Semiokinesis — Semiotic autopoiesis of the Universe

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> Thou shouldst unite things whole and things
> not whole, that which tends to unite and that
> tends to separate, the harmonious and the
> discordant; from all things arises the one,
> and from one the all things. (Heraclitus:
> Fragment 10)

Movement as a dynamic representation of signification

Signification and movement in physical space-time

Any description of movement in physical space-time contains the paradox formulated by Greek philosophers Parmenides and Zeno as a contradiction between the description of space consisting of the infinite number of points and the possibility of passing them in finite intervals of time. The paradox follows from the representation of a whole event as a finite set and is connected with the semiotic (i.e., non-physical) origin of any movement. The starting point of movement was defined by Plato as *exaiphnês* (instant, sudden) in his dialogue 'Parmenides': 'Then the one, if it is at rest and in motion, must change in each direction; for that is the only way in which it can do both. But in changing, it changes instantaneously, and when it changes it can be in no time, and at that instant it will be neither in motion nor at rest (156e)'. Thus, movement always is signified ('semiokinesis'), it is initiated by a significative action being its real cause which precedes movement and is absent at the time present in the point occupied by the moving object.

The moving object (Zeno's flying arrow) is embedded into physical space. At a concrete finite moment of time, the arrow is present at a certain point of space, and at the same time it is absent there, passing the semantic field signified by the person who flings it (the shot). Time

introduces that contradiction into the real world in a way that contradictory statements 'the arrow is at point A' and 'the arrow is at point B' are separated by the time interval. The relation of shot and arrow is a semiotic relation of signifier and the signified object connected non-locally but separated in physical space via time flow. When time is introduced, which separates contradictory statements, we face infinite regression avoiding simultaneous existence of opposite definitions. A signifier (shot) initializing the movement realizes the *exaiphnês*: kinesis starts not in time but as an instant setting of free will: following Schopenhauer we can say that the operating in a potential field *Wille* establishes its actual subset of *Vorstellung*.

The physical representation of kinematic paradox may be an assumption of space interval consisting of both real and imaginary points. Movement could pass through both types of them. The imaginary points represent some potential reality having no identification in real world whereas real points belong to the actualized world (Florensky 1991 [1922]). So, the structure of space is complex and reflects the existence of both the potential and the actual realities. Following Florensky, imaginary points in the time-space continuum serve to glue together the separate points of the Universe into the whole entity and reflect the semiotic origin of physical space-time structure: physically separated objects, being non-locally connected within the set of complex numbers, are semiotically united. For the 'imaginariness' which expresses a wholeness (for its referential object the place in real existence cannot be determined), the finite formula, i.e., the object expressed by real numbers, can be put into the symbolic signifying correspondence. The latter is a sign by means of which the unavoidable difference between finite and infinite sets is abolished. Signification is proposed to be a result of a transfinite over-logical action, in which a relation between finite and infinite sets, i.e., between wholeness and its model, is established.

From here we conclude that movement cannot always be in the actual, it should jump between the actual and the potential, non-locally returning to that who *signified*, i.e., initiated it by reducing the field of potentialities. The reduction of the field of potentialities (decoherence, actualization) is isomorphic to a quantum measurement described by the spontaneous collapse of wave function.

Logical and physical complementarity

The paradox of movement can be represented in actual kinematic description by introducing the complementarity principle, which suggests that

self-excluding descriptive classes are used in different pictures of the same reality. They correspond to the different moments of actualization within the reflective semiotic structure similarly like a word as signifiant relates to the same word as a metaphor (i.e., as a signifiant of the former signifiant taken as a *signifié*).

The complementarity is based on the fact that for reproduction of a holistic (total) phenomenon in the system of signifiants, the self-excluding, complementary classes of signifiants are necessary (Nalimov 1981 [1974]: 53–55). An infinite event is reflected into finity as a potentially infinite set of finite formal systems reflecting it. In modern logic, Gödel's incompleteness theorem is a relevant representation of Zeno paradox claiming that any sufficiently rich formal system is incomplete, it contains statements which cannot be proved inside the system, but they can be enumerated (encoded) in our representation of the system. The Gödel's theorem states that in any consistent system, which is strong enough to produce simple arithmetic, the formulae exist, which cannot be proved within the system. A system of axioms can never be based on itself since the statements from outside the system must be used in order to prove its consistency. Complementarity is represented as a possibility to describe a holistic state by different projections of this potential state. The most striking example of such a complementarity is the complementarity between the Gödel formal system and the Gödel numbering (the system and its embedding): in this structure the 'text in text' is complementary to the initial text. It causes growing of text via Gödel's self-reflective loop: Gödel's enumeration (which is a construction of the text in text, i.e., the embedding) can be reached by different complementary ways.

The quantum complementarity formulated by Bohr and Heisenberg is a physical representation of the logical (Gödelian) complementarity. The Gödelian embedding results in uncertainty — this is the main point of the logical complementarity. The quantum uncertainty principle claims that it is impossible to define strictly the position and impulse of a particle simultaneously, or to fix certain energy in a very short period of time necessary for its registration. The reason for this is that the measurement process is a representation into the represented (measured, observed), thus, quantum measurement produces an infinite recursion (Rojdestvenski and Igamberdiev 1999). The measuring device is a part of the system included in it as an embedding. The measuring system with its representation is a clear case of the Gödelian enumeration where the representation (a metalanguage statement) is included in the system. Reduction from the field of potentialities assumes the existence of alternative realizations that represent different projections into real numbers. Quantum complementarity arises as a set of these different projections

that cannot exist simultaneously where contradictory states generate the appearance of uncertainties in the coordinate/impulse or energy/time observables.

In modern logic, the embedding of meta-statement is included into a framework of the topoic logic as a special arrow (a subobject classifier) within the category (Goldblatt 1979: 81). Following topoic logic, the theory of quantum measurement should be based on the inclusion of the measuring device into its framework as such a subobject classifier. A topos is defined as a space with variable topology and a fixation of contradictory statements within the topos is possible by means of its intrinsic logic.

