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Darwin's Algorithms

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Abstract — An algorithmic concept of the physical world is proposed in which the main ideas of the Darwinian evolution act as algorithms of becoming.

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1. INTRODUCTION

Historia magistra vitae[1]
Cicero

In an effort to understand the reality around us, many scientists, starting from antiquity (see the reviews, for example, in [1]), distinguish between inert and living state of matter, which makes it possible to describe reality as a world of things and agents. Taking this terminology for brevity, we recall the common practice that the formation of the world of things is described by the fundamental particle physics, and the formation of the world of agents by the Darwinian evolution. The beginning of the Darwin evolution in this case is often positioned with the time of the appearance of living organisms [2], presenting this stage of formation as a transition from chemical evolution to pre-biology, as the rooting of the tree of Life in chemistry. Such point of view was formed under the pressure of the obvious fact that all known agents have an organic nature and that the rules of behavior of agents on the macroscopic level, accessible to everyday observation, turns out to be harder than those for things.

With the discovery of the subatomic structure of things in the 20th century, our understanding of behavior for things became much more complicated, and the standard model that divided the world of things into bosons and fermions with different behavior, and also introduced the concept of interaction carriers [3]. The events of this level are described by the sciences of quantum electrodynamics and quantum chromodynamics. They represent, more or less consistently, the descriptions of the electromagnetic, strong, and weak interactions and suffer from unsurmounted difficulties in describing the gravitational interaction. The problem may lie both in the features of the gravitational interaction, and in not fully understood features of the three interactions listed above.

The science concerning the world of agents experienced at that time a strong rise in the form of the formation of molecular biology, phylogenetics, genomics and other sciences, associated in some way with the molecular structure of organisms and with the evolution of these devices. It turned out that the molecular evolution of agents, as well as the macroscopic Darwinian evolution (not confused with macroevolution!) uses rules of heredity and variability and the natural selection. At this time, biology significantly advanced in understanding the mechanisms of phenomena important in biology such as the deployment of genetic information, the interaction of the sexes, interaction of species, interaction of the organisms and the environment [4], which allows us to talk about the biology of being and the biology of becoming and about the role interactions in the formation of the living, just as in the description of the world of things. Ilya Prigogine distinguished between the physics of being and the physics of becoming [5].

This brief, incomplete, and selective presentation of the achievements of physics and biology of the past decades aims to point out that there is something in common in the formation of agents and things, which goes unnoticed when they are compared at the macroscopic level, but occurs as you approach the comparison on the quantum level.

Describing this something general, we intend to show that there are no fundamental (analytical) obstacles to the formation and subsequent evolution of quantum systems whose characteristics would satisfy the rules

[1]History is a teacher of life.

of the Darwinian evolution. Most of our assumptions will refer to early events of formation, to the physics of the condensed state as a domain of free habitats of fundamental particles, energy, and elementary excitations, where we inevitably fall into, presenting the origin of life as an event of organization, starting in the possibility space [6].

We assume that it is on very this quantum mechanical space, in conditions of the global diversity of particles and the almost unlimited possibility of their interactions (fusions, compositions, and decays, as well as growth and quantization), a natural selection began to act, which, on one hand, led to a bifurcation of the process of becoming into the world of things and the world of agents, and, on the other hand, to their interaction. The assumption allows one the dissemination of Darwin's discoveries of the laws of evolution on the formation of the physical world as a whole. In that assumption, we expect to see what biology gives physics according to S. Ulam [7].

2. WHAT DARWIN DISCOVERED

"If you'll ask me about my belief
whether the current age will be called the Iron Age
or the age of steam and electricity,
I will answer without hesitation that our age will be called
the age of mechanical understanding of the world, the age of Darwin"[2]
Boltzmann, 1886

Modern interpreters of Darwin endure heredity, variability, and natural selection "out of the brackets" of the evolutionary process, defining them as "driving forces" of evolution. This drive to expand Darwinism is commendable, but the notion of "directing forces" requires careful consideration.

