S E S 2 0 1 8
Fourteenth International Scientific Conference
SPACE, ECOLOGY, SAFETY
7 – 9 November 2018, Sofia, Bulgaria

ON THE MODEL OF PHYSICAL EVOLUTION OF BIOSYSTEM

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Key words: *population; utilization; self-preservation; entropy; work; instruction; biosystem; ecosystem; ontogeny; immanent; ideal bio-system; interruption; biosphere; crisis; Phanerozoic; evolution; physical evolution*

Absract: *More than one specialist has dealt with the problems of the physical processes of this or that biological event. Recently, there has been a rapid development in biophysics, which encompasses the processes on subcellular as well as cellular levels [1, 2]. But in the macroscale of life organization, the research of physical laws was not very fruitful, which was connected with the general approach and concrete methodology to the problem [3]. Within the given work, trying to partly eliminate this flaw, we discuss physical mechanisms of functioning of different bio-systems (including the biosphere).*

There are two scientific approaches to the concept of life: structural and functional. As it is clear from the definition, the former generally focuses on the concrete physical and chemical basis and constructional peculiarities of organisms, while the latter focuses on their functional peculiarities. According to the one of the founders of quantum physics E. Schredinger: “The given part of materia is alive when it continues doing something, moving, producing metabolism with the environment, etc.”. In different sources, he gives general physical definition of life: “Life is an organized and regular behavior of materia, which is based on the existence of current order” [3].

According to a famous astrophysicist Academician I. Shklowsky: “A live system is a functional system and, therefore, one structural characteristic is not sufficient for it” [4]. According to one more quotation given in this textbook by Academician A. Lyapunov: “A wide, cybernetic management is the most characteristic feature of life, irrespective of its forms”.

From functional point of view, different authors [5, 6, 7] distinguish three components of functioning:

1. Functioning directed at self-preservation;
2. Functioning directed at preserving population;
3. Finally, functioning of highly developed organisms with complicated nervous system, which are not directly connected with the utilitarian biological needs but may possess significance in future survival of organisms or “population”.

These components are comparatively independent and at different moments of their lives and ontogenesis they can even contradict each other. Of course, these are not all the reasons why living systems behave in this or that way. But at the initial stage, it is important to understand the main issues of life processes, without which the existence of organisms or their population in the environment is simply impossible. That’s why we will deal with the functioning directed at self-preservation.

From physical point of view, self-preservation (survival) is characterized by the establishment of a certain level of organization, i.e. the preservation of structure. To describe organization, we can use the function of entropy. It is known that to preserve the reduced level of entropy in a system, energy current or the current of low entropy substance have to enter the system from the environment. As the dissolving process in nature is a permanent one, part of the energy current is transferred from non-heat to heat or is scattered [3, 8]. This is illustrated in thermodynamics by a well-known first law [9, 10]:

(1) $$dA + \Sigma_i \mu_i d n_i = dU - T d S ,$$

where Σ_i is an algebraic sum according to i; A is the work done by outer forces; μ_i – chemical potential of i-like substance which entered or left the system; n_i – the number of i-like substance; dn_i – the change in their number as a result of chemical reaction or mass exchange with the environment; U – inner energy of the system; T – absolute temperature; S – entropy of the system.

When the average amount of the existing substance and its consistency in the system do not change, it is usually considered that dn_i member of chemical energy is also included in dA. We can avoid those mathematical confusions which are connected with the existence of the member of chemical energy and are produced during the discussion of biosystem, whose mass is not permanent, thus: we will discuss not the developing system itself, but the system which involves all the substances used in the mass growth, i.e. substance plus any amount of substance which does not undergo changes. The amount of this kind of full system is endless and whichever we will choose – it is only the question of norm. This approach is used in the description of evolution of ecosystem and the biosphere. The latter is the full system of proximity, which makes it significantly easier to study its physical evolution.

To illustrate, let's discuss the following example. Theoretically, we can create the automatic machine which will be programmed or, in other words, it will have programs (instructions) to carry out functions which are directed at using certain types of energy or small entropy substances. Besides, the external energy will be used to preserve the reduced level of entropy, i.e. to "self-repair". We can't name this machine "alive" because in the process of creation of unknown external conditions, it won't be able to use this energy and will die. Living organisms, as seen from everyday observation, are not programmed very strictly and this is what enables them to become stronger and survive in different conditions.

From the above-mentioned we can conclude that self-preservation in the real environment of unpredictable variable situations requires not only: a) functioning programs (instructions) directed at using definite kinds of energy in certain conditions, but also b) the ways of finding new mechanisms and instructions of functioning in unknown situations.

In some cases, the organisms with developed nervous system possess the ability of experimentation which must be progressive from evolutionary point of view.

Thus, unlike the process of crystallization, during which the decrease of the level of the entropy of system goes on as a result of the reduction of inner energy, in cases of live system, this degradation is the result of the fact that the system is functional or "is able to" (knows how) to use external energy and can find new sources of energy. A number of authors have reflected on these aspects [3, 11, 12].

