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On the analogy in evolution processes and the behavior of a magnetically ordered systems

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ABSTRACT

Common regularities in the biology evolution and the magnetization processes of magnetically ordered materials have been demonstrated. The arrays of the experimental data have been accumulated in the registration process of a weak polarization-optical response of borate iron at the presence of external magnetic field. It is shown that the magnetic behavior of response in some respects analogous to processes in biologically systems, such as differentiation, convergence, the development of clones, etc. It is predicted the existence of the weaving development that combines the characteristics of the processes of differentiation and convergence. More detail are considered the phenomenon nie the branch points; it is shown the possibility of the acceleration, retardation, and wavelike development. The proposed approach may be useful for comparison, the study and predict development scenarios for actual organized systems of various natures (ecological, social, financial, informative etc.), and high degree of hierarchical complexity.

Keywords: Evolution; Biologically Systems; Polarized Light; Laser; Optical Measurements; Magneto-Optics; Ecological; Social; Financial; Informative Systems

1. INTRODUCTION

Study processes in a large organized systems, such as, for example, biological or ecological systems, greatly complicated by their complexity [1-3]. One way to overcome these difficulties could be to find analogies between the actual complex systems and formations of different nature that allow a more detailed study. An attempt to find some similarity between the behavior of magnetically ordered structures and the development of the evolutionary processes is described in this paper.

2. EXPERIMENTAL TECHNIQUE

The arrays of the experimental data have been accumulated by as in the process of recording weak polarization-optical response (further response) borate iron ($FeBO_3$), observed at the presence of external transverse magnetic field. Crystal $FeBO_3$ has as is well known, domain structure that is rearranged by the action of the field. This restructure leads to the changes the optical properties of the sample [4,5]. In our case it is allowed to allocate a small magneto-dependent part of the detected signals.

The measuring principle is easy to see from **Figure 1**. During the experiments, the investigated crystals probed by laser radiation (He-Ne laser, $\lambda = 0.63$ μ) with a strong modulation of the polarization state. The probing light passed through polarization modulator, investigated sample, and received in the registration system. After the optimal analog-digital conversion, the obtained signal was introduced into the computer.

Eq.1 gives the value R of the response that is measured by the setup in the simplest case:

$$R = (2\pi l/1)(n_1 - n_2). \quad (1)$$

Here l and n_1, n_2 are respectively the thickness and the main refractive indexes of the investigated sample. At presence in the measuring channel the sample of iron borate the value R is determined by the Cotton-Moutton effect [4]. Detailed measurement procedure is descried in [6-8].

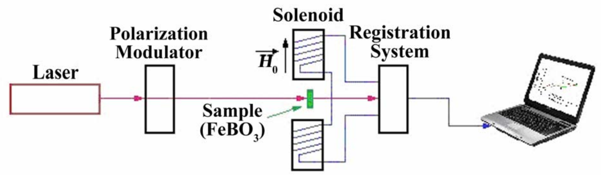

Figure 1. Experimental setup.

3. EXPERIMENTAL DATE

Figures 2-6 give the value of the response for the investigated sample of $FeBO_3$ versus the magnetic intensity of the external magnetic field. Curves 1-4 in **Figure 2** show the four dependences, corresponding to four possible scenarios of developments. All the curves start at point 0 (initial state). Next, clearly visible changes in the processes taking place at the branch points A, B, and C. These changes are connected with jump like rearrangements of the magnetic structure of borate iron (for details, see [8]).

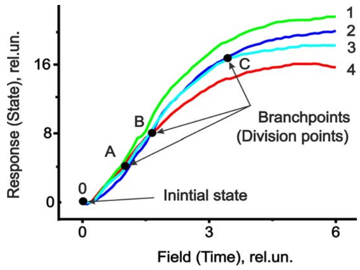

Figure 2. Differentiation (cell division).

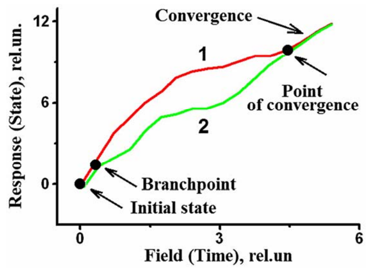

Figure 3. Convergence.

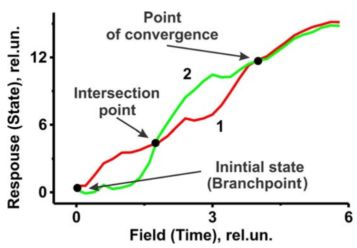

Figure 4. Weaving development.

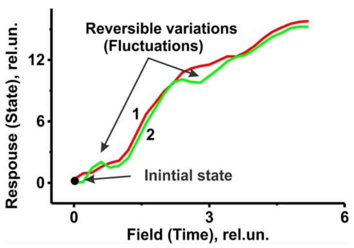

Figure 5. Development of clones (identical twins).