Measurement as a physical correlate of semiosis

An actualization takes place from the potential field, which is reduced. The potential field is a quantum vacuum and its state is described by the complex and hyper-complex numbers being a superposition of different opposite states existing potentially at the same moment of time. Before actualization this contradictory state allows a particle (e.g., photon) to go through both splits of the interferometer: this is possible as occurring in the potential, not in the actual state. After that passing, the particle is measured (actualized) at a certain point of the space. The measurement process is always scooping up from the vacuum, which is similar to actualization of the Kantian *Ding an sich*.

Measurement assigns the specific meanings to the indefiniteness; thus it is isomorphic to the signification process (Igamberdiev 1992). The reduction is represented as a projection operator acting on the wave function. It is irreversible and is incompatible with the Schrödinger equation. It halts the unitary development of the wave function, which is then immediately restarted with the new ('reduced') wave function (Dicke 1989). Measurement as a reduction of infinity into finity cannot be reversed and consequently the coherence of a state cannot be restored as it was, after it is destroyed by the measurement (Mensky 1996).

The measurement process is a perpetual interaction between 'known' (actual) and 'unknown' (potential) being a reduction from the field of potential states to real ones. Since this process is destined to be an indefinite interface between countable finite states and uncountable infinite states, it is formalized only as a paradox (a self-referential form of paradox). However, a paradox can be expressed as infinite regression that can be used as evolutionary process. It leads to the idea of a dynamically changed interface between the two kinds of state (Gunji 1995). The measurement

process is expressed as such a dynamically changing interface between the non-measured infinite states and measured finite states (Gunji and Toyoda 1997).

The external measurement is realized by the observer. Via the measuring device he/she actualizes the micro-level. The internal measurement is provided by measuring devices without the external observer, it is the basis of life and biological system operation (Rosen 1991; Igamberdiev 1993, 1998). The concept of internal measurement becomes familiar in theoretical physics: the interference pattern is demolished not only when we observe particles, but also when the information within them is encoded with which path is taken. Moreover, the internal labeling of paths does not even need to be read out to destroy the interference: all that is needed is the option of being able to read it out (Dürr et al. 1998).

Semiotic substantiation of fundamental constants

The point of equality of measurement and its result

The result of measurement is represented in modern physics as decoherence, a phenomenon leading to the appearance of classical features of quantum systems. The measurement and its result are connected in such a way that satisfies the condition of consistency: the expression of this consistency is the existence of invariants being fundamental world constants. The fundamental constants appear as a correspondence of actualization to the consistency of the actual world.

The reflection of the infinite part via quantum mechanical reduction determines the actual parameters of the world. The potential field (vacuum) is a superposition of opposite states. We can introduce a class of specific R-functions (operators) ('R' is from 'reduction'), which translates infinity to finite patterns, and P-functions ('P' from 'prehension' following Whitehead 1929) translating finite pattern to the infinite set. The concrete finite parameters exist which define the limits and bounds of finite patterns (e.g., constant c in the finite pattern of velocities). A choice of the definite set of constants is determined by the consistency and by optimality of all of them.

The human reflection, i.e., the human measurement of itself, possesses the trinitary semiotic structure introduced by Peirce as 'object — sign — interpretante' and discovered by Freud in psychology (*Id — Ego — Superego*). It can be reduced to the recursive Boolean scheme resulting in the appearance of strictly defined fundamental values characterizing human behavior, e.g., the golden section constant and

patterns of musical interval (Lefebvre 1990). Such an unfolding of reflection to the recursive schemes was described in a previous article (Igamberdiev 1999a). Reflection itself is a non-formal process, but symbols resulting from it can be organized in the formal system forming a specific mapping in which the recursive ('calculation') procedures can be realized, and the set of these mappings (i.e., of logical elements constituting a formal-logical system) underlies any concrete semiotic organization. The appearing fundamental values reflect the mean value of the majority of voices under conditions of uncertainty, i.e., they reflect the optimal way of the reduction of uncertainty or general quantitative regularity in human choice (Lefebvre 1995). The appearance of golden section value in this model is isomorphic to the process of gradual minimization of work lost by a heat engine system (Lefebvre 1992). The structure of the reflective choice provides operation of human consciousness as a filter during its action with the meanings of words that emerges as a result of measurement by context (Nalimov 1981 [1974]).

Considering fundamental constants of the physical world we return to the fundamental question of Albert Einstein whether God had any choice in the creation of the world. We can consider the Universe as a self-reference of its Logos: during this self-referential process the actual part of the world is restricted ('filtered') through introduction of certain fundamental values (constants). These constants should provide observability of the Universe and the possibility of free choice at higher levels of self-reference (the anthropic principle).

The following statements are discussed below:

- Finite gravitation constant follows from the reduction of superposed potential states during measurement,
- Finite velocity follows from the solution of measurement paradox,
- Finite quantum of action follows from the consistency of measurement process corresponding to causality (conservation laws).

Thus, our initial statement is that the fundamental constants divide infinite and finite parts of the world representing an interpretante (the 'measure' of Heraclitean ever-living fire) of the Logos in the space-time structure of the Universe. The three fundamental constants (and the three fundamental parameters: mass, length and time) arise from the trinitary reflective structure. A potential state is characterized by some mass (curvature) value (which determines its actualization). An actualization proceeds with finite velocity and 'packed' in quanta of action. Finite part is coherently embedded into infinity only at certain values of fundamental constants. Therefore, the fundamental constants are invariants of the functional of reduction of the sign (Logos) of the Universe into the actual

physical world, appearing as a result of the self-reference of Logos. The recursive part of the world, which can be described by mathematics, is self-defined within the whole set of potentiality by the fundamental length, time and velocity. Such a paradigm is not equivalent to the Pythagorean paradigm of search of fundamental constants as ideal, apparent and non-redundant solutions of general 'world equation' (Wilczek 1999), they appear rather as the parameters of 'fixed measures' according to which the Heraclitean fire (*Pyr*) is kindling and extinguishing (Heraclitus: Fragment 30). 'An unapparent harmony is stronger than an apparent one' (Heraclitus: Fragment 54).

