Case Report

Water - a foundation of dissipative regulation of a living organism

Abstract

Dissipative processes of self-organization occur in both living and non-living matter. The same laws govern living and non-living matter, but the mechanism of their manifestation is different. The distinctive feature of living matter is "functional information," which is an attribute characteristic only of living matter. Functional information is a purposeful indication of the change in the structural-functional state of the living matter. Feedback plays an essential role in self-organization and the dynamic balance of dissipative systems. Self-organization is based on positive feedback (PF). Dynamic equilibrium of the system is ensured by negative feedback (NF). There is a constant competitiveness between the two types of feedback - PF and NF. In biological systems, the balance of PF and NF is maintained based on auto-oscillatory homeostasis processes. The regulatory function of homeostasis correlates with the dynamics of the ratio of free and bound water phases in the hydration-dehydration processes of biopolymers. Water regulates homeostasis and supports metabolism by maintaining the bound-free water phase ratio balance.

Keywords: dissipative systems, dissipative self-organization, dissipative regulation, entropy, functional information, system sensitivity, self-oscillations, feedback, homeostasis, bound and free water, hydration, dehydration, biopolymer conformation, information density, synchronization, desynchronization

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Introduction

It is well known that water is the basis of life. Life, as a unique complex form of matter motion, is characterized by self-organization, self-regulation, self-renewal, and self-reproduction of multilevel open dissipative systems.[1] Open dissipative systems are space-time structures that can arise far from thermodynamic equilibrium in a nonlinear region at critical parameter values.[2] Open dissipative systems exchange substance, energy, and information with the external environment.[3] "Dissipative self-organization (synergetic approach) is a process of sorting (spatial, temporal or space-time) in an open system, due to the coordinated interaction of multiple elements that make it up. Hermann Haken gave this definition within the framework of the scientific paradigm, the theory of "joint action" - synergetics.[4] The ideas of synergetics of self-organization are widespread in modern science. On their basis, the unity of living and non-living nature and the unity of micro- and macrocosms are established—the unity of the two opposites of chaos and order.

Matter exists in two forms - matter and field. Matter exists in space and time. Any forms of motion and transformation of matter are impossible without energy. The non-material form of existence and manifestation of the matter is information. Energy and information are integral (attributive) forms of matter.[5] But what exactly is the difference between living and nonliving matter? No chemical elements are the basis of matter peculiar only to living matter in nature. The growth and development of matter also cannot serve as a distinctive and specific feature of a living object. After all, as it is known, crystals grow with the construction and organization of the structure of a particular order. Dissipative processes of self-organization occur in nonliving nature as well. The same laws govern living and non-living matter, but the mechanism of their manifestation is different. In living and non-living matter, information manifests itself differently. It is believed that the distinctive feature of living matter is "functional information.[6] "Functional information" appeared with the emergence of life, as it is associated with functioning complex self-organizing systems, including living organisms. We can also say that "functional information" is an attribute peculiar only to living nature. This is one of the essential attributes separating the living from the non-living objects in nature. In the hierarchy of levels of matter, it is believed that the bridge between living and nonliving matter is supramolecular systems.[7]

Supramolecular systems can recognize each other, move, and perform various transformations interacting with other molecules. Various molecular assemblies (genome, organelles, receptors, etc.) with new functional properties characteristic of biological systems can already be formed Figure 1. And the first functional system of the transitional hierarchical level between non-living and living matter is the cell. Functional information carries targeting structural change. Without targeting, the processes of directed transformation of living matter are impossible. In highly organized matter, intermolecular and intercellular interactions involving functional information form dissipative structures - dissipative systems. Dissipativity is a macroscopic dynamic state of a system (matter) caused by processes occurring at the micro level of this system.

