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SYNERGETICS: NEW UNIVERSALISM OR NATURAL PHILOSOPHY OF THE EPOCH OF POST-NON-CLASSICAL SCIENCE

1. NEW UNIVERSALISM: *PRO ET CONTRA*

From the very beginning, that is, from the early sixties, synergetics, or the theory of self-organization of complex systems, has been characterized by certain interdisciplinary, or transdisciplinary, aspirations. It has been neither one more scientific discipline, nor a subdiscipline as often appears in the course of development and specialization of science. Certain synthetic functions and profound generalizations have been intrinsic to synergetics from the time of its origin. The scientific trend of synergetics has been credited with the discovering universal laws of evolution and self-organization of complex systems. It has been presumed that the models elaborated within its frames are widely applied in science. "It is obvious that synergetics belongs to the school of universalism" —H. Haken wrote[1]. Synergetic statements function on such a level of knowledge at which the whole number of scientific disciplines concerning very different spheres of reality are embraced.

Following Hermann Haken, we call the modern theory of self-organization of complex systems "synergetics"[2]. This trend of scientific research still rapidly develops itself in different countries in various scientific schools, that is, in the theory of dissipative structures (I. Prigogine), the theory of deterministic chaos (B. Mandelbrot), the theory of self-organized criticality (P. Bak), the theory of autopoiesis (H. Maturana and F. Varela), etc. The key problem is similar in all the fields mentioned above. This problem consists in the search for the general laws of evolution and self-organization, laws of formation of structures (emergence of order out of chaos) and their transformation (synthesis and decay) in complex systems of any kind, regardless of the concrete nature of their elements or subsystems. This is exactly the direction of research in synergetics as determined by its founder, Hermann Haken.

The gradual, permanent widening of the boundaries of synergetics, or, more precisely, of the spheres of application of the synergetic models and research methods, could be roughly compared with the expansionistic policy of a national state. From history it is well known what the main features and results of such a policy can be. Being moved from the very initial stage by one all-engrossing idea, such a new political regime can loose a critical feeling of reality and limits of territorial expansion, as has happened with the empire of Napoleon in France and with the flourishing British empire in the recent past as well as with many other empires in the course of the history of the mankind. As a result, these unnaturally inflated geopolitical formations fell apart into a number of rather small-scale states which are structurally coherent.

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[1] H. Haken, M. Haken-Krell, *Erfolgsgeheimnisse der Wahrnehmung. Synergetik als Schlüssel zum Gehirn*, Stuttgart: Deutsche Verlagsanstalt, 1992, p. 242.
[2] H. Haken, *Synergetics*, Berlin: Springer-Verlag, 1977.

The analogy to the state expansionism is, of course, very restricted and rough, but it brings to light some features of synergetics as a new interdisciplinary movement in science. Synergetics has to be self-reflective and self-critical in respect of its tasks and possibilities. This is, in fact, rather a task of philosophical and methodological comprehension of the results of synergetics than the matter of synergetics itself. Such a comprehension is not thoroughly and sufficiently accompanied with the development of the theory.

An elation and excitement of founders and to a greater extent of adherents of the new theory of self-organization have characterized the first stages of development of the scientific field. I. Prigogine and I. Stengers expressed their mood and scientific attitudes as follows: "We have a feeling of great intellectual excitement: we begin to have a glimpse of the road that leads from being to becoming (...) The natural contains essential elements of randomness and irreversibility. This leads to a new view of matter in which matter is no longer the passive substance described in the mechanistic worldview but is associated with spontaneous activity. This change is so profound that we can really speak about a new dialogue of man with nature"[3].

Some authors noted that similar enthusiastic moods reigned in cybernetics three or four decades ago. The cybernetic approach had been considered as a universal or even only one philosophical having synthesizing functions: "The present tendency is to regard cybernetics either as a scientific umbrella of synnoethics (i.e. computer science and technologies, ranging from automata to the theory of programming), or as a philosophical approach aiming at synthesizing an enormous variety of science, both pure and applied—a veritable 20th century Queen of the Sciences that asserts the essential unity of the animate and inanimate"[4].