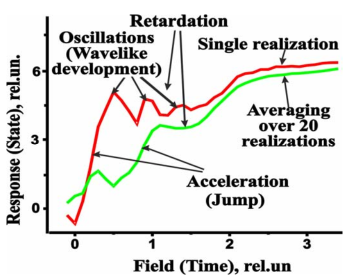

Figure 6. Processes near branch points.

When drawing analogies, the external magnetic field is interpreted here as generalized affecting factor. The time is also supposed to one of these influencing factors. The analogue of the response for the biological systems is the "State"—the generalized parameter, describing the system—analogue (see **Figures 2-6**).

By the comparison with the biological evolution the difference between the Curves 1-4 in **Figure 2** is due to, for example, the processes of differentiation. At the analogy with the systems of cells the branch points may be, for example, the points of the cells division.

Development scenario of the other type—the convergence is illustrated by Curves 1 and 2 in **Figure 3**. In the branch point Curves 1 and 2 (trajectories of motion of the system under study) are separated, and after a period of independent development the curves drift together again at the point of convergence. Such magnetic behavior of the sample can be considered, in particular, as an analogue of the ongoing in wildlife convergence of species.

Curves 1 and 2 in **Figure 4** show the trajectories of development that combine in a sense, the processes of differentiation and convergence. We call this situation "Weaving development". Certain stage of evolution begins to develop from an initial state that is at the same time, the branch point. After the independent development the trajectories 1 and 2 reach the intersection point. This point has the properties of the points of convergence and the branch points. Then trajectories are separate again, and after some development reach the point of convergence. As far as we know, the weaving development has not yet been found in the wildlife. We can expect that it can be found in the wildlife in future. We can assume also that it can be realized in other complex systems too.

At the present time is very living the problem of development of clones. With it is closely related, apparently, the long ongoing studies of the twin development [9,10]. **Figure 5** shows the appropriate to this case analogy with the behavior of magnetically ordered systems. Two clones (identical twins) will start its development from the initial state. Them exactly the same growth is illustrated by the almost complete coincidence of responses 1 and 2.

Note that beside coincidence, there are some differences between the developments of the two clones. One of them is that under the influence of certain factors in the clone 2 occur some variations. These fluctuations are reversible, since after them the trajectories are again identical. The cause of variations of the second clone may be, for example, various diseases. The availability of the reversibility can be explained in this case, the stabilizing effect of the immune system of the second clone.

For the magnetically ordered systems the coincidence of the trajectories 1 and 2 given can be explained by their greater stability as compare with other possible paths. By the analogy with the evolution processes featured reversibility may be due to the greater stability of new biological formations (species, subspecies etc.).

Figure 6 shows the trajectories of development in which the processes near the branch points are well identified. Clearly visible are periods of acceleration (evolution jumping), alternating with retardation of development. The retardation stage is accompanied by characteristic oscillations, *i.e.* periods of wavelike development, indicating the need to find a kind of steady state of systems-analogues.

In addition to the single realization, in this figure is presented an average over 20 such ones. The process of acceleration and retardation are stayed. The oscillations smoothed out, which may indicate a lack of a significant correlations between individual realizations.

From the above figures it follows that phenomena such as differentiation, convergence, etc., may be a consequence of the processes of acceleration or retardation in separately, as well as being the result of their joint action (compare with [10,11]).

4. ESSENCE OF PURPOSED ANALOGY

Overall assessment of relevance of developed here analogy leads to a natural question: "Is the considered analogy only external, or there is a much deeper similarity of processes occurring in the magnetically ordered system, we have reviewed, and in the biological systems?" By the attempt to understand this we should take into account that we have studied the object that is not as trivial as meets the eye.

Figure 7 shows the magnetic structure of the investigated sample. One can see individual domains witch are separated by the Neel walls and the Bloch walls [4]. The arrows indicate the magnetization M_s within the domains. The magnetic state of the crystal $FeBO_3$ can be realized by several differing configurations of the domain structure.

In papers [4,5] have shown that a significant contribution to the variation of the domain structure of iron borate in magnetization makes displacement of domain boundaries. Specified displacements can occur smoothly, and can also have a jumplike character. In the latter case magnetized crystal abruptly moves to energetically more favorable (equilibrium) state. The mentioned hoppings of the domain structure is called Barkhausen jumps [12].

Following [12], consider the energy balance in magnetized crystal. The decrease of the magnetic energy at the displacement of the domain wall by a distance δx along the propagation of light (see **Figure 7**) is

$$\Delta E_M = 2H_0 I_S \delta x, \quad (2)$$

where I_S: saturation magnetization.