We name some conditions of dissipative self-organization:

I. The system should be open.

II. The system must be in the vicinity of the thermodynamic equilibrium point.

III. The system must contain a sufficient number of interacting elements.

IV. Self-organization is based on positive feedback (PF.)

V. Dynamic equilibrium of the system is ensured by negative feedback (NF.)

VI. The presence of fluctuations is necessary for the emergence and maintenance of the dynamic order of the system Figure 2.

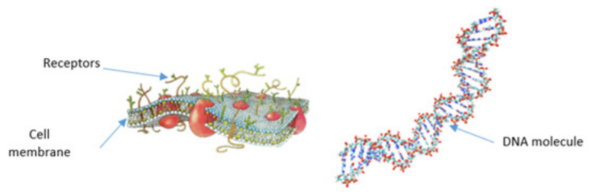

Figure 1 Examples of supramolecular systems.[8]

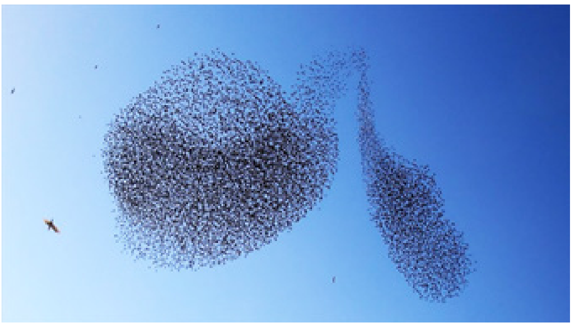

Figure 2 Dissipative system - by the example of a flock of starlings (the phenomenon of murmuration).[9] Similar dissipative structures (systems) are formed within a living organism in the form of an association of molecules and cells of the same type.

The cell, as the first functional system, implements one of the fundamental principles of biology - the principle of reduplication (doubling) of hereditary information (matrix principle). The level of living matter usually includes biological organs, organisms, populations, and ecosystems. Biological systems, and their structural and functional organization, are based on the principle of the fractal matrix Figure 3.

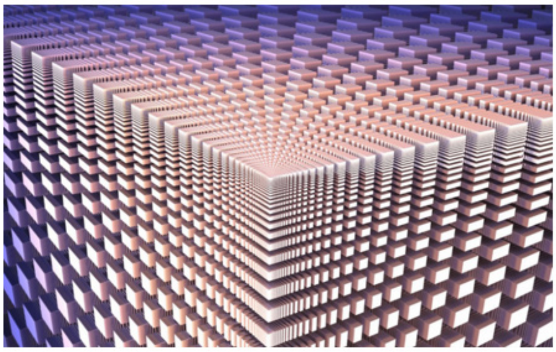

Figure 3 Example of a geometric fractal matrix. Dissipative systems are dynamic fractal matrices.[10]

What gives a living organism a large number of single-type structures combined into a system?

Erwin Schroedinger, an Austrian theoretical physicist and Nobel Prize winner in physics, is one of the developers of quantum mechanics and wave theory of matter. In 1944 Schroedinger wrote his book "What is life in terms of physics?" which significantly influenced biophysics and molecular biology. Schrodinger showed that "only in the union of a vast number of atoms do statistical laws begin to operate and control the behavior of these unions with a precision that increases with the number of atoms involved. It is in this way that events acquire truly regular features."[11] Behavior of quantum living systems can be described only on the basis of statistical (probabilistic) laws Figure 4. In essence, dynamic fractal systems (aka dissipative systems) - are a quantum level of matter functioning, with all inherent properties and laws of quantum biophysics. When researching and studying properties of living matter at the level of individual cells and molecules, we often overlook those essential qualities that living matter possesses only in its collective, fractal, dissipative state - quantum state.