It is clear that the views expressed here are excessive overstatements of the role of cybernetics in science. Of course, nobody ventures to name synergetics a Queen of Sciences now. But some elated adherents of synergetics, namely adherents, not founders, have told more about what synergetics is able to do than what it is not able to do.

It is not surprising, therefore, that along with a multitude of enthusiastic supporters of the theory of self-organization there is a group of its active critics and skeptics who consider the theory as a kind of "new religion" or "magic" dressed in scientific clothes.

This is quite usual in the history of science. A new field of research, especially, a profound and perspective one, can seem, at first, like a "new religion". The followers of the former traditions possess other scientific views and convictions, whereas scientists introducing new knowledge have not only scientific justifications but also personal convictions that they are right.

A similar situation could be observed at the first stages of elaboration of *Gestalt*-psychology. W. Köhler, one of its founders, remembered an episode that happened to him: "One day Karl Lashley, one of the most eminent psychologists at that time, said to me quite evenly when we held a conversation: 'Mister Köhler, the research that the *Gestalt*-psychologists do is certainly very interesting. But sometimes I cannot get free from the

[3] I. Prigogine, I. Stengers, *Order out of chaos. Man's new dialogue with nature*, New York: Bantam Books, 1984, p. XXX, 9.

[4] J. Rose J (ed.), *Survey of cybernetics. A tribute to Dr. Norbert Wiener*, London: Iliffe Books, 1970, pp. 9–10.

feeling that you take aim with it by stealth at a new religion. I do not know whether the joyful excitement of scientists if they notice that they came to a decisive moment is accompanied by a religious feeling'. At any case, the fact of the matter is that the *Gestalt*-psychologists continue to impartially conduct their research in order to discover what processes underlie the phenomena studied by them"[5].

Of course, generally critical philosophical consideration with regard to the initial intensive development of a new scientific field is delayed. However, by now both the theoretical frameworks of synergetics and the wide scope of its applications have been sufficiently elaborated. It seems that synergetics is now approaching certain limits of disciplinary extension, although one has to be very careful in speaking about any limits in science. At least, it is quite clear that the question of critical and reflective comprehension of the whole development of synergetics, its scientific foundations, wide possibilities and the possible boundaries of applications of the synergetic models, is on the agenda now.

The aim pursued in this paper is somewhat different from the reflections on the methodological and disciplinary foundations of synergetics. Without a brief consideration of main objections which have been expressed or could be expressed with regard to synergetics, investigations of the philosophical implications and consequences of synergetics as a new universalism are hardly possible.

To summarize, the main doubts or objections to synergetics are the following ones:

1) To what extent is it justified to transfer the models constructed for explanations in one scientific field to another field? How much is a *horizontal transition* legitimate?

2) Is it justified to make a transition, or a leap, from a model constructed and verified within a certain scientific field to the conclusions of a general theoretical value and even to some interdisciplinary conclusions or, if to proceed further, up to a philosophical view? In other words: how much is a *vertical transition* legitimate?

We would like to express at once our positive attitude to both possibilities and to give a brief answer to these fundamental questions.

Such transitions are possible; they can be made, however, not according to a generally applicable rule, i.e. a "presumption of universality" and an *a priori* possibility of a transfer, but by use of thorough considerations of such a transfer along a horizontal or a vertical line *in each particular case*.

One should proceed from the general criteria for scientific research. There is no automatic, universally pregiven synergetic description. In each concrete case, one should check whether the general prerequisites for self-organization are available. It is not possible to know beforehand, for instance, what are the order parameters for a given complex system, and what stable, long-living modes determining the general picture of behavior of the system exist.

Synergetics can provide us only with *general frames of consideration*, a *mental scheme* or a *heuristic approach* to concrete scientific investigations. Concrete applications of synergetic models to complex human or social systems presuppose further detailed scientific investigations. Such investigations can be carried out only with a profound knowledge of a certain disciplinary field and/or with a close collaboration with specialists in a corresponding scientific discipline. Thus, synergetics gives a certain *approach* or a *direction*

[5] W. Köhler, *Die Aufgabe der Gestaltpsychologie*, Berlin: Walter de Gruyter, 1971, pp. 36–37.

of research, or, to put it in terms of psychology, a *scientific attitude*. The rest is the matter of particular concrete investigations.