First, there is no such notion in physics as "directing forces." Secondly, a force, by definition, is a vector that characterizes the degree of influence on some body, and the level of abstraction of the concept of evolution is such that the evolution cannot be regarded as a body. Finally, thirdly, trying to understand the physical meaning of something, one must remember that modern physics describes the diversity of its phenomena using 4 types of interactions rather than forces.

These remarks in no way limit the significance of the Darwinian legacy; however, it is required to clearly define what kind of phenomena were described by Darwin, how they were interpreted at the time of their publication, and what interpretation they deserve now.

Thus, Darwin had compared the features of the morphology of fossil animals with geological age of the layers in which they occur, and came to the conclusion that the occurrence of species reflects their (groups, species) gradual change and mutual transformation in time [8]. He further realized that the species, like classification groups, are stable on one hand, retain (inherit) features of predecessors, and, on the other hand, they are changeable; descendant species have new signs. He connected the variability of species on the geological scale with the facts of the variability of offspring when crossing individual pairs of animals on the scale of modernity, i.e., attributed to the sexual process the meaning of the generator of variability at different levels of the representation of reality, and noted the random nature of the changes during crossing. Finally, he showed that, in paleohistory, the species whose traits are fixed are traits whose carriers have advantages for reproduction under the conditions of the time when they occur. He called this phenomenon the survival of the fittest and connected this with another random process, namely. the coincidence of new properties of descendant organisms with new (or current) requirements of the environment. He called this coincidence (or mismatch) and the subsequent growth or decrease in the number of organisms of the species the natural selection as opposed to artificial selection, where the breeder deliberately selects for reproduction the offspring with the desired traits.

Thus, Darwin for the first time carried out a diachronic analysis of fossil material and gave a verbal or example description of patterns (i.e., rules), which lead to changes in the classification. However, since the changes in the classification only *reflect* the course of the natural process of becoming, it turned out that Darwin described the naturally formed rules (they can be called instructions) of the evolution of natural living objects on the example of large animals. He indicated the sequence of the inclusion of rules in becoming and thereby introduced into the scientific use the basic *algorithms for the formation of groups of large animals*, without calling them algorithms. Fortunately, it turned out that the algorithms of formation corresponding to different branches and stages of our evolutionary development, for all its diversity, have much in common with both large and small animals and even plants and microorganisms. Therefore, the age of Darwin, which

[2]It would like to warn the reader against erroneous associations. Boltzmann the Great understood mechanics as the science of kinematics and dynamics, and supplemented this understanding with the evolution according to Darwin.

started more than 150 years ago, continues in our time: comprehending the reality, we understand how the basic algorithms of becoming were applied in nature to the process of formation of diverse agents.

Next, we intend to show that Darwin's algorithms are even more universal.

3. DARWINIAN ALGORITHMS AS FIRST PRINCIPLES

For the first principles of any theory one regards principles whose minimum set lets one to output everything else. Let us consider becoming as an empirical theory of evolution of our world, i.e., the co-evolution of living and nonliving systems, which, like Church's application, can be regarded in two ways: as a result of the process of becoming and as the process of becoming itself. Let us also agree that, in the system representation, the agents (i.e., organisms) are elements of living systems (populations, species, and other taxa). Things do not have such a sharp elemental distinction, their elements are particles, atoms, molecules, objects ..., forming systems of different levels of complexity. Let us note that, on the usual scales, things can be a part of agents, while the opposite in general case is incorrect. This presupposes, in our opinion, that there is no prerequisites for the formation of future agents in the organization of things.

A distinctive feature of agents is their ability to reproduce when interactions among themselves in their categories, during which they demonstrate properties of heredity and variability.