The influence of measurement on the measuring device

The fundamental constants divide the world in two parts: one being recursive (in which physical laws are operating), and the other is non-recursive (where algorithmic operations are impossible) (Conrad and Liberman 1982). The behavior of the one part is more or less derivable by computation from a limited set of physical principles known to be valid in very simple systems. The second part cannot be reduced to these fundamental principles. The physical limitations of computing determine the real limits of recursive mathematical description (Liberman 1979; Conrad and Liberman 1982). Life forms and acts on the interface between the computable and non-computable parts, which is the inter-ference between the two influences: the influence of the measuring device on the result of measurement and the influence of measurement on the measuring device.

If one (computable) part is taken separately, time (determined as the 'entropy time' by Boltzmann) is associated with physical movement of particles. The other (non-computable) part determines the non-local unity of all points of the Universe and provides the semiotic time (its definition arises from St. Augustine). The semiotic picture of the word should be constructed in such a way that both times are complementary reflected (as in real world). The idea of the two times arises from Aristotle who defined in *Physica* that there is the time which is measured and the time by which we measure: 'The time marks the movement, since it is its number, and the movement the time. Time is a measure of motion and of being moved, and it measures the motion by determining a motion which will measure exactly the whole motion, as the cubit does the length by determining an amount which will measure out the whole (4: 12)'. Time in Heisenberg's uncertainty relation 'energy-time' is the time of the observer by which he/she measures the energy of microsystem. The time flow of

microsystem is explicitly contained in its velocity and energy. The correspondence or certain equality of observer's and microsystem's times could be reached on the objective-subjective interface being possible only at the certain values of fundamental constants. Thus the latter results from an equilibration at the condition of uncertainty. Time as a reduction of potentialities is a construction, which therefore includes these both time constituents (the entropy objective time and the semiotic subjective time).

Measurement and gravitation

Quantum vacuum is a superposition of the potentially existing contradictory states. According to the hypothesis of Penrose (1989), the two states existing potentially as a quantum superposition might be judged (with regard to their respective gravitational fields, i.e., their respective space-times) to be too different from one another for them to be able to coexist in quantum linear superposition. Accordingly, reduction would have to take place at that stage. Now we regard superposed widely different states as unstable: the greater the difference, the faster would be the rate at which reduction takes place. We should introduce time whereupon a superposed state would spontaneously jump into one localized state or the other.

We can consider gravitational self-energy of mass distribution, which is the difference between the mass distributions of the two states that are to be considered in quantum linear superposition. Reduction is realized in an interaction with the measuring device — the latter represents a coordinate system limiting the potential field. Its curvature (gravity) causes a certain type of reduction. The complete theory of the putative reduction process would have to be an essentially non-computable scheme. The definition of the time-translation operator for the superposed space-times involves an inherent ill-definedness, leading to an essential uncertainty in the energy of the superposed state which, in the Newtonian limit, is proportional to the gravitational self-energy of the difference between the two mass distributions. This is consistent with finite lifetime for the superposed state, in agreement with gravitationally induced spontaneous quantum state reduction (Penrose 1989).

Measurement and finite velocity

We have mentioned that the structure of a vacuum is self-contradictory. Actualization results in this self-contradiction realizing one possibility from

many of them. But the measurement itself remains self-contradictory before we do not consider it as occurring with finite velocity. Otherwise it will contain contradictory statements at the same moment of time.

Unfolding the contradiction of movement via finite velocity of observation propagation was introduced by Gunji (1994) who emphasized that describing a system in which internal detection proceeds with a finite velocity is always destined to end up with a form of self-contradiction. Finite velocity in measurement provides decoherence that may be described as a continuous (prolonged in time) measurement. Decoherence of a continuously measured system is completely determined by the measurement readout, i.e., by the information recorded in its environment. Information determines the back influence of the measuring medium onto the measured system. This paradigm may be derived from the ideas initially expressed by Kozyrev (1991 [1963]) who proposed that irreversible time flow may lead to violation of the preservation of impulse moment, to the origin of optical dissymmetry in living beings, and to the appearance of the constant of fine structure. It may also be compared with phenomenological definition of time as a basis of coincidence between the phenomenon and its description, between the spontaneousness of consciousness and reflection.

Semiotic irreversibility of this understanding of time is also expressed in such a phenomenon that the path from sign to object is not the same as the path from object to sign (Peirce 1955 [1906]). Time represents as a consequence of passing the limit defined by a thing during the thing's signification. The exhaustion of a system leads to its evolution via dialogue between text and hypertext. Time is the difference of some thing from itself (Mamardashvili 1993), i.e., it is a reflective structure. The difference of A from A appears when A is both statement (object) and metastatement (sign). Reduction of metastatement to statement and prehension of statement to metastatement are both parts of semiotic cycle (Gödel's reflective loop). In the semantic paradox 'I am lying', 'I lying' is not equal to I saying 'I am lying': it is a self-interacting hypertext.

In Gunji's model of measurement, a certain transition rule is used recursively along time. In order to resolve the paradox, the form of a fixed point is identified with a domain equation and a reflective domain is obtained; however, any resolution is destined to be relative. Solving and obtaining a reflective domain is used as a new transition rule. Also, this process perpetually proceeds along time, and then the system perpetually proceeds while any solution is destined to be relative (Gunji et al. 1997). Finite velocity of observation propagation thus collapses into fractal space-time structure. This is an example of unfolding of non-local order in Bohm's sense to local order (Bohm 1980; Bohm and

Hiley 1993). The Universe, therefore, is a fractal structure resulting from the finite velocity of observation in the initial measurement that resulted in the Big Bang.

Measurement and minimal quantum of action

The potential field always generates a temporal actualization via virtual particle-antiparticle pair formation as a mode of its own fluctuation. This depends on the density (curvature) of the vacuum: when it is higher, the generation of these pairs is more probable. Such a generation should satisfy the condition of consistency, i.e., it should follow the conservation of energy law. Otherwise the symmetry of time inversed will be violated, and the condition of computability of the physical world will not be satisfied. The idea of the energy conservation law as a physical manifestation of consistency is quite old: it was clearly stated by Driesch (1924). The energy conservation law corresponds to the symmetry of time reversal (Noether's theorem) which is inherent in the physical description of the world based on computability of physical laws and, therefore, their independence of a concrete moment of time.

