existence, heavy elements can do without stars, forming, for example, structures of a new type: gas-dust clouds (from which stars of the next generations are formed), planets, *etc.*

The following examples represent biological evolution (Ward and Kirschvink 2015). It is not known exactly how this happened, but somehow the first living creatures emerged from complex organic compounds (perhaps, the so-called RNA world was also an intermediate stage). Anyway, the first living creatures conservatively included the elements of the previous phase of evolution – complex organic molecules. Most likely, the first living objects were prokaryotes – the simplest cells that do not contain the cell nucleus and other intracellular organelles. The next evolutionary level was eukaryotes. Each eukaryotic cell is a symbiont of several highly specialized prokaryotic cells. Again, we are dealing with the manifestation of conservatism using already available material. Further, multicellular beings are, in fact, colonies of highly specialized unicellular eukaryotes. Again, we are dealing with conservatism.

Finally, we turn to social evolution. Any society consists of separate individuals – social evolution is conservatively based on the previous purely biological evolution (Stewart-Williams 2018). At a certain stage of social evolution, consciousness arises, and then the mind in the human sense. Humanity, being the carrier of the mind, includes many individual biological specimens, conservatively based on all previous biological evolution. Every single person, being a carrier of the spirit, no matter how you understand it, remains at the same time an animal.

It may seem that the first arm is in some sense more trivial compared to the second. But it is not so! It is easy to imagine a Universe where the evolution of matter ends very early. For example, atoms cannot arise (for this it is enough to disturb the delicate mass balance of proton, neutron and electron), galaxies cannot arise (insufficient amount of dark matter), *etc.* Even for the realization of the first arm of evolution, an extremely delicate balance of fundamental constants is required (Rozental 1980). For example, the transition connecting the first and second arms of evolution has a curious feature: heavy elements are formed during stellar evolution due to the existence of an excited state of carbon nuclei with an energy almost matching that of the colliding ^{4}He and ^{8}Be nuclei.[3]

It is difficult to get rid of the impression that the two in some way completely 'natural', although essentially different strongly conservative arms of evolution are 'stuck together' with each other in some completely 'unnatural' way with the help of a very whimsically arranged weak conservative link. This causes an association with something like a key and a keyhole.

There is a reason to assume that we are here and now at the end point of the second arm of the evolution. Evolution enters a blow-up regime and cannot continue with the same rate of growth of speed – the end of the second evolutionary arm is the final singular point at which the speed of evolution should formally turn into infinity that is why the point of singularity is unattainable. Hence, the mode of the evolution must inevitably change when approaching it.

[3] That is why the nucleus of very short-lived beryllium-8 in stars can merge with the helium nucleus, resulting in a carbon nucleus. This merger is a critical link from which the synthesis of heavy elements begins. At the same time, the existence of this energy level looks like a completely coincidental circumstance. If it were not there, the heavy chemical elements in our Universe would never have been synthesized, and the emergence of life would have become impossible. One should note that the existing state is in a certain sense, more random than a random, successful selection of the values of the fundamental constants described by Rozental (1980). If such quantities as the mass of a proton, neutron, electron, the fine structure constant are indeed fundamental, then the energy level in the carbon nucleus is not distinguished by anything among a multitude of such objects and is something really completely random. The fact that so much depends on some random energy level of the nucleus seems completely incredible.

We are no more than a few decades away from the point of singularity, or, in slightly different terms, we have already entered a more or less prolonged 'zone of singularity'. The question is: what is behind this point of singularity? Are we at the beginning of the third arm of evolution, and what can it be, if so? Perhaps, it will be a new evolution arm with a slowdown again? And should not we expect the same 'artificial' character of a link of the second arm with the third, as well as the first one with the second? Will this link be strongly conservative, or weakly conservative? Is it possible to see the signs of an answer to these questions in the present time? Is it not our 'duty' to organize such a link?

