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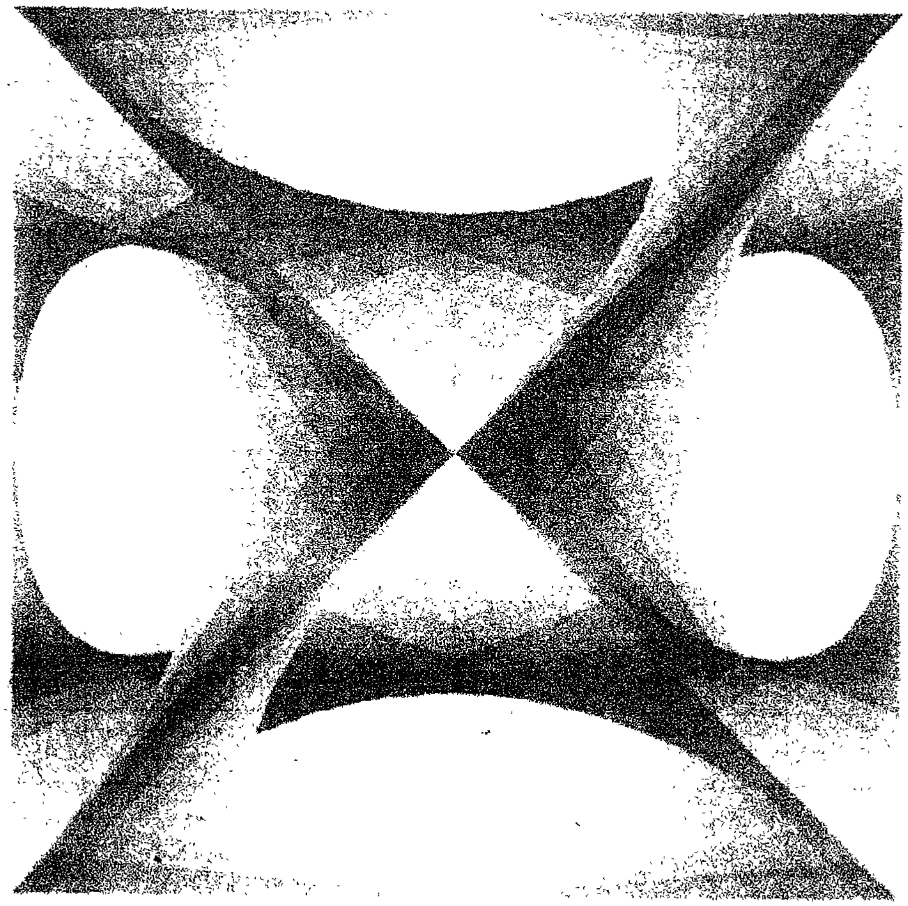

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INFORMATION PROCESSING IN BIOSYSTEMS: QUANTUM MECHANICALBACKGROUND AND RELATION TO SYMMETRY-BREAKING

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Abstract: *Life is characterized by the information processing which distinguishes it from inorganic matter. The background of information generation in living systems is a central problem for understanding of life existence and expansion. The symmetry-breaking phenomenon based on quantum irreversibility is preconditioned to all transformations which lead to the appearance of information transfer in biosystems. It underlies the origin of life and corresponds to the emergence of the genetic code and other semiotic relations essential for biological structures. In the present paper we discuss these fundamental aspects continuing the framework drafted in our previous publications (Igamberdiev 1992, 1993, 1994).*

1. RECOGNITION ACTIVITY OF BIOMACROMOLECULES

Biological system possesses a hierarchy, according to which the potentialities of constituent elements at lower levels are restricted by a higher level. The subdivision of a non-equilibrium biological system into levels corresponds to 'the vertical picture' of life processes in which the transduction-amplification cascades link molecular level processes to the macroscopic structure and behavior of organisms. The transduction-amplification cascades provide 'vertical flow' of information and that enables organisms to exploit the nonpicturable quantum dynamics at submolecular level to control their classical macroscopic behavior (Conrad, 1994a).