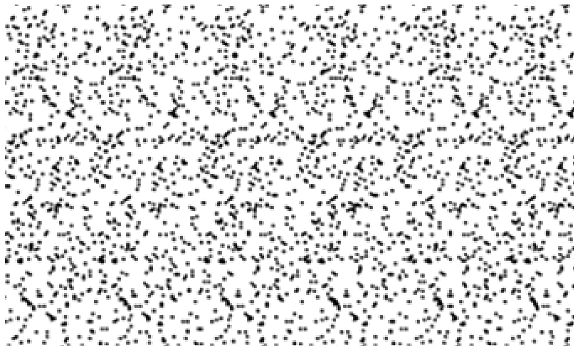

Figure 4 Static fragment of the dynamics of the relationship of a large number of system elements, demonstrating the statistical regularity (probability) of the predicted behavior of the system.

If life without water is impossible, it is quite logical to ask: how does water affect the processes of self-organization and self-regulation occurring in living matter?

The answer to this question should be sought in biophysical principles of the existence and functioning of living matter based on properties and regularities of operation of dissipative systems. The molecular and cellular level of living matter consists of a vast number of different biopolymers, all processes of the transformation and functioning of which are impossible without the participation of heterogeneous forms of water. Water, a thermodynamic and electrophysical non-equilibrium system, can provide many structure-forming effects and collective quantum processes.[12]

Water is a dynamic matrix of dissipative systems of living matter. Regulation processes in living matter, as was mentioned above, take place with the participation of "functional information." Information in molecular biology makes sense only through the function it encodes - "functional information." Information is a "differential characteristic".[13] This means that it occurs when there is some change in the initial state of the structure Figure 5. Information is contained in the measure of heterogeneity, changes in the conformation of the spatial structure of matter (substance, field), and the measure of system orderliness, connections between individual structural elements of matter. Nature encodes different information in a conformational (structural) way rather than a frequency one. Sources of information inside the organism are large and small molecules. Dynamic changes in molecular structures of living matter are information itself. In this sense, the structure of matter and its information (aka function) in living matter are parts of one whole. Proteins are the most variable structures in the molecular world of living matter. They have the most diverse functional properties. The biological function of a protein is determined not only by its chemical composition but also by its spatial (three-dimensional) structure, which depends, among other things, on the environment in which the protein is located.[14] In the dry state, the protein is electrically neutral and, therefore, inactive. The heterogeneous aqueous matrix in the liquid media of the tissue-extracellular matrix (ECM) and the protoplasmic matrix is active in the auto-oscillatory process of protein hydration-dehydration.[14] This auto-oscillatory process manifests the dynamic charge properties of the protein and changes its conformation and functional activity. The maximum functional activity of the protein is manifested in the unfolded (hydrated) state.[15]

Figure 5 Example - information as a "differential characteristic.

Auto-oscillations are a necessary condition for self-organization in open, dynamic systems to maintain their dynamic stability.[16] Excitation of self-oscillations will always be accompanied by a reduction of the total entropy of the system, i.e., reduction of dynamic chaos and maintenance of the necessary level of order in the system. The auto-oscillatory process in the dissipative system of a living organism provides conditions for maintaining homeostasis. Homeostasis is an integrative dynamic process regulating the functional and morphological (morphofunctional) relative internal constancy of a living organism.[17,18] In homeostasis and metabolic processes, feedback plays an important role. Norbert Wiener, one of the founders of cybernetics and artificial intelligence theory, regarded the feedback principle as the "mystery of life," giving it a fundamental role in the study of living phenomena.[19]

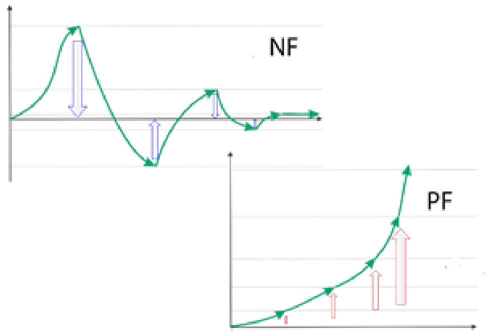

Figure 6 Directionality of the PF and NF influence on the dissipative system processes.