It is rather curious that the question of the nature of the link of the second arm with the third one is easily connected with the problem of artificial intelligence (AI). More precisely, the question can be associated with the ability to create strong AI (Kurzweil 2012). By strong (or general) AI is meant AI that surpasses all human intelligence in all aspects. Obviously, such AI should be capable of self-development (this follows simply from the fact that people, after all, were able to create strong AI, therefore, it should have such abilities by definition). Being capable of self-development, strong AI will not need further contact with its parent, humanity, and, in principle, can proceed to an independent evolution in full isolation from the human mind that created it. This may mean weak conservative link of a new, cybernetic, evolutionary line with the previous, biological one. On the contrary, if the creation of strong AI is impossible, then AI will have to exist in symbiosis with the human mind that gave rise to it; mind and AI can form a single super-system of a new evolutionary level (which actually already seems to be happening), and the transition to the third arm of evolution will then be strongly conservative – the super-system is based on both biological and artificial intelligence as on subsystems. The same will happen if strong AI is possible, and is created once, but for some reason it does not want to separate itself from humanity. What awaits us? It is not yet completely clear whether the above questions are even correctly formulated, but, essentially, the idea of the two arms of megaevolution[4], the nature of the links between the arms, at least inevitably leads to the need for their formulation.

The present volume is dedicated to the discussion of this set of issues. It is the eighth issue of the 'Evolution' Yearbook which consists of three sections.

Section I. Political Aspects of Social Evolution consists of three contributions and opens up with the article by **Sergey V. Dobrolyubov** 'The Two-Factor Model of the Society's Life Span for an Attempt to Reconcile Evolutionary Contradictions' which offers the simple model of the society's life span which takes into account two factors of social changes – political power and social solidarity. The model describes the rise and decline of political integrity

[4] For more details on the two arms of megaevolution see LePoire 2020 and Tsirel 2020.

and collective solidarity of different scales. Accordingly, the author considers two types of social structures representing these factors – political organization and society itself. Political organization of power is considered as an active social entity and an agent of intentional social transformations. Solidary society is considered as an inertial and unintentional social entity that carries social tradition, culture, collective identity, *etc.* The interaction of political and societal entities pushes the entire socio-political structure towards a gradual expansion, which inevitably ends with its collapse. Due to this civilizations' dynamics gets a cyclical pattern. Therefore, the model allows to reconcile the unilinear (progressive, gradual) and multilinear (nondirectional, cyclical, *etc.*) course of social evolution, since we distinguish between meso- and macro-levels of analysis. On the meso-level we observe the structural cycles of the rise and fall of societies that repeat development from more primitive to their peak level. On the macro-level one can observe evolution as a process of inheritance and accumulation of basic technological and social innovations in the course of the cycles of development and decline of civilizations. This is analogous to how we distinguish between the evolution of an organism in its life span and the evolution of a given species of organism. Such analogy is not complete, but it allows us to distinguish between the specific transformations of historic societies, for example Egypt, Mesopotamia, Rome and progressive evolutionary typology of indefinite 'society in general', for example, modern, slave-owning, hunter-gatherers.

The contribution by **Leonid E. Grinin and Andrey V. Korotayev** 'Alternatives of Social Evolution at the Societal Level of Medium Complexity: Chiefdoms and Their Analogues' is devoted to the analysis of chiefdom analogues or various evolutionary alternatives to the chiefdom: poleis, autonomous towns and complex village communities, cast-clan systems, non-hierarchically organized territorial groups and federations of villages, certain types of tribal systems, *etc.* All chiefdom analogue forms can be subdivided into a few types: monosettlement analogues (with the majority of the population concentrated in a single central settlement); horizontally integrated polysettlement analogues; and corporate analogues. The notion of chiefdom analogues which we put forward will advance the theoretical analysis of the cultural-political variations among medium-complex societies where chiefdoms are bound to occupy one of the main positions.