The essence of synergetics consists in universalism and in interdisciplinary transfer of its models. Synergetics seems to have some soft and gradually extending boundaries. Hence, it follows that synergetics at the developed, self-reflective stage has to possess a concentrated and detailed self-critical attitude towards its own scientific foundations. This can serve as a basis for great possibilities of synergetics and for positive research stimuli. Lack of such reflective work may lead to a danger of scientific devaluation of the synergetic approach.

2. SYNERGETICS IN THE CONTEXT OF THE HISTORICAL TRADITIONS OF THE NATURAL PHILOSOPHY

Synergetics provides us with the knowledge of behavior of complex nonlinear systems in nature, society and in the human consciousness. The theory teaches us how we can comprehend this complexity and cope with it. In other words, it pretends to universalism. The question arises what is the difference between synergetics and the known systems of natural philosophy which consider nature in its integrity when resting upon concepts elaborated in natural sciences? Can we consider synergetics as a natural philosophy of the epoch of the post-nonclassical science?[6]

Every system of natural philosophy, be it Aristotle's physics, Giordano Bruno's or Tommaso Campanella's natural philosophical study in the Renaissance, a system of natural philosophy of one of German philosophers, such as Leibniz, Schelling or Hegel, builds a certain general picture of the world. As a rule, there are certain first principles in it and a path is laid *top-down*. For instance, Aristotle says that first principles should be accepted (their credibility can be established only through themselves) and all the rest should be proved. Then, in the frames of this or that system, some mental speculative reflections on nature are built: how—in accordance with these speculative principles of organization of the world—must behave nature in each individual its fragment?

In opposition to the natural philosophy, synergetics prescribes nothing, it only describes and develops some theoretical notions determining how nature conducts itself and how it organizes itself. Synergetics investigates what general laws underlie the appearance of complex structures. It discovers some universal patterns of self-organization and evolution. Therefore, synergetics has strong empirical grounds. It is not speculative but scientific study. It is not a question of *invention* of laws in accordance with a certain general picture of the world, as it was in the systems of natural philosophy in Renaissance and in the present times, but of revelation and of *discovery* of laws of organization of reality *per se*. This difference is a matter of principle: a result of the process of invention is creation of a new entity (for example, of a wheel, a simple gear), whereas, as a result of discovery, something in reality itself is revealed, a mysterious curtain over reality is half-open.

Synergetics studies the processes of self-organization in certain fragments of nature, for example, the formation of coherent radiation of laser, structures which develop in plasma or convective cells in a liquid, and builds a model, which allows to describe these processes in

[6] This term was introduced by Vyacheslav S. Styopin, an academician of the Russian Academy of Sciences.

a mathematical way and to represent them in a theoretical way. This model turns to be deeply substantial, and it functions successfully in many other fields of scientific cognition. This is a path *bottom-up*, from careful scientific studies to theoretical and further even to philosophical generalizations, not vice versa. The synergetic models contain no prescriptions and, moreover, no compulsion with respect to nature to behave exactly in this way, not in a different way. To use the synergetic models means to understand better the internal machinery of evolution and self-organization, of the growth of complexity in nature.

The synergetic worldview is not philosophy in the strict sense of this word, and it is not legitimate to consider synergetics as a modern "speculative physics", i.e. as natural philosophy of new type. However, there is no doubt that on the basis of synergetics a certain worldview is built and this worldview oversteps the boundaries of basic scientific disciplines and reaches a meta-scientific research level.

Synergetics comes quite naturally to traditional philosophical problems which are permanently under discussion and which are solved proceeding from the spiritual situation of a corresponding historical epoch:

• What is new? Does something new appear in general under the Sun? Or is every event simply *déjà vu*, a repetition of a known case, which happened once earlier?

• What is time? How does time correlate with eternity? How is the present connected with the past and with the future? And what is the present in general: is it an eluding instant between the past and the future or their eternal presence? Is the utility of the teleological thinking justified? And if yes, to what extent it can be used in the cognitive activity in the modern science?