The reliability of information transfer inside the biosystem is determined by the specific features of the operation of enzymes and other biomacromolecules. The specificity of biomacromolecules for the strictly determined interactions (i.e. their recognition activity) can be explained by low dissipation of energy during their operation, which provides registration of signals not distinguished by their energy from the surrounding noise. In analysis of operation of these molecular machines we should take into account their quantum properties. As it was stated by Marijuan (1994), every enzyme is a pattern recognition machine. We cannot recursively formalize its internal dynamics as we can in Turing machines and conventional computers: enzyme is a structurally non-programmable device (Conrad, 1992). There appears a substantional difference between the switching function provided by a logic gate in a digital computer and the switching provided by enzymes and proteins. It seems that the Turing-Church thesis about the equivalence between computation and dynamics cannot be substantiated in cellular systems (Conrad and Liberman, 1982; Conrad, 1992; Marijuán, 1994).

During enzyme operation a non-picturable quantum dynamics takes place. Enzymes determine the boundary conditions which direct the course of a reaction into a certain route. Under these conditions certain states of particles (electrons) are not allowed, whereas in a coordinate interval defined by the active site, the new wave function is coincident with the one that existed before the action of enzyme. An electron is therefore evolved, being directed into the passage of routes which is determined by the coordinate scale defined by an enzyme. This results in the prohibition of some previously probable trajectories of electron movement in the substrate molecule, whereas other trajectories become more probable leading to the redistribution of electron density and hence to the internal polarization of the molecule determining substrate conversion into a product (Green and Vande Zande, 1981; Igamberdiev, 1993).

According to Conrad (1994b), each input signal at the molecular level triggers the appearance of a specific conformational change or a release of a specifically shaped macromolecule. The signal pattern is thus represented as a set of conformations. Electronic-conformational interactions that accompany molecular recognition processes allow the non-picturable superposition of electronic states to percolate to higher levels of function. The self-assembly process converts a symbolic pattern recognition phenomenon into a free energy minimization process. This process is non-integrable, i.e. it cannot be evolved deterministically from the primary structure of macromolecule and from the nature of input signal by the finite number of operations. The situation is similar to the well-known "three-body problem".

Conformational relaxation of macromolecular systems is considered to be an elementary action of the bioenergetic process (Blumenfeld, 1983), in which the fast quantum effect (e.g. the capture of an electron by macromolecule) is followed by a slow conformational transition being the mechanical motion of a macromolecule. During this transition, the energy is not dissipated remaining stored for a total lifetime long enough for the work to be performed (Kremen, 1992). Thus, its motion is many times slower than the initial quantum effect, and the rate of a bioenergetic process is therefore determined by the rate of conformational relaxation. The latter takes place only after the action of a force converting the system into the new conformational state, i.e. after the generation of a non-equilibrium state resulting from the fast initial interaction. From this point of view the specificity of biomacromolecules is connected with the recognition of specific configurations of electron clouds in certain compounds and should therefore be described using quantum mechanical formalism.

Braginsky et al. (1980) had analyzed the conditions necessary for the detection of weak forces. It was shown that according to the Heisenberg uncertainty ratio, interactions between a quantum system and a macroscopic measuring device can take place by a path that provides practically non-demolition registration of strictly determined weak signals. These interactions are characterized by high precision and certainty of the result of measurement, as the sensitivity of the detector is determined by its relaxation properties. Quantum measurement is connected with low energy dissipation in the case where the relaxation period of a macroscopic oscillator is many times larger than the time interval of measurement. Under the condition of quantum non-demolition (QND) measurement, internal fluctuations of the oscillator will not unmask the action of detected weak force, and certain motions in a macroscopic oscillator can be transformed into high-frequency vibrations without information loss. This provides electron movements over considerable distances with great speed and specificity through the metabolic network. Low energy dissipation during the recognition of weak forces is provided by mobile proton states appearing in biomacromolecules.