   According to Matsuno (1995), the condition of energy conservation should satisfy a certain minimal quantum of action. It underlies the consistency and recursivity based on special symmetry of time reversal and physical reversibility of computational part of the world, since irreversibility appears only in quantum measurement. This generates the energy-time uncertainty principle from both measurement and conservation law. The minimum time interval for measuring conservation laws internally remains finite and non-vanishing (to jump through an imaginary point of vacuum space consisting of complex and hypercomplex points). The consistency is expressed in the symmetries of the Universe and reflected in conservation laws.

Autopoiesis: Universe, life, and consciousness

Evolution of the Universe as quantum measurement

What is the temporal evolution of the Universe and what is the initial point preceding the Big Bang? In our semiotic analysis, evolution of the Universe is a self-representation of its Logos in the space-time structure of the Cosmos. The initial point is not the actual point, it is a potential point (vacuum) characterized by superposition of different possible states that

could be actualized. Following Penrose (1996), the premise of evolution of the Universe could be a collapse of alternative representations of Logos when the two potential curvatures overcome the limit defined by the fundamental mass.

Our Universe being one of many bowls (universes) in the inflationary model (Linde 1994), possesses its own mass (reflecting evolution of its curvature). In the initial point the triadic structure of the Observer, Device, and Object (corresponding to Consciousness, Life, and Objective World — Universe) are coincident in one point, and the fundamental constants appearing as parameters of optimal mode of this initial reflection-measurement (that constructed our Universe) have determined its visible structure. During evolution of the Universe, its every point reflects all other points as well as the initial point preceding the Big Bang. In a certain sense (in semiotic time) they all are the one point: the Omega point of evolutionary process described by Teilhard de Chardin (1965) is equal to the Alpha point of the Big Bang. This point cannot be reached via movement in space. It can be reached via the non-local movement, via the movement through the embeddings.

Thus, autopoietic evolution of the Universe is semiokinesis (or, following Bohm, holomovement). According to Bohm (1980), on the level of potentiality (of the vacuum state preceding actualization) the Universe has an implicit order, which explicates itself in its evolution. In the actual Universe (Cosmos) each point, therefore, reflects all other points, and everything is embedded in its part and in other things (bootstrap). Mind and matter have no causal connection, they are the same, being the embeddings of different levels. Matter is the correlate of mind, its *signifié*. Decoherence functional depends on the initial density matrix of the Universe. According to Bohm, trajectories arise from wave structures. The whole of geometry would be invariant to unfolding transformations. The order of space (and ultimately of time) is flowed out of a deeper implicate order of the pre-space (the vacuum field).

According to Linde (1994), different vacuum states correspond to different types of symmetry breaking between fundamental interactions and, as a result, to different laws of low-energy physics. Each bowl corresponds to the alternative laws of particle interactions. Different bowls in his model may possess different values of fundamental constants, but some of them may not be suitable or even possible according to the anthropic principle, or they may be excluded by previous evolutions. Thus, holomovement in which 'beginning and end are common' (Heraclitus: Fragment 103) enfolds as a realization of semantics of possible worlds in the framework of Hintikka (1989). Every possible world has its own intrinsic logic with its own axiom system (which

corresponds to its own system of fundamental constants in physical representation).

Logical and physical coherence

Reflective domain arising from the description of the infinity — finity relations and being a basis for construction of the system with regulation is expressed as a structure of Gödel's reflective loop. It was determined by Hofstadter (1979) as a 'Strange Loop' structure. It possesses two ways ('way up' and 'way down' in a Heraclitean sense; they are the same in wholeness, but their representations are different) which can be described by introducing the two arrows (functions). R-function is the reduction function, P-function is the prehension function. The reduction function determines concrete pattern of decoherence. The prehension function is realized via search of new coherent states (i.e., new coordinate scales). The reflective loop structure appears when systems turn back on themselves. The reflective loop phenomenon occurs when we are moving upwards (or downwards) through the levels of some hierarchical system, we unexpectedly find ourselves right back where we started. The reflective loop generates tangled hierarchy that includes the appearance of recursivity and Gödel numbering. In a physical one-level picture it degenerates into the cycles of interactions between the 'objective' particles in time which becomes an independent variable.

Reduction is described by the R-function (operator) that is non-determined in quantum mechanics. It becomes defined in reflective (e.g., living) systems and may be connected with the selection of optimal state (Stapp 1993). The boundary of finite-infinite should satisfy the minimum uncertainty condition (Mensky 1997). Maximal consistency after measurement corresponds to the optimal control within the system.

Hierarchy of the Universe in this picture is a consequence of an infinite recursion followed from the reflection of Logos generating complex interfaces between being-possibility and being-actuality. It includes both reductions as decoherences in quantum measurements and prehensions established via search of coherent states. The phenomenon of quantum coherence refers to the circumstances when large numbers of particles can collectively cooperate in a single quantum state that remains essentially unentangled with its environment. Coherence refers to the fact that we are dealing with a single quantum state. Coherent state follows from the non-local origin of different particles; it is their history kept as a potential connection via coherence. This reminds one of Lotman's (1990) formula 'language is code plus its history' (i.e., its code plus its unique

language game that cannot be repeated in the same consistency). Every physical state is 'the observed plus its history'. Historicity of significa-tion corresponds to Hegelian 'memory as sign-creating activity' (Hegel 1971 [1830]: 213). The Hegelian dialectical unfolding via triads (e.g., Being — Notion — Idea) also defines the levels of creative recursion expressed in the specific language of his philosophy.