• What is correlation between the potential (the feasible or for the time being the unfeasible) and the actual, the latent (the unrevealed) and the realized (the revealed) as well as the accident and the necessary in the world?

• What is the whole? How does the whole correlate with parts? According to what principles is the complex evolutionary whole built, does the assemblage of a complex structure from simple structures occur? What new holistic notion does synergetics develop?

Although these philosophical dilemmas are generally considered as ultimately insoluble ("eternal"), synergetics provides us with some additional arguments in favor of a certain solution. Namely, synergetics substantiates the following statements:

• self-creation, autopoiesis, the constructive role of both order and disorder in the process of appearance of something new;

• quasi-teleology, processes flow as if they have objective aims (structure-attractors of evolution), but they do not;

• holism, the whole determines the development of parts.

3. THE CONCEPT OF SELF-ORGANIZATION IN THE NATURAL PHILOSOPHY OF SCHELLING AS A FORERUNNER OF SYNERGETICS

In his classical system of the natural philosophy Friedrich Wilhelm Joseph von Schelling (1775–1854) came very close to the modern synergetic worldview. Although not he but Kant began to use the term "self-organization" to grasp processes in the living nature

already in the precritical period of his work, it was Schelling who for the first time extended the concept of self-organization to the description of processes in the inorganic nature and gave an integral picture of evolution of the universe from primary entities up to the emergence of life and of the human mind. In his "speculative physics" (he called so the natural philosophy), the self-creation, the self-formation of the organized forms turned to be in the focus of attention. In his philosophical system self-organization became one of key notions of the consideration of the historical development of nature, its inorganic, organic and cognitive spheres.

The natural philosophy is a necessary initial stage of development of the philosophical system because, according to Schelling, "philosophy should descend to the depths of nature in order to ascend from there the heights of spirit"[7]. Such a penetration into the concealed essence of nature allowed for stating that nature is not a static and mechanical system, but a "dynamic process" or "progressive genesis", starting from inorganic systems up to the appearance of the human consciousness. This *idea of formation (or becoming)*, going through all forms and structures of nature, was carried on by the British philosopher Alfred N. Whitehead in his "philosophy of process".

Another important idea, which can be traced back in Schelling's natural philosophy, is *the idea of productivity*, of the active and creative forces of nature. Schelling understood nature not as a product (*natura naturata*) but as a productivity and product simultaneously, i.e. nature is not simply something created, but it continuously and endlessly creates itself (*natura naturans*). In his "Introduction to the Draft of the System of the Natural Philosophy" (1799) he wrote that "in nature all is endlessly a subject and an object for each other, and nature is primordially a product and productivity simultaneously"[8]. "Strictly speaking, nature as endless productivity should be conceived as being in the process of infinite evolution".[9] Hundred years later, in Henri Bergson's work "Creative Evolution" (1907) the idea of productivity and creativity of nature, of creation of new forms in nature and of open future turns again to be in the center of attention.

From the standpoint of the modern views of synergetics, Schelling's *idea of holism*, of the deep inner relation of parts to the whole and of whole to the parts is of great significance. "The whole displays itself in the single, because each part is absolutely co-participant in the nature of the whole, whereas the present being (*Dasein*) of a numbed entity rests just upon the fact that parts, which are relatively different from each other, are diametrically opposite to each other"[10]. Both nature as a whole and its separate natural entities undergo the process of the unlimited and eternal becoming which is recurrent by its nature. "Separate things of nature make not a discontinuous and going into infinity row, but a continuous, returning to itself chain of life, each link of which is necessary for the whole, just as it feels the whole and cannot undergo changes of its relation without the manifestation of signs of life and sensitiveness"[11]. The building of separate things into this

[7] F.W.J. Schelling, *Works*, Moscow: Mysl, 1989, v. 2, p. 479 (cited from the Russian edition).
[8] F.W.J. Schelling, *Works*, Moscow: Mysl, 1987, v. 1, pp. 196–197.
[9] Ibid., p. 195.
[10] F.W.J. Schelling, *Works*, v. 2, p. 45.
[11] Ibid., p. 46.

united dynamical process is an indicator of the fact that "the temporal is brought into the eternal" and "the eternal is reflected in the temporal".