According to Witten (1982) the key feature in QND measurement is repeatability. The observable in such operation must be that which can be repeatedly measured, with the result of each measurement, in the absence of classical force, being completely determined by the result of an initial precise measurement (Caves et al., 1980) One way to achieve this capability is to measure an observable that does not become contaminated by uncertainties in other noncommuting observables. The concept of QND arises out of need to monitor the values of single observable over and over again. The existence of QND observables and measurements provides a means of escape from the problem of nonrepeatable experiments (Witten, 1980).

Internal QND measurements are inherent for biological organization and determine the essential features of living systems. Low energy dissipation in these measurements provided by slow conformational relaxation of biomacromolecular complexes (regarded as measuring devices) is the main precondition of enzyme operation and information transfer determining the steady non-equilibrium state of biosystems (Igamberdiev, 1993). We show here that quantum mechanical uncertainty that underlies the appearance of bifurcations is the main physical foundation of complication and irreversible transformation of biosystems, i.e. of their information capacity.

2. QUANTUM-MECHANICAL BACKGROUND OF SYMMETRY-BREAKING

The transition from the set of possible worlds to the description of the real world results from the process of reduction of potentialities. In the conditions of QND measurements, provided by long relaxation times, the possibility of non-predictable alternative result of measurement (i.e. of bifurcation) is minimal. If relaxation periods are shorter, the system is less stable but in can evolve in a different state via generation of the alternative description. This generation is a symmetry-breaking phenomenon which underlines the formation of new structures. Therefore the ratio between the measurement time and the relaxation period determines the state of equilibration between the stability of the system and its ability to change.

The generation of an alternative description corresponds to the arising of bifurcation within the system. Bifurcation analysis is developed in the catastrophe theory. It claims that at a certain stage of evolution the parameters of the system attain critical values at which the steady state bifurcates and hence the stability is lost. In addition to the customary catastrophe-theoretic model of bifurcation, which operates with non-linearities, it is important to state that the initial instability arises from the non-absolute character of the internal QND measurements. As was shown by Matsuno (1992), local fluctuations are accompanied by the non-vanishing rate of variation because of the uncertainty relationship, and the endogenous transformations refer to the symmetry breaking of the Hamiltonian, which has its own dynamics. Irreversible symmetry-breaking emerges from indefinite states, and indefiniteness is provided by the quantum measurements. Under this consideration, macroscopic bifurcations seem to be the consequence of the quantum properties of the biosystem, and only the measurement process is responsible for the branching behaviour of biodynamics. At the macroscopic level, the alterations in relaxation processes lead to the redistributions between different steady states within the biosystem. Thus, non-linearity arises from high order relaxation processes. This leads to instabilities and to initially unpredictable transformations, resulting in macroscopic bifurcations.

Bifurcations being symmetry-breaking phenomena generate 'voids' which are acknowledged by the whole system and internalized during ontogenesis and evolution in generated higher structures (Alves and Marijuán, 1995). The bifurcations that arise during the operation of the genome and enzymes and provided by the non-absolute character of non-demolition measurements (i.e. primarily non-internalized bifurcations) are essential in the evolutionary process. Therefore the evolutionary process seems to be a consequence of the quantum uncertainty that appears at the macroscopic level. In general, a change in relaxation time leads to the alteration in specificity of biomacromolecules to certain interactions, and this can result in branching behaviour. Perturbed versions of the original functions can interact in such a way that a property of their commutativity breaks down, and a new global function for the system is generated (Matsuno, 1985).

In physics the concept of symmetry is connected with the most generalized characteristics of the Universe. Physical symmetries correspond to conservation laws, and violations of symmetry lead to the formulations of more general, global symmetries. The CPT theorem claims the invariant character of all physical processes in relation to the turn of charge, space and time constituents. In physics violation of symmetry is an initial point for seeking a global symmetry, and the final dream of physics, 'the Generalized Field Theory' should be based on formulation of invariant characteristics which are constant under all possible transformations. W. Heisenberg named such fundamental theory as 'Urgleichung', i.e. as the basic generalized equation.

For understanding of the symmetries in living systems we should realize that every irreversible process is reflected in space coordinates as a symmetry breakage. Followed after this, the generation of a new organization is realized as a building of the symmetry of a higher level.