Coherent events form coordinate scales. We are reminded of the geometric approach to morphology: different biological forms appear as a result of transformation of coordinate systems (Thompson d'Arcy 1917). When a curvature change is introduced, the scale collapses and a new coherence is formed (this procedure is similar to taking limits in Poincaréan dynamics). It corresponds to the formation of meta-statement A expressed as appearance of a reflective arrow that reduces the potential field. The formation of metastatement within formal system (embedding) can be defined as an establishment of logical coherence. When A becomes a metastatement, nothing is changed in the formal system and at the same time all is changed: probability spectrum is changed, all is glued together, 'prehended'. The construction of the Gödel number is that which is defined as '*exaiphnês*' in Plato's dialogue 'Parmenides'. This is an initial point of infinite recursion of the inter-face between finite and infinite: an increasing complexity is assigned to some configurations only because they are interpreted by a discrete metaprocedure of placing text in text such as selection, combinatorial event, establishing of scale correspondence, interaction between different programs. This is a referential act, and appearing description enables the non-trivial increase of complexity.

Life

The essence of life is self-reference. A living being possesses a self-determining adaptive loop on the edge between classical determinism and quantum indeterminism that can jump out of its own system. Aristotle (*De Anima* 2:1, 412a) determined life as a body's feeding, growth and decline reasoned in itself (*di'ayton*). Following his approach, the definition of life was introduced corresponding to a framework of modern science: 'Life is a self-organizing and self-generating activity of open non-equilibrium systems determined by their internal semiotic structure' (Igamberdiev 1996: 129). In the frames of this definition, a living organism resembles the world as a whole rather than any finite object of the world, which rises to Bergson's ideas in his *L'Évolution Créatrice* (Bergson 1917).

In Aristotle's view, everything which is changed may be divided (*Physica* 7: 5, 257a): therefore, living objects (which change according to their internal determination) should be complex, one part moving, the other being moved. The moving part is an actual form (*entelechy*) subdivided into two parts, one being entelechy as a possession of knowledge, and the other entelechy as an actual exercise of knowledge. The part being moved is matter (a substrate) that is only a possibility of realization of form (*De Anima* 2: 1, 412a). Therefore, life possesses the property of wholeness that is considered as a background for biological movement and development. This is reflected in the hierarchical structure of living organisms. The higher level of organization 'moves' the lower level, which actually accomplishes the movement.

According to the ideas of modern biology, 'the entelechy as a possession of knowledge' is expressed in certain structures, e.g., in the genetic code. It is present even when visible features of life ('actual exercise of knowledge') are absent, e.g., in dormant seeds, and also undergoes transition to future generations. Heredity, according to Aristotle, is not the transfer of ready-made forms, but the transfer of patterns (i.e., of information), which acquires a certain sense in the whole system of developing organisms (during accomplishment of the actual exercise of knowledge). The development of biological objects is based on non-spatial (non-mechanical) movement (i.e., on qualitative changes), which is actually a realization of pre-existing possibilities in accordance with their determination by the entelechy ('as a possession of knowledge'). In this sense, irreversible time corresponds to the realization of potentialities within the system. Spontaneous activity determines the semiotic features of biosystems, that are realized at the level of the internal structure of organisms as well as at that of interactions between organisms.

Our further considerations will reflect the development of Aristotle's ideas in relation to modern biology. The biological code has its specific invariants (triplet structure, complementarity, four elementary letters) that could be derived from the model of reflection (Igamberdiev 1997). We could remember that the reflective structure in Lefebvre's (1990) model also generates triads of binary compositions forming combinations which number is multiplied by four (Igamberdiev 1999a), and this is directly deducted from the triadic reflective action. The similar generalized structures (square matrices of grouping of pairs of opposites corresponding to the temporal progression of the phenomenal world) are present in the Chinese 'I Ching' book and it may represent a general rule for establishing invariants through the unfolding of reflection (Merrell 1992). It can be followed in the genetic code model as a finite reflective

structure of Gödel numbers (that initially appears as a result of infinite reflection into finite). The letter (number) N (e.g., adenine) reflects in its complementary number N^- (e.g., thymine), then duplication of signs leads to the appearance of additional letters N_1 (guanine) and N_1^- (cytosine). The combination of these letters satisfying the principles of consistency, simplicity and optimality generates the observed structure of the genetic code. It is arbitrary in the sense of the Saussurean arbitrariness of sign, but it satisfies optimality principles of construction of Gödel numbers during Wittgensteinian language game. The pattern of genetic code can be explained on the basis of search of the optimal variant of reflective domain structure. Thus we have Peircean trinitary structure in a living system: (a) metabolic network, (b) genome as a signifying embedding within metabolic network, and (c) superposition of genome rearrangements as an interpretante of the genomic system. Following Aristotle (*De Anima* 2: 1) metabolic network corresponds to *hyle* (matter) of living being, genome corresponds to 'the *entelechy* as a possession of knowledge' and language game generated by genome corresponds to 'the *entelechy* as an actual exercise of knowledge'.

Thus, a biological system has its own invariants for unfolding in its space-time which results in generation of structures more complex than that of non-living forms. There is no algorithm that will take us from primary structure to tertiary structure directly, there is further no algorithm that will take us from tertiary structure to functional activity, or 'active sites' (Rosen 1991). They emerge through a process of morphogenesis. Kauffman (1993) claims that the occurrence of something like positional 'maps' and ordered spatial heterogeneities can be understood as generic self-organized properties in biological systems: thus, morphogenesis includes complementary interaction of digital information (encoding) with non-digital information (templating) which reads (decodes) code (i.e., realizes reflective action). Interaction between these two types of information non-recursively forms an interpretante for the semiotic system of a living being.

A physical basis of prehension in biological systems is quantum coherence (this idea rises in Gurwitsch 1923), and sequence of coherent structures determines computational properties of biological systems. In the previous article (Igamberdiev 1999b) I tried to work out how coherence provides computational properties in metabolic networks. The information based on specific recognitions triggering dynamical energy-driven processes appears as non-digital; the transfer of digital information is realized within hypercycles and corresponds to operation of the genetic code (Igamberdiev 1998). In the physical world infinity appears as a potential, in life and consciousness the potential coherently holds

as an actual, i.e., it operates by infinite limits. A biological system can assimilate the potential: this determines its possibility to emerge and evolve.