3.1. Heredity in biology is found during the reproduction, it is understood as the transmission of genetic traits from parents to offspring (organism level), it limits the scale of trait changes in generations (population level). Things do not reproduce, but their interactions demonstrate patterns resembling heredity. It can readily be seen that the collision of stones, their separation into parts does not change their "stone" nature. In nonliving systems, heredity manifests itself as a property to preserve elemental affiliation in the lines of formation from atoms of elements to their chemical compounds, i.e., minerals, deposits, etc. This type of heredity can be broken only in the course of strong interactions, for example, by irradiation substances with high energy particles.

It follows that the transfer of important features during interactions is not limited to biology, this is a phenomenon of a more general order. In general, in a form characteristic for both things and agents, heredity can be understood as a special case of the law of conservation of the archetype, i.e., the principles of organization achieved by the elements of the system at the stage of consideration. In such a general way, heredity can manifest itself in interactions at different levels of becoming both for agents and things.

3.2. Variability is often regarded as a separate feature of living [9]. The reason for this may be that Darwin could not have known about the reproduction even at the cellular level: the term *gamete* was introduced into science only in 1877 by E. A. Strasburger. As a result, in the Darwin presentation, the concept of "descent with modification" has more space for variability and, in the latter, the role of chance was exaggerated.

We understand the variability as a function whose range of values does not go beyond the borders of the area of heredity. For agents, this limit means belonging to a species or population, and for things this means belonging to a substance or chemical element. The limit of variability of things is connected with changes in electron shells, i.e., belongs to the field of chemistry. Changes in the structure of nuclei change the belonging of a chemical element, i.e., changes the archetype. The variability of things has a quantum combinatorial basis: a set of three quarks (selections of six by three) could explain the origin of dozens hadrons.

In such a general representation, the rules of heredity and variability can be regarded as dual interaction algorithms, which also underlie the emergence phenomena, determine the occurrence of new features thanks to which some of the descendants turn out to be the "fittest" for the agents and the "most stable" for things.

3.3. Natural Selection

For the agents this is an embedding operator on the set of organisms carried out by embedding the possibility space of organisms into the possibility space of the environment. Only realized embeddings are preserved in the evolution. Moreover, the most complete (adapted) investments multiply; in other words, the selection discards the unrealizable possibilities, leaving a room of opportunities for more probable potentials. The selection does not operate from perspective considerations, it is blind: unembedded options are discarded by the becoming itself, empirically. This is the meaning of application, which is an applying the selection to a set.

A similar selection occurs in the evolution of things: in the formation, only those options are involved that retain the potential for further transformations under the given conditions. It can be said that the selected realizable entities "better fit" the algorithms of becoming. The result of the action of the selection on sets of things makes a strong impression on researchers and got the name *self-organization* [10], which, of course, leads away from the problem of unification, multiplying the essence.

Evaluating all three algorithms together, it should be noted that, up to a certain level formation (complexity? generalizations, generalities?), these algorithms are applicable both to things as well as agents. The value, the scale of Darwin's algorithms is that they are largely invariant on all types and scales of the representation of the reality and are suitable for describing interactions. This happens because the history of becoming is largely the history of interactions. The invariance of algorithms is not absolute. The reason for this is the difference in the nature of the things and agents.

4. THE ROLE OF THE MASS DEFECT IN THE INTERACTION OF THINGS

The world of things is relatively stable. Mountain ranges have existed for millions of years. Their stability is associated with the stability of atoms, the variability potential of which was exhausted with the formation of the atomic nucleus. The specificity of a chemical element is determined in its nucleus, where particles are held by nuclear forces. To change the set of particles in the nucleus, it is necessary to spend a lot of energy. This energy determines the mass defect as the difference between the masses of the nucleus and the sum of the masses of the nucleons [11]. The presence of mass already for fundamental particles provides high threshold for the interaction of things and makes problematic the transition from the fundamental particles to agents even through the chemical evolution.

When speaking about the unsuitability of elementary particles for the evolution of agents, one must understand that, with the formation of matter, the role of natural selection in the evolution of things is not cancelled. The formation of matter is achieved in this state of the system formation, when the energy available in the system is not enough to overcome the threshold of the element interaction. Without an influx of energy, things turn out to be isolated according to Gibbs [12] and cannot provide the selection with the necessary variability.