3. QUANTUM MEASUREMENTS AND INTERNAL COMPLEXITY OF BIOSYSTEMS

The transition from the set of possible worlds to the description of the real world results from the irreversible process of reduction of potentialities in which the reflection from the set of complex variables to real numbers takes place (Rosen, 1977). During this process, the system, considered a device, can generate independent descriptions which are alternative constructions without an implicative relation between them. The point of discrimination between these two descriptions is considered to be the bifurcation point (Rosen, 1979). The relation of two biological systems or two states of one biosystem in different moments of time (i.e. of two reflections to real numbers) is realized by the principle of epimorphism, i.e. of many-to-one mapping. These ideas arise to Rashevsky (1961). The complexity of biological system in this paradigm is a result of the interference of restrictions based on the internal formal description, which can act reciprocally with the set of physical laws. These restrictions are called constraints, in contrast to physical laws. Constrains in which many-to-one mapping is realized are called non-holonomic constraints (Pattee, 1970).

In different physical models we reveal the reflection from imaginary to real numbers.

The idea arises to P. A. Florensky who suggested at the beginning of the 20th century that imaginary points in the time-space serve for gluing together of the single points of the Universe into the whole entity (Florensky, 1993). Time coordinate in the theory of relativity is described by imaginary numbers, whereas spatial coordinates are real. In the model of the Universe suggested by S. Hawking (1988) the imaginary time is introduced in which the Universe is appeared as a closed holistic structure without frames. After the transition to real time the reduction to the model in which "the beginning" of the Universe and its inflation are present. But the most developed the idea of reduction of potentialities described as a reflection from complex to real numbers is present in quantum mechanical formalism. Complex psi-function of Schrödinger equation during measurement is reduced into the set of real numbers. The generalization of quantum theory was suggested using biquaternions - hypercomplex numbers (Conte, 1994).

The reduction to real numbers can be determined as dissymmetrization in the field of potentialities and can be considered as an important precondition of semiotic structures (Igamberdiev, 1992). A specific recognition is characterized by the minimal energy dissipation during interaction between the measuring device and the measured object. The chemical reactions which proceed under enzyme control retain all the equilibrium and other thermodynamic characteristics they possessed before this control. They are only influenced by the enzymatic constraint insofar as the substrate conversion proceeds via a strictly determined route according to enzyme specificity. Under this control the transition to macroscopic time takes place, as the conformational relaxation of slow enzymes is realized in seconds. This can be explained as the effect of a strictly determined electron state on the enzyme molecule. As a result, the system is subdivided into two subsets: one controlling and the other being controlled.

Controlling (information) level gives the appearance of placing extra restriction on the system (constraints). The system operates not only according to physical laws, but also according to its own restrictions (constraints), encoded in the internal description which determines the specificity or 'individuality' of the system. These internal restrictions can be conceived as 'arbitrary' in relation to physical laws, so we can introduce the idea of 'arbitrariness' between the signifiant and the thing it signifies (signifie). From a physical point of view, this connection is presented as arbitrary or casual, and its reproduction can be represented as a result of the storage of casual choice. The problem of interference between physical laws and internal constraints can be seen as the problem of interconnection between the physical and the biological in organic life. Biological system operates according to both physical laws and its own internal constraints, which determine its specifity; under these constraints 'the molecule becomes a message' (Pattee, 1970). H. Pattee (1989) emphasized that measurement itself is a non-formal process and cannot be programmed but its results are symbols that can be used in a formal system as information.

The act of recognition (based on QND measurement) involves a low-energy interaction between a component of a non-linear system (macromolecular device) and an environmental (epigenetic) input signal that causes the component to undergo a state transition (Barham, 1990). In such a system a low energy recognition stroke and a high energy or work stroke constitute the work cycle. Both phases of the cycle are viewed from a physical perspective in which the low energy (information or recognition) constraints act as signs with respect to high energy (pragmatic) constraints, leading to 'semiotic correlations' that have predictive values (Yates, 1992).