To create new structures and new organs in the process of growth and development of the organism, positive feedback (PF) is necessary, loosening the system (taking this system to a new level of structural organization), and negative feedback (NF) is necessary to maintain a steady state Figure 6. The balance of PF and NF ratios ensures the ability of the living organisms both for growth and self-regulation of an individual organism and, as a result, for self-preservation and sustainability of the species. The formation of dissipative structures occurs with the participation of positive feedback (PF) and underlies tissue differentiation during morphogenesis. The preservation of the auto-oscillatory mode in the dissipative structure occurs with the participation of the negative feedback (NF).[20]

Homeostasis can be maintained only under the conditions of the NF, which regulates homeostasis, and the PF, which creates a necessary and sufficient number of interacting system elements and a necessary-sufficient order structure between the elements of this system. Homeostasis is, in fact, an auto-oscillatory process with the NF of information regulation (dissipative regulation), maintaining the constancy of the most important structural characteristics of living matter, the living organism as a whole.[21] Normal homeostasis, as a criterion of health, is related to relative order - the "norm of chaoticity" of structural elements of a dissipative system. For maintaining homeostasis, it is necessary to maintain some "norm of chaoticity" in the regulated system. Both high entropy (excess chaos) and minimal entropy that tends to zero (complete phase coherence) lead to loss of information in living matter and, consequently, to loss of its normal physiological functioning. There is constant competition between two types of feedback - PF and NF. For example, in the nervous system, positive feedback causes enhancement of reaction, which may underlie the development of diseases. Negative feedback, on the contrary, reduces the activity of CNS neurons and response, which is the basis of self-regulation (adaptation). If the balance of feedback is disturbed, PF puts the functioning of the dissipative nervous system into a new functional (morphofunctional) state, which usually leads to pathological homeostasis and even possible destruction (death) of the functioning dissipative system.[20]

What is water's role in the dissipative regulation of homeostasis?

Water in the body is represented as free and bound.[22] Free water is a part of the cell cytoplasm, vacuole; it fills the intercellular matrix (ICM), connective tissue. It is necessary for the transport and transfer of substances. Bound water is a part of cellular structures (proteins, membranes) and maintains their structure Figure 7,8.[23] The maximum hydration of biopolymers corresponds to the maximum amount of bound water (gel phase), and dehydration is correlated with an increase in the proportion of free water (sol phase). Note that the concepts of "bound-free" water, "hydration-dehydration," and "gel-sol" states should be perceived as relative, not absolute, bimodal distributions of ratios, these phase aggregate states of dynamic processes (dissipative processes) in living matter Figure 9. The biphasic state of water is in an auto-oscillatory process of hydration-dehydration of biopolymers. The regulatory (informational) function of homeostasis is carried out in the Gel phase (maximum hydration of biopolymer, maximum amount of bound water). Metabolism, movement of molecules, tissue growth, development, etc., are performed in the Sol phase. The diffusion rate of substances in the Sol is 10^7 (7 orders of magnitude!) higher than in the Gel.[26]

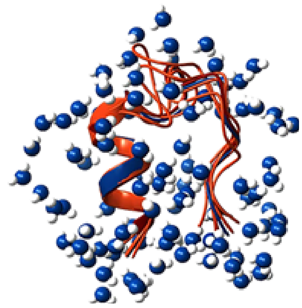

Figure 7 Hydrate shell of protein molecules.[8]

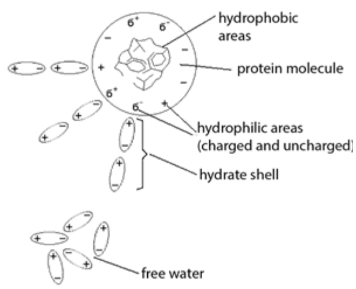

Figure 8 Free water unbound to biopolymer and bound water as hydrate shell of biopolymer.[24]

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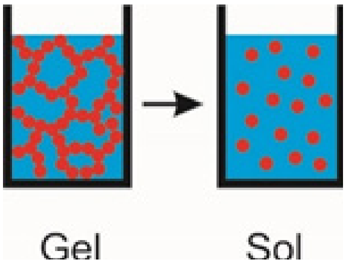