Darwinian algorithms govern the evolution of things on the segment of the evolution from the fundamental particles till the creation of matter. On this, the evolution of things ends, having no analytical prerequisites for moving into the evolution of agents with its phenomena of reproduction, sexual process, and ontogeny. We believe that an empirical solution to the problem of analyticity was found before its arrival because the evolution of agents can start from entities for which the mass defect does not occur. These entities are quasiparticles, sets of collective excitations involved in becoming on a par with the material substrate [13]. Their evolutionary advantage is that the interactions associated with them do not reveal the dependence of the mass defect, do not have a high interaction threshold and, therefore, special phenomena of interaction of agents (reproduction and ontogeny) are modelled by interactions of quasiparticles.

5. QUANTUM FOUNDATIONS OF DARWINIAN ALGORITHMS

Formulating the rules of evolution, Darwin had at his disposal a fossil material representing a short interval of the history of our planet. The world science at that time was far from the unity of views on the formation, and the French Academy of Sciences was just preparing to announce a prize for solving the problem of spontaneous generation (1860). A whole century separated physics from the standard model.

The current arsenal of knowledge is immeasurably richer and, if our assumption about unsuitability of fundamental particles for the evolution of agents is not without reason, then, in a search of an alternative, another fundamentality must be considered, namely, an elementary excitement.

The quasiparticles are generated differently than the "inert" particles [13], they allocated with a different margin of complexity and with a different type and set of relationships. They fall under the descriptions of Shannon's connection theory [14] and, therefore, their interactions can be regarded as communications, which guides their research in the field of informatics. The quasiparticles as localities are held by bondes weaker than the covalent and Coulomb forces, which are responsible for the defect of masses. In the plane case, their unity is determined by the envelope, which is usually represented by function rather than by force. Due to this, quasiparticles easily enter in the interaction with each other, easily carry out the action "fusion/division" that allow them to establish causal connection with the environment (exchange, internalization), develop the variability and enter into relationships with the natural selection.

Modern practice associates quasiparticles with excitations over some macroscopic body [13, 15]. Bogolyubov did not bother any characteristics of the body and wrote the theory of interaction (of weak interactions of quasiparticles) per se [16]. He stressed separately, referring to Landau, that the elementary excitations are a collective effect and cannot be identified with individual molecules. Here it is useful to refer to the standard model, according to which, macroscopic bodies in the condensed state did not exist (the pairs were separated), but there were interactions, including those with photons, i.e., excitations. For this very reason, we believe that in the early stages, the quasiparticles existed *on a par* with mass particles. This *equally* requires that the quasiparticles are to show the quantum dualism, and they manifest it by their dependence on mass carrier, without which they do not exist. The quasiparticles, according to our assumption, show the momentum-mass dualism, temporarily borrowing from the carrier the missing characteristics, such as constraints.