The relative autonomy of the biological system from local energy gradients is provided by the 'on board' energy supply in the form of macroergs. Owing to this, biological system is able to distinguish between the conditions external to itself which will support its continued oscillations, and those which will not support them. The low-energy environmental inputs which happen to be correlated (semiotically, i.e. based on the internal constraints) with those propitious conditions in order to correlate oscillator's high energy interactions with the environment are recognized. Barham (1990) states that these low energy inputs constitute 'information' in its semantic sense. In other words, biological system possesses an ability to measure certain environmental signals which are transformed into the actual work. In accordance with this, every biofunction from enzymes on up, contains a subsystem ('epistemon'), a sort of sense organ which acts as a trigger for the functional action of the whole system. Active sites of enzymes, various receptors are considered as such epistemons.

The structural stability and reliability of the biological system can be considered in relation to physical grounds, making apparent various semiotic relations (i.e., constraints) within the system. The state of non-equilibrium in which biological system exists is stabilized, and internalized within its cyclic organization. The system itself seeks for non-equilibrium flows which maintain its own existence in accordance with the selection of distinct signals from a chaotic set of environmental factors forming 'a noise field'. Therefore, the system is not only internally organized; it also organizes the surrounding environment. As mentioned by Prigogine (1980), the first mechanism of non-equilibrium evolution is the one that resulted in the system's movement out into strongly non-equilibrium conditions.

4. NON-FORCE CORRELATIONS IN BIOSYSTEMS

Operation of biosystem as an entity is provided not only by the interactions between the informational and energetic levels, but also by the formation of the other level – the level at which the system acts as a whole entity. The physical foundation of such a level is a consequence from the Einstein-Podolsky-Rosen (EPR) paradox. Low energy dissipation during the conformational relaxation of biomacromolecules provides for the possibility of long-distance non-locality transfer for electron and proton flows through the metabolic networks. In such systems a non-locality in the quantum mechanical sense and non-force correlations can arise between subsystems of the biological system in accordance with the EPR-paradox.

The EPR correlations can appear within systems which realize QND measurements. Two particles arising from a single system (e.g. two electrons with opposite spin values from the same atomic sublevel) can store 'knowledge' about a previous state when they are later non-disturbed, i.e. when non-controlled quantum measurements hiding the initial picture have not happened. Otherwise, information about the whole system will be unavoidably lost. Therefore the preservation of knowledge (memory) about the whole system is possible only in the case of non-demolition measurements that are realized on its subsystems, and low energy dissipation during conformational relaxation of biomacromolecules can be considered as a main precondition for providing and maintaining EPR correlations.

The verification of Bell's inequalities determining the existence of non-locality effects which can really prove actual wholeness of biosystems arising to their non-local properties is important for the confirmation of such an approach. The verification procedure could show that certain correlations in biosystem result from non-local interactions arising from the EPR effects. Non-force interactions could explain the co-ordination of the parameters of elementary particles during the action of protein molecules and their complexes. In the scheme of slow conformational changes, Bell's inequalities can be interpreted as the quantum mechanical background of the operation of macromolecular subsystems in a biological system.

The hypothesis of non-force quantum field in biosystems was discussed by V. E. Zhvirblis (1993). He proposed that the non-force three-dimensional field, provided by different topological structures in DNA (according to the quantum Aaronov-Bohm effect) may determine structure generation. In this model the basic morphogenetic bioinformation ('Gestalt-information') arises from the solenoidal non-force field not consisted of real physical interactions but only derived from them. The vectorial movement of particles during morphogenesis may be determined by these quantum properties. According to the presented ideas the holistic properties of life can be rationally explained in correspondence with the concepts of modern physics.

5. TIME ASYMMETRY AND BIOLOGICAL SYSTEMS

Each temporal event is an actualization, i.e. the irreversible transition from the field of possibilities to real events. It can be represented as a reflection into real numbers, where the previous event is put into correspondence to the appearing event and considered as its possible cause. This shows the resemblance of temporal process with the quantum reduction of potentialities, i.e. with quantum measurement.