Figure 9 Example of "gel-sol" states.[25]

External energy is consumed during the transition from Gel to Sol, and external energy is released during the transition from Sol to Gel. The rhythms of colloidal transitions from Gel (gelatinous state) to Sol (liquid state of protoplasm) and back underlie all intracellular movements.[26] External energy is consumed during the transition from Gel to Sol, and external energy is released during the transition from Sol to Gel. The rhythms of colloidal transitions from Gel (gelatinous state) to Sol (liquid state of protoplasm) and back underlie all intracellular movements. Mismatch in the balance of competing processes of NF and PF will manifest itself in changes in the regulatory role of homeostasis and general metabolism, development of diseases, and acceleration of aging. Almost all diseases can be traced to changes occurring at the protein (protein) level,[27] with a change in the ratio of water phase states.

The body expends ATP molecules to hydrate protein (create its maximum unfolded structure). A decrease in ATP in pathologies and aging of the body leads to a low degree of protein hydration, a shift of the Gel phase toward the Sol, a decrease in controlling regulatory processes, and a decrease in overall homeostasis.[28] In this regard, the possibility of homeostasis regulation mediated through the water matrix becomes particularly meaningful. Factors affecting the degree of protein hydration include intrinsic natural (amphoteric) properties of the protein, pH of the environment, and concentration of toxins. The lack of ATP spent on protein hydration, and water structuring can be partially compensated by the intake of negative air ions and water with a negative redox potential (optimally from -50 to -150).[26]

It is important to remember that a decrease in the number of mitochondria and ATP formation occurs in various diseases and in the organism's aging process. Maintaining a high level of homeostasis allows not only to maintain normal metabolism but also to control the growth and development of tissue proliferation between the constantly competing processes of autophagy and apoptosis. At the same time, maintenance of high homeostasis level, and an optimal degree of synchronization (maximum sensitivity) of the dissipative system, allows for achieving maximum information density of regulatory signal with a decreased amount of ATP, i.e., with minimum consumption of the cell's own energy.

Desynchronization of dissipative coupling is necessary for the processes of weakening pathological homeostasis. The information density of the dissipative system can be regulated by an external control parameter coupled with the dissipative system's own field. This control parameter can enhance dissipative coupling by increasing synchronization and weaken dissipative coupling by desynchronizing the system. The cause of many diseases with pathological homeostasis is desynchronization in dissipative systems of normal physiological processes. Disbalance of the psycho-emotional state is correlated with the activity of inflammatory reactions in the body. Inflammatory processes show a correlation with the development of somatic-psychological reactions. At the same time, excessive psycho-emotional states and prolonged stress lead to the development of psychosomatic problems. For example, the excessive response of neurons to the action potential during the stress response is associated with a change in the cell's membrane potential. This, in the structures of the nervous system, causes changes in the excretion of neurotransmitters, neuromodulators, and neuropeptides, affecting tissue metabolism and homeostasis.[29] Water performs one of the critical functions in maintaining normal homeostasis and metabolism. The organism's adaptation to adverse environmental factors, including psycho-emotional ones, greatly depends on the state of general homeostasis. At the same time, water is the "structural basis of the organism's adaptation" Figure 10.[28]

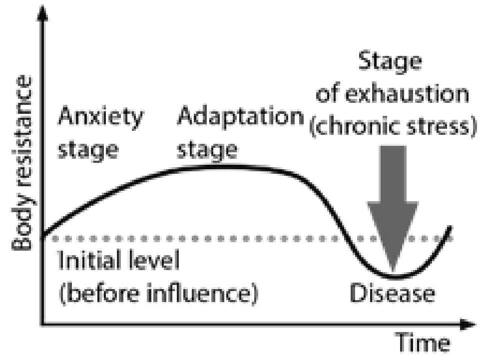

Figure 10 The body's reaction to stress according to G. Sellier.[30]