Having arisen, the quasiparticles exist for that (often short) time until they get energy from outside. For example, optical phonons exist as long as the vibrations of a crystal lattice are supported by an external electromagnetic radiation. Thus, various authors (see the review in [17]) supported the population of polaritons by irradiating them with a laser beam. Here structures were formed, "artificial molecules," that had fundamentally different energy states, optical properties, and vibration modes =https://www.skoltech.ru/2021/03/iskusstvennye-molekuly-otkryvayut-put-k-sozdaniyu-sverhbystryh-polyaritonnyh-ustrojstv/. Thus, the energy received by quasiparticles can be used for the transformation of elementary excitations that make up the main content of a quasiparticle. From here, the internal evolution of the object can began, the creation of its informational entity, which, through many critical transitions, will become the current genotype. The collective excitations, in the form of a pair "particle/antiparticle", demonstrate properties of sequences with mirror symmetry in the structure and antiparallel in the direction [18]. Possibly, the properties of antiparallelism, mirror symmetry, and base complementarity are inherited by the DNA double helix directly from the quasiparticles. It is also possible that Okazaki fragments occur in the DNA replication (see Fig. [4]) occur not to save money on the second replisome, but because the quantum reasons for the antiparallelism of (+) and (-) circuits retain their fundamental importance and cannot be violated without destroying the system itself. Showing mainly a wave character, quasiparticles have only the dynamic mass, and they are to purchase the rest mass, which is a characteristic of agents. Definitely, the quasiparticle acquires mass as a result of the exchange of substances and energy [18]. However, it can be assumed that the acquisition of mass begins even earlier, with the beginning of the formation of a virtual coat on the particle surface. If these wrappings were the first participants in interactions, they are more suitable for the role of the precursor of the phenotype, which is a special structure created by a living system to interact with the environment. The collective excitation with all its potentials in the space of possibilities and with material coat from the quantum environment contains analytical premises to create a protocell.

For quasiparticles that demonstrate predominantly a wave character and the absence of electrically repulsive protons and, therefore, having a low energy interaction barrier, the interaction is possible under milder conditions of cooling down. When the universe cools, this means the possibility of evolution (to interact) for a longer time. This time can be used for ontogeny.

Although the creation/annihilation is also characteristic for fundamental particles, the ontogenesis is not characteristic for them: the same quantum locality cannot be measured more than once. Fock [19] stated that "Assuming that the final stage of one experiment is at the same time the initial stage of another, we see that the wave function that gave the probability distribution of the outcomes this experience, should be replaced by another, corresponding to the result obtained in fact. Such a replacement occurs suddenly; the change of the wave function does not occur according to the Schrödinger equation". "Real" elementary particles are identical. But identity cannot provide variability, without which the selection is impossible.

Another topic is given by mesoscopic living systems; their ontogeny allows one multiple measurements. Thus, with the help of vision, we can observe the development of an experimental object, for example, a rat or Arabidopsis, since we do this in the light they scatter and reflect. We can also construct a macroscopic instrument such that the contact with it will not significantly change the object state. For example, a light microscope or a fluorescent probe allow one to return to the measurement of the microbe many times, and then one can construct an individual trajectory, and to study its ontogeny.

5.1. Interactions of Agents and Things. Interaction of agents with things in biology are often considered to be an exchange of matter, a metabolism. In the general case, the exchange is the absorption of matter and energy by agents. However, interactions of agents with things are not exhausted by such an exchange. We introduce the concept of internalization, to mean not only the absorption of substances or the energy by agents, but also their mastery of functions characteristic for the external environment. Such is, for example, the mastering of the function of catalysis with the invention of enzymes. In a similar way, the struggle for life (intraspecific and between species) can be understood as the result of internalization of the natural selection, its immersion in the system of relations between elements of living systems.

The internalization of the external is a general rule for relationships of a separate "live" locality with the environment. Starting from a certain moment after birth, the living creates itself from nonliving by the interaction. The notorious "metabolism" is the first scientifically observed example of internalization. The creation of inner cycles to produce substances that are necessary for evolution and for the construction of the phenotype is the second example of such internalization, the misunderstanding of which led researchers of the last century to the creation of theories of autopoiesis according to Varela [20] and abiogenesis according to Oparin. In our time, both theories reveal, in our opinion, an insufficient breadth and depth to model life.

6. DISCUSSION

Brandt and Kul'bachinsky [13] believe that "The concept of quasiparticles is ... an analog of the idea of elementary particles as elementary excitations of quantum fields located in the lowest (vacuum) energy state". Lee Smolin [21] generally admitted that all quantum mechanics can be rewritten from the standpoint of elementary excitations. We are strengthening these representations, believing that this concept is a two-pronged *alternative* of becoming, which removes the contradiction of absence of analytical premises of prebiology in chemistry. Our discovery of the universality of Darwin's algorithms, the universality extending to the quantum stage of formation and covering the dynamics of the formation of both fundamental and virtual particles, also pushes towards the search for a quantum alternative.