The genome is a language, which possesses an internal complementarity between text and its superpositions. The possibility of emergent constructing of text in text is the only reason of self-growing Logos, i.e., of the development and evolution. Complementarity means that text and hypertext cannot be viewed at the same moment: they should be separated by a time interval. It is the example of uncertainty between the system and its embedding. Overlapping genes, alternatively splicing sequences, RNA and DNA editing, introns, and recombination according to molecular addresses are the features of this hypertext generating a potentially infinite number of language games. The genome as a complete language exists as a complementary set of its alternative combinations. This 'existence' can be possible in potentiality, not in actuality, and this is a superposition, which is reduced during evolution. Holding of such a potentiality is some type of unconscious (in the Freudian sense) entity. Liberman (1979) was the first who claimed that a molecular computer could not work without molecular rearrangement of its text and predicted splicing before its discovery. Thus, the total 'true' genome is a superposition of contradictory arrangements, which generate one single arrangement in a concrete moment of time. An ambiguity in meaning is analogous to the quantum uncertainty principle in which it is impossible to define strictly the position and impulse of a particle simultaneously, or to fix certain energy in a very short period of time necessary for its registration.

The mobility of a genome is an example of semiokinesis. It corresponds to certain definite structure of the potential Gurwitsch's field (i.e., to the P-function of the system). In combinatorial genetic events, selection of a new combination is determined by curvature changes (collapses). It is not written in the genome. The shape of the enzyme is formed by optimal coherent scales within a molecule, which corresponds to 'minimum free energy' in electronic-conformational interactions. Topologically, non-equivalence appears at reaching critical point, which means catastrophe according to Thom (1983). Concrete modes of prehension in a biological system are still not yet recognized (R-transformations are more explored than P-transformations). We are still far from relevant understanding of the role of DNA curvature in prehension process realized in topological coupling of promoters, cooperativity and anticooperativity, reconstructions and rearrangements of the genome.

Thus, in life we face the genetic language with a distinct finite alphabet of the genetic code and potentially infinite language game. 'Eternity is

a child at play, playing draughts: the kingdom is a child's' (Heraclitus: Fragment 52) — these words of Heraclitus characterize infinity as the game of a child. Wittgenstein (1953) describes language game as an action in which we do not know the boundaries because none have been drawn.

Placing text in text is described as the Gödel enumeration. The text in text is a contradictory structure possessing complementary features. Self-reproduction is a creative process of placing text in text with following self-growing of this joint structure. Any evolutionary change also begins from placing text in text. This is possible because most of the genome serves for realization of such a non-trivial function. Moreover, even point mutation or deletion may be considered as generative if it is placed in the repeated (e.g., diploid) structure. This is the main reason that the chromosome number is doubled in cells. The doubling is a premise of metasystem transition, which includes duplication of the original system and the establishment of control over multiple copies (Turchin 1977). Thus, self-reproduction is an interpretation of two interacting texts within the wholeness of the two systems. For development, self-reproduction and overcoming the tendency to self-degradation, the complex system should be a part of a larger system in which it is included, and it should generate reflective arrows (Gödel numbers) (Neumann 1966). The reproducing configurations of biological systems are at a level that defines identity of these systems. This construction means the establishment of a configuration with a description that cannot be given in advance, for the reason that it is being defined just in this process. Thus statements of our metalanguage that reflect the ways configurations change cannot be given independently from the configurations themselves (Kampis 1996). The procedure of attaining these configurations is therefore a language game which rules are established during the process of realization of configurations.

Internalization via the genetic redundancy (insertion of a new meron in the system of holon according to the terminology of Barham 1990) is the main way of evolutionary process. It corresponds, for example, to the insertion of a new domain into the protein molecule. Insertion of the potential field into a space-time map formed by coherent events leads to actualization of contradictory potential states, e.g., different conformations of enzymes can exist being separated by time. This time of conformation turnover may be connected with useful work realized by the enzyme, i.e., with transformation of substrate into a product. Different states of genome are also its different conformations corresponding to different modes of existence of a living organism.

The selectionist paradigm represents the most understandable language in evolutionary biology. Even being in its frames (which could be

reasonable as it describes the selection similarly to the reduction in quantum physics) should realize that the two types of selection exist: in the potential and in the actual. If we assume only the latter, we get Darwinism in its strict sense considered as an extreme simplification of the selectionist principle. We should come to a broader assumption that selection is realized only on a quantum-classical interface, so it can happen not only in the space of actual forms. This takes off the initial contradiction between Darwinism and Lamarckism. Darwinism is a theory claiming the selection in the actual space, Lamarckism postulates the possibility of the selection in the potential field as it was comprehensively interpreted by Ogryzko (1997). The quantum mechanical approach provides explanation of sorting in the potential field via searching coherent solutions (the optimal coordinate scales). Stapp (1993) proposed that in biological systems the collapse location is based on selectionism. Really, the systems having consciousness realize collapse by selecting different decoherence patterns in the potential field. The unconscious biological systems are also selected not only in the actual but they can be selected in the potential as optimal patterns of decoherence in evolutionary process. This is not claiming of consciousness in organic life: it is simply a consequence of internal measurements, which are equilibrated in optimal decoherence pattern including all conditions of adaptive environment. Life optimizes the measurement process on a quantum-classical interface, so that the price of action is minimal.

Consciousness

Our analysis leads to the conclusion that the invariants of the real world may be deducted from the isomorphism between the potential (ideal, phenomenal) and the actual (physical, material) which is the semiotic isomorphism between the *signifiant* and *signifié*. This isomorphism being an optimized semiotic interpretante is based on invariants. The interconnection between the potential and the actual provides that the two systems with the same fine-grained functional organization will have qualitatively identical experiences (Chalmers 1996). The idea that corresponding mental and physical events occur simultaneously was clearly expressed by Leibniz; it means simply that both the events are the non-locally connected different embeddings of the same reality. This also clarifies the statement made by Stapp (1993): physical and mental events are the two aspects of the same event-like reality. A physical event is an image in the physicist's representation of reality. Consciousness is the ability to hold the potential (infinite) in actual (finite) and

is represented by the essential Platonic structure of Eidos/Object. Consciousness is holding the potential as a possibility of actualization limited by the laws of the physical world. According to Penrose (1989), consciousness is the link between the quantum world, in which a single object can exist in two places at the same time, and the classical world of familiar objects where this cannot happen. However, the existence in two places at the same time is a potential existence and an embedding within that potential existence is the actual existence. Only the latter corresponds to the definition '*esse est percipi*'. In a certain sense, the potential existence is non-perceptual. According to Heraclitus, opposites are the same not in matter, but in Logos.