The temporal process is based on quantum irreversibility (Igamberdiev, 1985). Although the quantum laws are time-reversal invariants, a contradiction appears if two measurements performed by a single observer, and described according to these laws, are performed in two opposite directions of time. This contradiction leads to bringing forth the concept of an observer's private time, and then to building up a temporal parameter common to several observers from their private times. Time asymmetry turns out to be a consequence of the latter construction (Bitbol, 1986). The concept of time flow as a consequence of quantum measurement is developed by Mensky (1993).

The 'energy-time' uncertainty ratio can be considered as a complementarity ratio between time and alteration. In this ratio, time appears as the time of the observer but not of the quantum system (de Broglie, 1982), which leads to the impossibility of formulation of the Hamiltonian for this ratio. Possibilities of disturbances and bifurcations in the system arise from this ratio. Irreversibility of time in quantum mechanics appears to be the consequence of subsequent measurements at the stage of information gathering on the whole sequence of outcomes (Dicke, 1989). Branched evolutionary processes lead to the actual irreversibility, which contradicts the formal reversibility of Schrödinger's equation (Toyozawa, 1989), i.e. irreversibility arises as a symmetry-breaking at the macroscopic level and is connected with bifurcations. The latter can therefore be considered as the precondition for irreversible development in ontogenesis and evolution and the reason for the complication of organization.

The original approach to understanding of time was drawn out in "the causal mechanics" of N. A. Kozyrev (1991). He considers the transition from the cause to its result as a basic event on which the conceptual basis of mechanics can be built. According to Kozyrev, the transition from the cause to the result being an initial irreversible process is realized as a jump through the "empty" (in our consideration - imaginary) point. This can be actually compared with the quantum theory of measurement in which the reflection to real numbers is realized. The speed of transition from cause to result, according to Kozyrev, is described by a pseudoscalar and could be connected with the finite speed of "a jump" through the "empty" point. In our approach it may correspond to the time of relaxation of a measuring device.

In the direction of the time flow an absolute distinction between the past and the present is reflected in the similar absolute distinction in the symmetrian properties of space which is realized not in the differences in the spatial directions, but in the absolute distinction between the right and the left. The flow of time is described by the value which determines the linear rate of turning. Kozyrev proposed that life uses the flow of time as an additional source of energy and that the optical dissymmetry of biological molecular structures (of nucleic acids, proteins, etc.) corresponds to the actual irreversible processes in living systems, to high "density of time" in biological systems. "The density" of time in Kozyrev's conception may correspond to the intensity of irreversible processes, i.e. of the reductions of potentialities, which influences on other processes by the non-force way (we may correspond this to the influence via EPR-correlations). The possibility of a connection through time in quantum mechanical paradigm we can explain as a connection via EPR-correlations, i.e. as the effects of a wholeness, and EPR-correlations themselves are the result of the reduction of potentialities (i.e. of time in general sense).

In the spatial region where irreversible process takes place, "the density of time" is changed, and a non-force action of one process on the other without contact by physical forces is possible. This was demonstrated by the experiments conducted by Kozyrev with rotating balance. Irreversible process absolutely separated spatially from the balance (i.e. evaporation process separated from the balance by a wall) nevertheless turns the balance. Active properties of time (its 'flow' and 'density') connect all events in the world into a total wholeness and can realize the interaction of different phenomena without causal (material) connection. In Kozyrev's theory the irreversible process changes "properties of time" (and vice versa - anisotropy of space causes irreversible process), generates dissymmetry and the effects of wholeness. This is reflected in biological systems in their dissymmetry and chirality. The degree of "the density of time" generates the complexity, hierarchical structuration, i.e. the decrease of entropy.

Some fruitful ideas in Kozyrev's conception are expressed in inadequate way and many of his conceptual innovations are not clear and difficult for interpretation. Translation of these ideas into the language of quantum measurement theory may clear up some his thoughts and develop them in positive direction. Understanding of the temporal process as a basic event for the description of the Universe and non-derivable from something else is the main suggestion which can explain fundamental symmetrian properties of space. From this point of view time represents as an internal process of actualization.
Intensive actualization process in living systems corresponds to their complex molecular, metabolic and morphologic spaces.