At the initial stage of stress reaction (stage of mobilization of protective forces), the organism reacts by increasing the proportion of bound water, the maximum proportion of which falls on the stage of adaptation (resistance). With the prolonged persistence of a stress factor for the organism (depletion stage), the phase relation "bound-water" shifts towards an increase in the proportion of free water. In this case, the regulatory function of homeostasis decreases. Risks of the development of pathological conditions increase. Excessive mental reactions, including those caused by drugs that stimulate physical performance, such as Phenamine, reduce the content of bound (structured) water.[28] On the contrary, adaptogens (ginseng, magnolia vine, Eleutherococcus, Rhodiola Rosea, etc.) increase the amount of bound water and decrease the amount of free water. Thus, adaptogens increase the body's nonspecific resistance (increase of adaptation reserves). In acute alcohol intoxication, there is a decrease in bound water and an increase in free water, lasting up to 5 days.[28] The proportion of bound water increases in winter and free water in summer, which also affects homeostasis and metabolism.[26,28] A change in the bound-free water ratio leads to a change in the homeostasis state and the dissipative system's corresponding state. A mathematical function of a strange attractor describes the behavior of a dissipative system. The attractor is a set of trajectories that the system makes in an auto-oscillatory mode Figure 11.[31]

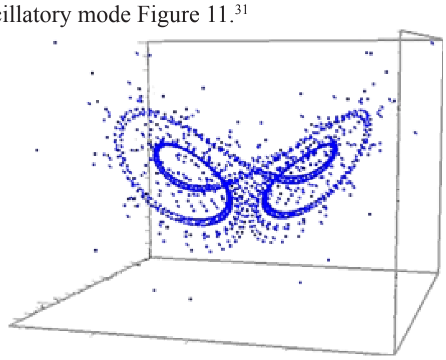

Figure 11 Example of a dissipative system attractor.[8]

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One of the essential properties of an attractor is its ability to respond to a periodic external influence. This external influence, complementary to the system state, can change the attractor trajectory and switch it to a new form of auto-oscillatory mode and, consequently, to a new homeostasis state. Since the controlling parameter of the dissipative system, functioning by the NF mechanism, is an external field coupled with the internal field of this dissipative system, such an external field can affect the homeostasis state. The control parameter can enhance dissipative coupling through increasing synchronization and weaken dissipative coupling through desynchronization of the system. Spatially inverse (mirror-symmetric) controls parameters perform desynchronization in the dissipative system. Desynchronization in the dissipative system can be used to reduce the pathological homeostasis function. In addition, a dissipative system is a dynamic multidimensional fractal structure, and the internal field of this structure also has the appropriate volume configuration - conformation.[32, 33] Thus, the external control parameter of a dissipative system (external field) should have a relative complementary conformation and carry a corrective conformation (external functional information), which can switch the attractor of the dissipative system to a new trajectory (vector) of its existence. The properties of molecules and their ability to enter into metabolic reactions and processes are determined by their chemical composition and conformation. Conformation also determines the biological function of proteins.[33] Almost all diseases can be traced back to changes occurring at the protein level.[28] The organism, being a single dissipative system, contains multiple individual dissipative structures (dissipative systems) on different hierarchical levels. Disruptions of homeostasis and metabolism may occur within a single dissipative system and in cross-dissipative links between these systems.[34]

Conclusion

Water, as the basis of life, creates conditions for the emergence and realization of "functional information." Water provides a dynamic internal environment of all dissipative systems of the organism governed by functional information. Water regulates homeostasis and supports metabolism by maintaining the balance of "bound-free" water phases. Thanks to water, the functional quantum properties of living matter, which create conditions for self-organization, self-regulation, self-renewal and self-reproduction, are manifested in living organisms.

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Conflicts of interest

The authors declare that they have no conflict of interest.

Publisher's note

The article has been published for the first time.

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