Leonid E. Grinin in his paper 'Complex Chiefdoms vs Early States: The Evolutionary Perspective' gives a suitable example for illustration of a very important issue of multilinearity of social evolution, the peculiarities of its development, and its alternatives. The author proceeds from the point that principally equal levels of systemic complexity can be achieved not only in various forms, but also through essentially different evolutionary pathways. It is often noted in the academic literature that chiefdoms frequently prove to be troublesome for scholars because of the disagreement as to whether to categorize this or that polity as a complex chiefdom or as an early state. This is no wonder, because complex chiefdoms, early states, as well as different other types of sociopolitical systems (large confederations, large self-governed civil and temple communities, *etc.*) turn out to be at the same evolutionary level. In the present article it is argued that such complex societies can be considered as early state analogues. The most part of the article is devoted to the analysis of the most developed chiefdoms – the Hawaiian ones. It is argued that before the arrival of Cook there was no state in Hawaii. It should be classified as an early state analogue, *i.e.* a society of the same level of development as early states but lacking some state characteristics. It proceeds from the fact that the entire Hawaiian political and social organization was based on the strict rules and ideology of kinship, and the ruling groups represented endogamous castes and quasi-castes. The transition to statehood occurred only in the reign of Kamehameha I in the early 19th century. A scrupulous comparison between the Hawaiian chiefdoms and Hawaiian state is presented in the article.

Section II. Contemporary Level of Evolution and Its Future Projections consists of three contributions.

According to **Marc Widdowson,** the author of the contribution 'From Covid-19 to Zero-Gravity: Complex Crises and Production Revolutions', historically, pandemics have occurred in the context of complex crises involving other human and natural disasters, including war, rebellion, flooding, and economic collapse. This is because they all derive from increases in population and world connectedness, which produce epidemiological vulnerability, domestic conflict, hegemonic challenge, risky economic behaviour, and environmental over-exploitation. Such complex crises are learning experiences for humanity and, as people solve the attendant problems, they culminate in breakthroughs in social and material technologies that are sufficiently large and abrupt to be perceived as shifts of historical era. COVID-19 is no exception, occurring amidst growing geopolitical, financial and cultural stresses, and points to what is likely to be a deepening crisis over the coming years. As before, it should generate an unmistakable advance in social institutions and human capacities, which can be identified with Leonid Grinin's forecasted Florescence of the Information-Scientific production principle *c.* 2030–2040. Besides presenting this verbal argument, the paper includes some mathematical explorations to verify the logical consistency of the concepts and their proposed relationships.

The paper by **David Lempert** 'The Logic of Cultural Suicide and Application to Contemporary Global Strategies: Drawing from Models in Psychology and Biology' offers a preliminary test of the hypothesis that there are processes of cultural 'suicide', that are analogous to individual suicide or genetic suicide. It attempts to offer definitions and typologies of this phenomenon for future measurements and analysis within the context of theories of cultural change and processes of collapse and seeks to determine whether certain cases of cultural extinction or rapid transformation could be reclassified or classified as cultural suicide. If this is a valid category for social processes, it may offer a logical explanation for what appears to be current choices of cultures in regard to strategies for human survival that are environmentally unsustainable or that appear to invite potential wars that threaten human holocaust. Analogies with other disciplines also suggest that in some cultural groups some processes of self-destruction may be at work that facilitate collapse and rebuilding or extinction as part of a cultural dynamics within groups of cultures. This could explain some current behaviors that are otherwise described as 'irrational'. Nevertheless, we are only at the very early stages of modeling, explaining and predicting such behaviors. Opening up this topic also points to many of the unresolved paradoxes and difficult measurement issues that social sciences need to confront.

Anton L. Grinin and Leonid E. Grinin, in their contribution 'Cyborgization: To Be or Not to Be?' note that cyborgization is a hot topic these days. This is an intriguing process that is the subject of many futuristic novels and which at the same time takes place right before our eyes. In this article the development of cyborgization, its place in Big History, its background and future directions, as well as the problems and risks of this interesting process are discussed. The authors are concerned about the question of whether the time will come when a human will mainly or completely consist not of biological, but of artificial material. The article also touches upon other problems and risks associated with future scientific and technological progress.

Section III. Singularity as Trend and the Future consists of four contributions.