Consciousness, therefore, is not equal to existence in the sense of Berkelean '*esse est percipi*'. It is that which makes possible actualization and hence existence being on the other level than existing things. The famous Cartesian formula *cogito ergo sum* means that *sum* (actual existence) is the subset (embedding) of *cogito* (consciousness). *Cogito* unites both the potential and the actual realities, realizing reductions in the potential field. We define the Platonic-type reflection as a transformation of the infinite set (presented to us as being-potentiality with simultaneous existence of contradictory statements and which reference can be the set of complex and/or hypercomplex numbers) to the finite spatial structures (expressed by sets of real numbers). Infinity is a contradictory concept if we take it as an actual in one moment, but it is unfolded in finite spatial structures via time, which separates contradictory statements. Understanding of myself as an embedded text — this is the basis of self-reflective consciousness.

What is *veritas* (truth) in this context? We have to remind the phenomenological determination of the true structure as a structure which makes it possible of a vision of things as they are, i.e., of possibility of the equality (adequation) of thinkable and visible. The criterion is a process of living-in of this adequacy. More widely, in reflection structure, truth should be determined in the embedding paradigm. 'For God all things are fair and good and just, but men suppose that some are unjust and others just' (Heraclitus: Fragment 102). Thought and thought about thought are the same in 'true' reality, but inequality of thought and thought about thought is an initial point of realizing of 'untrue' reality being a beginning of autopoietic development. Knowledge is a gradual realization of total-unity via going of the knower out of himself from finite to eternal reality; it is real unification of the knower and that which is known (Florensky 1998 [1914]).

The subdivision into different levels is a background of understanding of truth. A direct isomorphism between certain physically embodied

information spaces and certain phenomenal (or experiential) informational spaces is characteristic for consciousness (Chalmers 1996). More widely, adequacy of embedding to the embedded reality is truth. There are different representations of such a truth in different cultures. The logical representation arising to Plato (with analysis of paradoxes following from this representation) is a feature of Western thinking tradition, whereas the mystical thought overcoming paradoxes corresponds (more or less approximate) to the Eastern tradition. Both the traditions are complementary and exist in both cultures (as Heraclitus and Parmenides).

We are reminded again of Plato's '*Parmenides*' 'Then let us say that, and we may add, as it appears, that whether the one is or is not, the one and the others in relation to themselves and to each other all in every way are and are not and appear and do not appear' (166c) and Heraclitus: 'Listening not to me but to the Logos it is wise to agree that all things are one' (Fragment 50).

The Universe is a semiotic connection of the infinity of *Logos* (Word) and the finiteness of its representation in the spatial-temporal structure of *Cosmos* (World). *Logos* interprets itself in *Cosmos* via Kinesis of *Pyr* (Ever-living Fire). Arguably, it includes a spectrum of meanings, which may be contradictory and exist simultaneously before meaning reduction in the context. The meanings, which can be allotted to words, represent a set with a certain probabilistic distribution. But when we arise to the total set of all meanings, we come to the total being-potentiality (the set of all infinite sets) taken in the actual. This is that initial Word of the New Testament, which holds all the potential in its eternal actuality.

References

Aristotle (1984). *The Complete Works of Aristotle*, ed. by Jonathan Barnes. Princeton, NJ: Princeton University Press.

Barham, James (1990). A Poincaréan approach to evolutionary epistemology. *Journal of Social and Biological Structures* 13 (2), 193–258.

Bergson, Henri (1917). *L'Évolution Créatrice*. Paris: Alcan.

Bohm, David (1980). *Wholeness and the Implicate Order*. London: Routledge.

Bohm, David and Hiley, Basil J. (1993). *The Undivided Universe. An Ontological Interpretation of Quantum Theory*. New York: Routledge.

Chalmers, David J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. New York: Oxford University Press.

Conrad, Michael and Liberman, Efim A. (1982). Molecular computing as a link between biological and physical theory. *Journal of Theoretical Biology* 98 (2), 239–252.

Dicke, Robert H. (1989). Quantum measurements, sequential and latent. *Foundations of Physics* 19 (4), 385–395.

Driesch, Hans (1924). *Metaphysik*. Breslau: Hirt.

Dürr, S.; Nonn, T.; and Rempe, G. (1998). Origin of quantum-mechanical complementarity probed by a 'which-way' experiment in an atom interferometer. *Nature* 395 (6697), 33–37.

Florensky, Pavel A. (1991 [1922]). *Imaginaries in Geometry*. Moscow: Lazur. [In Russian.]

—(1998 [1914]). *The Pillar and the Ground of the Truth*, trans. by Boris Jakim, with an introduction by Richard Gustafson. Princeton, NJ: Princeton University Press.

Goldblatt, Robert (1979). *Topoi: The Categorial Analysis of Logic*. Amsterdam: North Holland.

Gunji, Yukio-Pegio (1994). Autonomic life as the proof of incompleteness and Lawvere's theorem of a fixed point. *Applied Mathematics and Computation* 61 (2/3), 231–267.

—(1995). Global logic resulting from disequilibration process. *BioSystems* 35 (1), 33–62.

Gunji, Yukio-Pegio; Ito, Keisukej; and Kusunoki, Yoshiyuki (1997). Formal model of internal measurement: Alternate changing between recursive definition and domain equation. *Physica D* 110 (3/4), 289–312.

Gunji, Yukio-Pegio and Toyoda, Shin'ichi (1997). Dynamically changing interface as a model of measurement in complex systems. *Physica D* 101 (1/2), 27–54.

Gurwitsch, Alexander G. (1923). Versuch einer synthetischen Biologie. *Schaxels Abhanglungen der Theoretische Biologie* 17 (1), 1–83.