The energy of the boundary zone γ increases in this the value of

$$\Delta E_\gamma = (\partial\gamma/\partial x)\delta x. \quad (3)$$

The equilibrium value of the field $H_0^{(Eq)}$ corresponds to the equality of the increments ΔE_M and $\Delta E\gamma$, defined by **Eq.2** and **Eq.3**:

$$H_0^{(Eq)} = (1/2I_S)(\partial\gamma/\partial x). \quad (4)$$

If the magnetic field H_0 does not match the equilibrium value given by **Eq.4**, there is a shift of boundaries and even the collapse of domains. As a result changes the total magnetization of the crystal [4,5,12].

In terms of optics, the domain structure in **Figure 7** can be seen as a package of anisotropic plates, the principal axes of which are oriented according to the directions of the magnetization vectors M_s [4,8]. In our previous works was performed a complete analysis of the formation of polarization-optical responses in the measurement shemes with strong polarization modulation of probing laser radiation [6,7]. From this analysis it follows that the response R_p of the package of plates can be represented as the sum of the responses R_i of individual plates (domains):

$$R_p = \Sigma_i R_i \cos 2\psi_i. \quad (5)$$

Here the values of R_i are given by the **Eq.1**, and angels ψ_i determine orientation of the principal axes of the indicatrix [7]. According to this simple model, the restructuring of the domain structure occurring during magnetization, involves changes R_i and ψ_i, that in turn leads to change of the recorded values of R.

Note that **Eq.5** can be used only in the simplest case of small amplitudes of these separate responses. In the general case should be used the solution of the task about transfer of laser radiation through a medium in which the components of the dielectric tensor depend on three spatial coordinates [7]. Beside this the walls are not the ideally planes, but have their own forms [4]. Such a way, the real magnetic structure of $FeBO_3$ can be much more various than that shown in **Figure 7**.

Thus, in a general case, the observed response is a rather complicated function of the magnetic field strength.

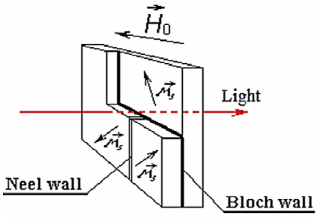

Figure 7. Domain structure of the $FeBO_3$.

In the experiments, this is manifested in a wide variety of development scenarios (trajectories of motion), from which the above are discussed only some of the most common. This fullness of development trajectories is very similar to events occurring during the evolution of some systems, especially biology systems.

On the other hand, biological evolution, as is well known, to be closely linked to changes in DNA [9,11]. As a molecule (polymer), DNA has the discrete quantum structure with a fixed formation. Mutations associated mainly with rearrangement of DNA. The theoretical description of the mutations, occurring in the process of biological evolution, is very complicated task and can not be given here. We only note that changes in the genome can be registered directly, as is done today with the help of modern methods of gene analysis [9-11]. Beside this, the changes of species, following the example of Charles Darwin, can be directly observed in the wildlife [13].

However, it should be emphasized that the essence of the carried here analogy is based on the some similarity between the restructuring of the domain structure during magnetization and the changes in DNA, occurring in processes of the natural development of biological organisms. The considered mutations are not arbitrary—the possibility of a certain mutations is determined in particular the previous configuration of DNA. Completely analogous way the magnetized crystal is also a quantum structure, the configuration of which may change abruptly during the magnetization. These changes also are not arbitrary. Just as in the case of DNA, the determining factors are the initial state (the configuration of the magnetic structure of $FeBO_3$), from which happen the jumps, and the set of possible realizations that meet this initial state.

All the above considerations can indicate not only the purely external similarity, but also the more deep nature of analogies given here.

5. CONCLUSIONS

A number of general patterns of evolution occurring in a biology systems and behavior of the magnetically ordered materials have been shown. Introducing the idea of the generalized parameters, which describe the action on the system being studied, and their responses (reaction) to these impacts. Some analogs are considered of the processes of differentiation, convergence, and cell division. Predicts the possibility of "weaving development", discusses some new features of the development of the twins and clones. Processes are considered that taking place near branch points: acceleration and retardation of development, and characteristic oscillations (wave like development).

Note that can be definitely indicated a similarity between biological evolution and another physical phenomenon. Here is considered an analogy just with the magnetically ordered substance, since this object is examined fully enough, hopefully, to achieve the goals of this work.

Came to the problem from another side, is useful to examine not only the evolution of the biological systems. There are, of course, the general features of the development of many organized systems. From this point of view it can be assumed that the suggested approach can be extended to the actual systems of a different nature, such as ecological, social, financial, information, and high degree of hierarchical complexity.

6. ACKNOWLEDGEMENTS

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