6. METABOLIC ORGANIZATION AS A CONSEQUENCE OF SYMMETRY-BREAKING

What is a background of metabolic organization? The formation of an alternative product in enzymic reaction because of the non-absolute specificity of the enzyme is a direct consequence of the dissymmetrization which basically is derived from the non-absolute character of QND measurements. This possibility of appearance of a void within non-equilibrium biological organization can be an initial point of further informational growth realized in the complication of hierarchical organization. Therefore the dynamical organization of biosystems is characterized by the possibility of appearance of a functional void within biological cycles. Functional voids are symmetry-breakings which counteract within the system (Marijuán, 1995; Alves and Marijuán, 1995).

The separation between the direct and reverse routes of biochemical reaction, one being linked (coupled), whereas the other non-coupled with the pool of certain (often energy-rich) compounds, results in the symmetry-breaking and in the arising of "the inequality" between the direct and reverse pathways. Consequently, the separation of the direct and reverse reactions leads to the generation of elementary metabolic substrate cycle. Reactions connected with the significant changes of free energy are preferable for the generation of such cycles. The realization of the direct and reverse reactions by two different enzymes leads to the transformation of initially linear pathway into the cyclic one.

The initial uncoupled structure of futile cycle seems to be very disadvantageous, but the transition to the hierarchical organization with strongly coupled reaction networks converts it into a powerful mechanism of reciprocal regulation of the direct and reverse metabolic pathways. The allosteric and covalent modification are the most effective means for the reciprocal regulation of two enzymes forming the futile cycle. They result in the effective regulation of the direct and reverse routes in such a way that these reactions become separated in time and the energy loss is minimized (Koshland, 1984).

The logic of futile cycle transformation into metabolic cycle was considered in our previous paper (Igamberdiev, 1994). The enzymes catalyzing correspondingly the direct and reverse reactions are distinguished (at least slightly) by their specificity to their substrates. This leads to the generation of bifurcation in one branch and consequently to the appearance of the alternative pathway of metabolic conversion. The latter can result in the formation of a compound identical to the initial substrate. Therefore the futile cycle subsequently unfolds into the complete metabolic cycle.

When a certain subset of a substrate set of the catalytic system realizes the function of a matrix which determines the formation and reproduction of this catalytic system, the structure arises defined as hypercycle, It can be considered as a generalization of the selfreproducing metabolic system. Hypercycle corresponds to the appearance of internal invariants within the system which are conserved during its reproduction. Low energy dissipation in the recognition, as well as in the reparation and editing processes, ensures the stability of the hypercyclic structures.

The emergence of reflectively autocatalytic sets of peptides and polypeptides is considered by Kauffman (1986) to be an essentially inevitable collective property of any sufficiently complex set of polypeptides. The participation of nucleic acids provides a new means to select for peptides with useful properties. It becomes evident that the self-replication is an emergent property arising from local interactions in systems that can be much simpler than it generally believed. This property is a result of a spontaneous dissymmetrization arising from internal possibilities of autocatalytic sets.

7. GENERATION OF MORPHOLOGY

Morphological structure of biosystems is based on their metabolic organization. This determination is connected with the symmetry breaking processes in metabolic pathways which are considered as the main precondition of generation of morphogenetic information.

The kinetic parameters of metabolic reactions provide spatial geometric effects, and the structures appear as morphological fixations of kinetic processes. The cyclomeric concept of Petukhov (1987) claims that the biochemical cycle being a system of incomes and outcomes of certain compounds can be defined as an axis of symmetry relatively to which biological structures are organized. Even insignificant changes in the parameters of cycles can lead to the essential morphological reconstructions. Morphology is formed by the stable trajectories of the formation and deposition of compounds formed in biochemical cycles. The formation of new cycles leads to the overbuilding of new metabolic trajectories, and this corresponds to morphological changes. Regulators of growth and development via influence on bifurcations make it possible for the system to transform into a new state. Under their influence the system becomes more dissipative (consequently less stable) and can more easily be transformed.