Hegel, Georg Wilhelm Friedrich (1971 [1830]). *Philosophy of Mind*, trans. by William Wallace. Oxford: Oxford University Press.

Heraclitus (1987). *Fragments*, trans. by T. M. Robinson. Toronto: University of Toronto Press.

Hintikka, Jaakko (1989). *The Logic of Epistemology and Epistemology of Logic*. Dordrecht: Kluwer.

Hofstadter, Douglas R. (1979). *Gödel, Escher, Bach: An Eternal Golden Braid*. New York: Basic Books.

Igamberdiev, Abir U. (1992). Organization of biosystems: A semiotic approach. In *Biosemiotics. A Semiotic Web 1991* (= Approaches to Semiotics 106), Thomas A. Sebeok and Jean Umiker-Sebeok (eds.), 125–144. Berlin: Mouton de Gruyter.

—(1993). Quantum mechanical properties of biosystems: A framework for complexity, structural stability and transformations. *BioSystems* 31 (1), 65–73.

—(1996). Life as self-determination. In *Defining Life: The Central Problem in Theoretical Biology*, Martino Rizzotti (ed.), 129–148. Padova: University of Padova.

—(1997). Information processing as an intrinsic property in living systems. Origin and dynamics of information. *World Futures* 50 (4), 571–582.

—(1998). Time, reflectivity and information processing in living systems. A sketch for the unified information paradigm in biology. *BioSystems* 46 (2/3), 95–101.

—(1999a). Semiosis and reflectivity in life and consciousness. *Semiotica* 123 (3/4), 231–246.

—(1999b). Foundations of metabolic organization: Coherence as a basis of computational properties in metabolic networks. *BioSystems* 50 (1), 1–16.

Kampis, George (1996). Self-modifying systems: A model for the constructive origin of information. *BioSystems* 38 (2), 119–125.

Kauffman, Stuart A. (1993). *The Origins of Order. Self-Organization and Selection in Evolution*. Oxford: Oxford University Press.

Kozyrev, Nikolai A. (1991 [1963]). On the possibility of experimental investigation of properties of time. In *Selected Works*, 335–362. Leningrad: University Publishers. [In Russian.]

Lefebvre, Vladimir A. (1990). *The Fundamental Structures of Human Reflexion*. New York: Peter Lang.

—(1992). A rational equation for attractive proportions. *Journal of Mathematical Psychology* 36 (1), 100–128.

—(1995). The anthropic principle in psychology and human choice. *Psycoloquy* 6 (29).

Liberman, Efim A. (1979). Analog-digital molecular cell computer. *BioSystems* 11 (2), 111–124.

Liberman, Efim A. and Minina, Svetlana V. (1996). Cell molecular computers and biological information as the foundation of nature's laws. *BioSystems* 38 (2/3), 173–177.

Linde, Andrei (1994). The self-reproducing inflationary universe. *Scientific American* 271 (5), 48–55.

Lotman, Yuri M. (1990). *Universe of the Mind: A Semiotic Theory of Culture*, trans. by Ann Shukman. Bloomington: Indiana University Press.

Mamardashvili, Merab K. (1993). *Cartesian Thoughts*. Moscow: Progress. [In Russian.]

Matsuno, Koichiro (1995). Quantum and biological computation. *BioSystems* 35 (2), 209–212.

Mensky, Mikhail B. (1996). A note on reversibility of quantum jumps. *Physics Letters A* 222 (3) 137–140.

—(1997). Decoherence in continuous measurements: From models to phenomenology. *Foundations of Physics* 27 (12), 1637–1654.

Merrell, Floyd (1992). As signs grow, so life goes. In *Biosemiotics. A Semiotic Web 1991* (=Approaches to Semiotics 106), Thomas A. Sebeok and Jean Umiker–Sebeok (eds.), 251–258. Berlin: Mouton de Gruyter.

Nalimov, Vasily V. (1981 [1974]). *In the Labyrinth of Language: A Mathematician's Journey*, ed. by Robert G. Colodny. Philadelphia: ISI Press.

Neumann, John von (1966). *Theory of Self-Reproducing Automata*. Urbana: University of Illinois Press.

Ogryzko, Vasily V. (1997). A quantum-theoretical approach to the phenomenon of directed mutations in bacteria (hypothesis). *BioSystems* 43 (2), 83–95.

Peirce, Charles Sanders (1955 [1906]). Pragmatism in retrospect: A last formulation. In *Philosophical Writings of Peirce*, Justus Buchler (ed.), 269–289. New York: Dover Publications.

Penrose, Roger (1989). *Emperor's New Mind. Concerning Computer, Minds, and The Laws of Physics*. Oxford: Oxford University Press.

—(1996). On gravity's role in quantum state reduction. *General Relativity and Gravitation* 28 (5), 581–600.

Plato (1997). *Complete Works*, ed. by John M. Cooper. Indianapolis: Hackett.

Rojdestvenski, Igor and Igamberdiev, Abir (1999). Recursive embedding, quantum measurement and uncertainty principle. In *Humanity, Science, Technology: The Systemic Foundations of the Information Age*, Martin L. W. Hall and Jenifer Wolby (eds.), 347–348. Asilomar: International Society for System Studies.

Rosen, Robert (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Stapp, Henry P. (1993). *Mind, Matter, and Quantum Mechanics*. Berlin: Springer-Verlag.

Teilhard de Chardin, Pierre (1965). *The Phenomenon of Man*. London: Collins.

Thom, René (1983). *Mathematical Models of Morphogenesis*. Chichester: Ellis Horwood.

Thompson d'Arcy, Woodworth (1917). *On Growth and Form*. Cambridge: Cambridge University Press.

Turchin, Valentin (1977). *Phenomenon of Science*. New York: Columbia University Press.

Whitehead, Alfred North (1929). *Process and Reality*. New York: Free Press.

Wilczek, Frank (1999). Getting its from bits. *Nature* 397 (6717), 303–306.

Wittgenstein, Ludwig (1953). *Philosophical Investigations*. Oxford: Blackwell and Mott.

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