David J. LePoire in his article 'A Potential Simple Analogous Heat Flow System to Explore Big History's Singularity Trend' points out that many historical systems (*e.g.*, civilizations) demonstrate trends towards acceleration of knowledge, energy flow, and complexity. These systems are far from thermal equilibrium as they depend on great flows of energy through them to maintain their structure, similar to Dissipative Dynamics Systems (DDS). This dissipation causes entropy, but while entropy is often associated with disorder, often ordered patterns can spontaneously develop in them to facilitate entropy generation. That is, entropy gradients (and the second law of thermodynamics) might be the driver to higher complexity. In addition, optimized engineered systems that are far from equilibrium, such as removing heat from electronic chips, also follows fractal pattern formation. A major trend in Big History is the singularity trend of complexity, which has substructure where the complexity tends to increase by a factor of about 3 for every shortening (by a factor of ⅓) period. At the same time, the energy flow tends to increase at a slightly faster rate of about 4–5 within each period. This paper develops a simple analogous energy flow system that may help gain insight into this Big History trend, however, it is incomplete. Research areas are identified to tighten this approach.

According to **José Díez Faixat** ('Non-Dual Singularity'), the Universe emerged in a violent Singularity – basically of energy – generating vertiginous transformations. Later, due to cooling, the emergence of novelties slowed down gradually. After the formation of the solar system and the subsequent emergence of life on our planet, the rhythm of creative transformations began to increase progressively, first through biological evolution and, later, through human development and expansion of civilizations. Currently, the emergence of novelties is again dizzying and everything seems to indicate that we are fast approaching another imminent Singularity – basically of consciousness – of infinite creativity.

In this paper the author supposes that both Singularities – A and Ω – are nothing but the polar expression of the fundamental Void always present, 'prior' to its apparent dualization as energy and consciousness. The initial and final Singularities would not be, in this way, but the points of exit from and entry to this eternally self-evident non-dual Emptiness that, instant after instant, manifests itself in and as the world of forms.

Sergei V. Tsirel in his paper 'Technological Achievements of the Future as the Path of Destruction of Habitual Human Society?' assumes that extensive experiments on the correction of the human genome will fall on the 2030s and 2040s. The author comes to the conclusion that the real problems associated with the emergence of new subspecies of *Homo sapiens* will arise already in the 2070–2080s or even in the 2060s. Although such prospects are usually considered in an apocalyptic manner, the tragic course of events is not necessary. But, in any case, there will arise new unprecedented problems, primarily inequality problems, not only socio-economic but legal and political ones, as well as generally the possibilities of democracy in a society of genetically different people, *etc.*

In the article 'The Cybernetic Revolution and Singularity' **Leonid E. Grinin, Anton L. Grinin, and Andrey V. Korotayev** consider a long-term dynamics of technological progress, providing one of the options for measuring its rate throughout the entire historical process. The authors are based on the theory of technological (or production) revolutions and the theory of production principles, which allow to measure the speed of technological progress as well as to make some predictions. It has been found that the general dynamics of accelerating technological growth over the past 40,000 years can be described with amazing accuracy ($R^2 = 0.99$) by simple hyperbolic equation: $y_t = C/t_0 - t$, where y_t is the technological growth rate, measured as a number of technological phase transitions per unit of time, while t_0 and C are constants, whereas t_0 can be interpreted as a 'technological singularity' point. Although the rate of technological progress since 40,000 BP in general has been increasing, following a hyperbolic acceleration pattern, however, according to the theory of production principles and historical facts, the acceleration of technological progress has noticeable fluctuations. These fluctuations can be explained by the fact that technological development proceeds within the framework of super-long cycles. It is shown that within these cycles, the phases of accumulation of basic breakthrough innovations are replaced by the phases of rapidly growing improvements and their wide distribution. The point of singularity and the possibility of radical changing of the previous technological progress pattern are also discussed. According to their calculations, based on the selection of the most important phase transition periods in technological evolution, the singularity date is expected to happen in the early 22nd century.

There is an idea that technological progress has been slowing down from the 1970s. However, as already mentioned, there are strong fluctuations in the acceleration of technological progress. According to the theory of production principles, after the 2030s we expect a new powerful acceleration of technological development followed by its slowdown in the late 21st and early 22nd centuries. Their idea is that global ageing will be one of the major factors of this technological acceleration and then, by the end of this century and the beginning of the next century, on the contrary, it will be a brake on scientific and technological progress. The socio-economic mechanisms for such acceleration and deceleration are considered in detail.

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