The size of the paper does not allow us to give at least a somewhat complete description of the evolution properties of the physical world, taking into account the concept of quasiparticles as a source of carriers of the Darwin algorithms. However, it should be stressed that Darwin, having described the evolution types of macroscopic living systems, gave an example of how a Turing machine works in nature [22]. Certainly, this was an example of only one type of a machine. But the model of such a machine is good due to the fact that it allows options with arbitrarily many of tapes (a parallelism), with multidimensional tapes (scaling). The description of the formation of the physical world as a co-evolution of agents and things with the internalization of things by agents and with emergent interactions raises the potential of a Turing machine to the complexity of a neural network and prepares us for the use of this formalism at all levels of development.

Difficulties associated with the definitions of unlikely events can be removed by translating the problem into a more general context [23]. The majority of problems of formation (except for critical transitions) were solved in this very way. Therefore, our understanding of the Darwin triad enables us to combine, in an algorithmic concept, many phenomena of formation that were previously considered as separate properties of systems, for example, self-organization, autopoiesis. Now we know that self-organizing maps is one of the varieties of neural network algorithms. Autocatalysis can also be interpreted in a similar way. The formalism of neural networks is a tool for solving problems similar to the problems of empirical formation, for example, a clustering problem is similar to a classification problem. There is a hope to establish that other algorithms of neural networks of becoming, including the becoming of living systems, have their models already in a condensed state. A recent paper [24] can serve as a pointing to this way.

Moreover, the condensed state itself can be regarded as a cosmically large array of data in the space of possibilities, potentials of embodiment, and critical transitions. The evolution of this array was carried out according to the rules of the Darwin triad, according to a scheme indistinguishable from that of actions in the "reverse error propagation". As is known, the method consists of a repeating cycle of operations consisting of the weight re-evaluation and the array reclassification based on the overvalued values. Roughly speaking, we can say that the natural selection, discarding discrepancies (the possibilities of the environment and the organism), re-evaluates the fitness of organisms and thereby, as it were, carries out the network run in one side. The revaluation occurs simply because the selection that has been made puts into the possibility space (old or new, this does not matter) what is a clearly new set of organisms. The run in the other direction is carried out by a propagation according to the rules of heredity and variability, creating an even newer set for the new selection cycle. Although pairs of runs can be put into correspondence to generations and describe them as cycles, in reality, both runs operate continuously, gradually increasing the fitness of the population. This mechanism is in line with gradualism. In the stages of formation corresponding to the theory of catastrophes, the reassessment is initiated by a sharp (catastrophic) change in the space of possibilities.

7. CONCLUSIONS

The value of Darwin's legacy lies primarily in the fact that the algorithms, on one hand, require and, on the other hand, pave the way for the unification of science, to the harmonization of all scientific knowledge through its representation in empirical theory of becoming.

The algorithmic concept of becoming systematizes many phenomena of this remarkable process, although it does not solve all the problems of its description. The restoration of the events of formation, even in algorithmic descriptions, remains to be problems solving based on inaccurate signs and incomplete data. Especially, this concerns phenomena of emergence and critical transitions with the presence of energy cracks. Neural networks serve as a good tool for simulating the stages of formation, according to which we have enough data. However, so far, neural networks add little to understanding the mechanisms of evolution, since their training only imitates the natural selection. Therefore, the physical meaning of learning, especially of deep learning, is hidden from the understanding by the creator of the network.

An important contribution to the incompleteness of the data is the lack of a consistent theory of the gravitational interaction. This incompleteness may also be the cause of the incorrect choice of signs from which the picture of formation is rebuilded. The high probability of such an error follows, for example, from the fact that, in the standard model and in the theory of becoming, there is no idea of the evolution of information, although in the past century Wheeler wrote about the relationship between information, physics and quantum [25].

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