These characteristic features of self-preserving bio systems are connected with their two important features: first, in order to save and remember the existing or newly-acquired functioning instructions, it is necessary to possess memory mechanisms; second, in order to realize point b, it is required that in contradictory situation the system must not be strictly determined and be able to choose this or that variant of behaviour.

This kind of random search and choice can be found at all stages and in all aspects of functioning of live systems. Random movement of the simplest organisms, fluctuations of the growth of some of the structures in ontogenesis of plants and animals, finally, constant detection of mutant formation in such bio systems as ecosystem – all these are the examples of random search and selection of functioning and beaviour at different levels of biological organization. In this or that situation connected with brain work, there is a need for spontaneous/random search because, due to the lack of time and brain recourses, it often becomes impossible to use the whole information connected to the situation, or this information is simply not enough. Besides, according to the result of Gedel's second theorem, it is impossible to prove this theory within any theory [13]. This means that in case of strict logical definition of thinking, which prohibits the possibility of free intuitive search and, therefore, free choice necessary for construction, it is impossible to establish a radically new image. But this conclusion is actually unfair.

All this can be generalized in the following way: the freedom of choice in behavior and in thinking and, therefore, search for new instructions (programs) of functioning – is an immanent feature of a living creature. In other words, the feature of searching for new instructions of functioning is derived from the freedom of inherent volition for all living creatures, while the realization of this free behavior leads to the uniqueness of any human or, generally, living creature. Subjectively, the feeling of freedom is the sign of being outside individual environment and necessity. That's why the feeling of freedom is one of the most important current motives of the behavior of living creatures. To achieve this immanent freedom, living creatures need additional activity, compared to the activity necessary for self-preservation in surrounding environment.

The search and selection of new mechanisms of functioning are carried out among a limited number of variants. It is realized in a certain field of choice which is defined by individual and evolutionary data. The evolution process can be discussed as a process of gradual acquisition of the growing number of variants of existence, which is necessarily connected with thinking.

The process of generalization of physical and functional features of the bio systems leads to the construction of physical models of their evolution.

In a strange and contradictory situation, living system has to have experimentation skills in order to self-preserve. A successful experiment conditions the production and concept of the new instructions of functioning, which encourages the creation of organisms and their adaptation in a strange environment [14, 15]. The actual results of a certain experiment can be unsuccessful, that's why it is useful to introduce the concept of *ideal bio system*. Its characteristic feature is that during "the lack of energy and resources" this bio system looks for, finds and then uses the new ways and methods of receiving energy. The last requirement is added because in critical situations the newly-acquired ways or methods are not always standardly used. We should also mention that one of the characteristic features of a real system is the principle of stability of the current [14, 16].

Every method of receiving energy from the environment can be adjusted to the channel of transferring energy. The reduction of transfer of energy current or its temporary interruption in one or several channels causes the reduction of total current by *j* magnitude. Let's call this process *interruption*. During every interruption, an ideal bio system acquires a new channel of energy which supplies it with the lacking energy current. After the next interruption, the bio system uses them to reduce the level of entropy. A lot of real bio systems, e.g. separate organisms, do not use all the channels they have and interruptions cause the growth of the channels which can be used only potentially.

Do bio-systems actually have analogues?

Nowadays, there are several distinguished levels of organization of bio-system: hereditary substance, cellular organelles, single cellular and multicellular organisms, populations, ecosystems, the biosphere [17, 18]. According to functioning, in order to preserve the unity of the system, it is logical to distinguish the following levels: unicellular organisms, cells of multicellular organisms, multicellular organisms, ecosystems, the biosphere. Populations are not functional bio systems of interrelated functions of bio system. It can be said that in functional aspect, ecosystems and the biosphere are the closest to ideal bio systems.

As it has been mentioned above, under ideal bio systems we mean the full systems which look for, find and then use the new ways and methods to acquire energy from the environment. That's why, its total current of energy doesn't decrease during each interruption, and after its completion, it increases compared to its value. At this time, the level of bio system entropy is reduced. The expected limitations from the environment can lead to the crisis (see Fig. 1). To receive descriptive equalities of an ideal bio system, let's discuss the case when at the moment of interruption the acquired energy decreased after each interruption by the equal constant *j*.

After each *K* interruption we will have the following for the energy *G(K)* current:

$$G(K) = j_0\,(1+K\,\beta), \tag{2}$$

but when $K\to\infty$,

$$G(K) \approx j_0\,K\,\beta, \tag{3}$$

where *G(K)* is the energy current in bio system *K* after interruption; *K*- the number of interruptions; j_0 - initial current of energy in the bio system (energy current before the first interruption) and $\beta < 1$ is that current reduction, i.e. *j* equals $j_0\beta$ during each interruption. Generally, we can write:

$$G(K) = j_0 + \sum_{K=1,K} j_K, \tag{4}$$

where j_K is the magnitude of current reduction during *K* interruption, and $\sum\limits_{K=1,K}$ is the algebraic sum according to *K*, when it changes from *1* to *K*. At the moment of interruption the constant of the current can't exceed the value of the current.