According to Schelling, evolution is self-similar, since in its course the recurrent production of matter on different levels takes place. This notion resembles the modern notion of fractal form which appears in the processes of self-organization of nature.

Finally, Schelling's *idea of self-organization of consciousness* is of great importance for the modern researches in the field of synergetics and of cognitive sciences. The human consciousness must somehow correlate with nature since otherwise consciousness would be unable to cognize nature. The process of nature self-organization indicates that even consciousness undergo the process of self-organization. The one fact is directly connected with the other because, in Schelling's opinion, "nature must be a visible mind, while mind must be invisible nature"[12]. We are in the unrestricted process of self-organization which goes through all our structures when finding in not a single structure of them its complete and final realization. The German scholar M.-L. Heuser-Keßler noted that Schelling hypothesis was the following one: "In our consciousness, we find out the unrestricted aspiration for self-organization, and something similar should manifest itself in the external world as a general trend to organization."[13] Consciousness is productive by its character, like nature as a whole. Therefore, Schelling's philosophy can be called the philosophy of productivity.

4. SYNERGETICS AS AN EMBODIMENT OF THE HOLISTIC TREND IN THE MODERN SCIENCE

The natural philosophy sought to comprehend nature in its integrity, when resting upon notions of natural sciences of a corresponding historical epoch, often identified phenomena observed in micro- and macrocosm. Synergetics continues in its own way this cogitative tradition. It is the holistic trend that determines the image of the modern science. To all appearances, this trend will become stronger, and the ability of scientists to think in a nonlinear and holistic way will be of great value.

Therefore, one of tasks of an urgent reform of systems of the modern education and self-education on all levels is the development of the *holistic thinking*, the formation of the ability to understand wide, and sometimes even global, *context* of the problem under investigation, i.e. the problem of the *ability to contextualize knowledge*. One cannot study parts without the knowledge of the whole, and one cannot understand the functioning and the development of the whole without the knowledge of its parts. The whole acquires emergent properties which are absent in parts, but at the same time it transforms parts, which as components of the whole display new, unprecedented properties. The complex, hierarchically organized phenomena can be understood only in the holistic perspective.

To train a holistic rather than analytical view is, to all appearances, the today's need of the managerial practice. "To think globally in order to succeed in solving a local and peculiar problem!"—that is a slogan of the modern times. The comprehension of the barest

[12] M.-L. Heuser-Keßler, *Schelling's concept of self-organization*, in: *Evolution of dynamical structures in complex systems*, Berlin: Springer, 1992, p. 400.
[13] Ibid., p. 401.

reform of systems of management is based on non-traditional knowledge of sociosynergetics, i.e. upon the understanding of laws of co-evolution and self-organization of complex social, economic and geopolitical systems. These results are of great and inestimable significance as a kind of worldview necessary for the understanding of the course of evolutionary processes in complex systems; to those systems human and social systems *par excellence* belong.

To carry out appropriate reforms of social management, it is necessary to change mentality, the very mode of thinking. Thinking should be global, non-linear, holistic, solidary, based on the understanding of constructive principles of co-evolution, i.e., at bottom of fact, of rules "to live together" and "to develop together in a sustainable way". In other words, to think globally means to think integrally and holistically, to understand ways of integration of structures, which develop in different tempos and are on different levels of development, into a united concordant evolutionary whole.

It is not superfluous here to remember that complexity (from Latin: *complexus*) literally means that which *is weaved, interlaced together,*[14] that a single cloth is created. The complexity appears only as different elements begin to make a single whole, only as they become inseparable from each other and their interdependency takes shape, only as one and indivisible interactive and retroactive cloth is created.

The constructive principles of co-evolution. The evolutionary holism

The idea of co-evolution has been introduced by the Moscow school of synergetics, led by one of authors of this article. Synergetics discovers the *constructive principles of co-evolution of complex systems* and, therefore, there is a possibility to *master time and to construct a desirable future.*

Why do we call these principles constructive ones? Because they may be used for the effective management activity, for the strategic vision of the future, and for long-term planning, for elaboration of rational national and state policy in the modern globalizing world. Because the synergetic principles of co-evolution are substantial and oriented to the remote future, which is practically impossible to predict using the traditional methods. Because the deep understanding of the synergetic principles of co-evolution, of non-linear synthesis of parts into a sustainable evolutionary whole can and should underlie the modern "art to live together", when promoting the strengthening of the position of tolerance and the preservation of diversity in globalizing communities[15].