Thus, morphology is a result of the temporal and spatial organization of matter and energy flows in biosystems. Morphological transformations occur via changes of organization of these flows. This results in the transformations of coordinate scales describing biological forms (Thompson d'Arcy, 1917). The degree of curvilinearity of 'the space of biological forms' is determined by the periods of cycles' turnover and by the differences in the rates of reactions providing depositions from the cycles. If the deposited compounds can turn into reverse transformations, oscillations are possible, but if they turn into the insoluble form, they participate in the construction of rigid skeleton. The formation of morphological structures is a result of interference between concentration oscillations of compounds participating in the structure formation.

The morphology being a reduction of potentialities of the metabolic system is a projection from the multi-dimensional space of kinetic equilibria and processes into the three-dimentional space. Alterations of the time intervals of the cycles (i.e. changes of cyclic symmetrian characteristics) can lead to the changes of such projections which results in the modifications of morphology. The morphogenetic field operates in the space of physical fields, and the metabolic cycle as being a primary morphological generator provides the conditions of structure formation.

The problem of morphogenetic information cannot be reduced only to the linear information of the genetic code. It was proposed that DNA may be a source of coherent photon storage, and besides the genetic information it can be a carrier of the information for 'pattern recognition' (Popp, 1989). This may be realized via coherent interactions in DNA-sequence-specific biophoton transfer. The coherence of biophotons may form 'Gestalt'-information, essential for morphogenesis. Ultraweak or even "non-force" (according to the quantum Aaronov-Bohm effect) three-dimentional field, provided by different topological structures in DNA is proposed for explanation of the structure generation (Zhvirblis, 1993).

The problem of morphogenetic information was stated for the first time by A. G. Gurvich who considered non-equilibrium macromolecular constellations as a possible source of biological informational field. These constellations may be connected not only with DNA. Electromagnetic bio-information may be generated via extinctions of photons in the enzymatic reactions connected with changes of free energy and generation of free radicals during enzymatic conversions (Gurvich and Gurvich, 1948). It was shown that light-emitting processes are connected with normal reactions in living tissue, and peroxidases and other enzymes utilizing peroxides and active oxygen forms are involved in such a process. The extinction is increased before cell division and morphogenetic process, and it is most expressed in highly developed species. Therefore the ultraweak photon emission may be proposed to be a biological phenomenon, which is a carrier of morphogenetic information (Popp, 1989).

The separations of the direct and reverse metabolic flows leading to the transition from the simple uncoupled processes to the integrated strongly coupled networks, the depositions from the cycles and the appearance of rhythms of concentrational oscillations are the basical events determining the temporal and spatial organization of biosystems. Topological reconstructions of DNA and enzymatic reactions of oxidative metabolism may provide low energy informational interactions via electromagnetic extinctions. This can result in the coordination of different metabolic fluxes which provides three-dimensional pattern of morphology of the whole organism. Low-energy influences on bifurcations provide cyclomeric transformations which alter dissymmetric relations between the direct and reverse routes within the cycles. They interact with high-energy non-equilibrium processes via the transduction-amplification cascades realized in cyclic processes. The low-energy influences themselves are connected in the total informational set directing morphogenetic events, and the minimization of disturbances in this set provides the effects of non-locality which tie system's parts into the whole entity.

8. CONCLUSION

Life is a specific form of existence, internally determining itself in the Universe. It can be defined as the self-organizing and order-generating activity of open non-equilibrium systems based on their semiotic structure. Biological activity corresponds to specific informational organization which provides high energy interactions connected with non-equilibrium states, low energy interactions being a background of the recognition processes and realized as quantum non-demolition measurements, and non-force (no energy) correlations of quantum mechanical nature which determine operation of living system as a whole entity.

Biological organization provides the 'spontaneous' activity of life which corresponds to the specific understanding of time as an internal process of actualization. Intensive actualization process in living systems corresponds to their complex molecular, metabolic and morphologic spaces.

The emergence of a new order cannot be recursively calculated: The generation of bifurcations in living systems determined by quantum uncertainty appears to be the physical basis of this symmetry-breaking process. It becomes internalized within the system and results in 'the self-growing Logos' (Herakleitos) realized in the development of complex informational network of biosystems.

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