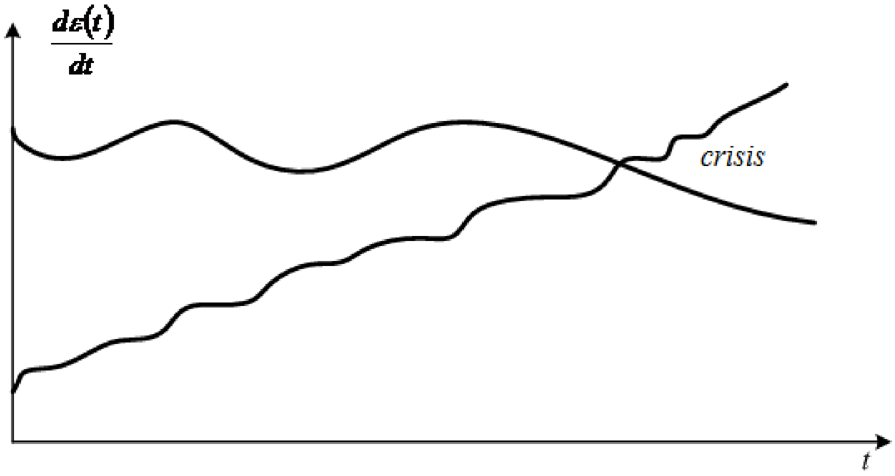

Fig. 1. Generating crisis of an evolutionary ideal bio system.

In case of Phanerozoic (cellular dissolving) biosphere, which supposedly developed in analogy with the ideal bio-system, it can be considered that during the interruption caused by the fluctuation of solar insolation, the magnitude of the deduction of the acquired and used external energy is proportional to the general current of the biosphere. In this case, it is easy to guess that:

(5) $$G(K) = j_0\,(1+\gamma)^K,$$

where $j_{K+1} = j_K\,(1+\gamma)$, i.e. the magnitude of relative reduction of the energy current acquired from the environment during interruption using traditional ways.

If γ is small and K is not big enough, as, e.g., for the separate epoch of geological history, then (3) ratio shouldn't give us a very large error compared to relation to (5). Meanwhile, γ parameter is replaced by β, which enables an easier estimation.

When the environment has limited energy, all available sources of energy will sooner or later expire and the following interruption will cause energy crisis (see pic. 1). As we see from the picture, the crisis is produced during the last interruption due to the impossibility of preserving energy current, which is conditioned by the environment due to the restricted growth of the current – upper surrounding curve. In bio system the total energy current increases even during interruption. In case of identical interruptions, when all j_K equals a certain j, it is not difficult to estimate the initial time of the start of the crisis, if we think that the crisis will happen when the G energy current in bio-system equals the accepted $Emax$. current. We will receive the simplest formula if besides $\beta = j/j_K$ parameter we introduce $\sigma = j/Emax$. Parameter where j is reduction of the current during interruption. Then, the number of interruptions will be:

(6) $$K = (E_{max.} - j_0)/j,$$

At the same time, $K = tcris./\tau$, where $tcris.$ is the time interval from t = 0 moment till the crisis, and τ is the average period of interruption. Thus, we can easily get the following:

(7) $$T_{cris.} = \tau\left(\frac{1}{\sigma}\frac{1}{\beta}\right),$$

The given images are useful only for orientation initial calculations and estimation. Despite this, they help us to understand the regular physical evolution in systems such as the biosphere. Before finding out about the final regulations of its evolution, it is necessary to prove the fact that from functional point of view, the biosphere is very close to the ideal biosphere.

The biosphere of the Earth represents the highest ecosystem. It has hierarchical structure, unites the ecosystems of lower hierarchical levels and separate interrelated populations of organisms. Ecosystems and separate organisms are discussed in the general model of physical evolution of bio systems as self-preserving and self-restoring bio systems which participate in the process of life evolution.

In the given model, by the physical evolution of bio systems we mean the growth of energy current in this system during its existing period. The main postulate of this model is the following: in changing environmental conditions, any bio system strives for the functioning in which energy current is not reduced. Only the bio systems with these features can be self-preserving in the changing conditions. Thus, short interruptions of energy currents received through this or that channel stimulate the bio-system to look for new compensating ways of acquiring energy. If it fails to do so, the bio-system undergoes a crisis and dies.

Thus, every interruption of energy current in a bio system creates a necessary condition for physical evolution. They are realized in the cases of nearly ideal bio systems (ecosystems, the biosphere), which have no specific restrictions about using existing, traditional and later created energy channels, unlike separate/individual organisms which are abundant with these restrictions. Physical evolution in evolving bio systems conditions the creation and development of new and strange features and adaptations but, therefore, it is followed by the creation of new energy channels and factors for the following evolution.

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