The complexity of a structure is connected with its coherence. By coherence, we understand the concordance of tempos of life of structures by means of diffusive, dissipate processes that are a macroscopic manifestation of chaos. In order to build a complex organization, it is necessary to coherently joint subsystems within it, to synchronize tempos of their evolution. As a result of the unification, structures fall into one tempo-world, so

[14] Latin: *complexus* = *com* (*cum*) – with, together + *pleco, plexi, plexum, ere* – to weave, to twine.
[15] See: H. Knyazeva, S.P. Kurdyumov, *Synergetics: non-linearity of time and landscapes of co-evolution*, Moscow: URSS Publishers, 2007 (in Russian).

they acquire one and the same moment of peaking; they start to co-exist in the same tempo-world[16].

To create a complex structure it is necessary to know how to unify structures "of different ages", i.e. structures of different stages of evolution and having different rates (tempos) of evolution. It is necessary to know how to include the elements of "memory", the biological memory, DNA, or the memory of culture, cultural traditions. Inasmuch as the structure-attractors, which characterize the developed, steady evolutionary stages of structures in the nonlinear world, are described by the invariant-group solutions, the spatial and temporal properties of structure-processes turn to be tightly bound. The dynamics of development of a complex structure needs a coordinated (with one and the same moment of peaking) development of substructures of "different ages" within it; this leads generally to the breakdown of spatial symmetry. The insertion of "memory" (of elements of the past) signifies the symmetry breakdown in space.

Different but not arbitrary structures can be unified. The degree of connection of structures, which are to be integrated, and the stages of their development are not arbitrary as well. There are various but not arbitrary ways of the unification of structures into integral ones. There is a restricted set of integration ways, ways of construction of a complex co-evolutionary whole.

The selectivity (the quantum character) of ways of integration of parts into a whole is connected with the imposed requirement of existence in one and the same tempo-world, i.e. of the development of all parts at one and the same moment of peaking. This is the physical basis of quantification by integration of complex evolutionary structures. If joinable structures have even slightly different from each other moments of peaking, then, near the moment of peaking (the singularity), they will become incomparable in intensity.

Thus, the synthesis of relatively simple evolutionary structures in an entire complex structure occurs by the establishment of a common tempo of evolution in all unified parts (fragments, simple structures). The intensity of processes in various fragments of the complex structure (for example, for the social medium—a level of economic development, quality of life, provision with information, etc. in different countries) can be diverse. The fact of integration signifies that structures becoming parts of a whole acquire a common rate development.

An integrated complex structure arises only if there is a certain degree of overlap–ping of simple structures. There must be a certain topology, "architecture" of over–lapping. A constructive "sense of proportion" must be observed. If the area of overlapping is not sufficient, then the structures will develop independently, they will not feel each other, they will live in different tempo-worlds. However, if the overlapping is too wide, then the structures will flow together very fast, they will straight away "degenerate" in one rapidly developing structure. One may attempt to formulate rules of symmetry breakdown when uniting structures of "different ages" into a whole, and indicating an optimum degree of connection (of overlapping of areas of localization) of substructures within a complex structure, a proper topology of their location, laws of switching of regimes and other factors, ensuring a sustainable concordant development in one and the same tempo-world.

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[16] H. Knyazeva, S.P. Kurdyumov, *Nonlinear synthesis and co-evolution of complex systems*, "World Futures" 2001, v. 57, pp. 239–261.

When integrating structures, a magnitude of maxima of intensity of processes occurring in them must be in an appropriate way matched with their distance from a center. Three structures having equal maxima of intensity (levels of development) settle themselves in apexes of an equilateral triangle when are integrated. If one of these structures is more developed, the equilateral triangle turns into an isosceles one: bigger intensity of burning is "compensated" by its bigger distance from the center of symmetry. Still, there is no continuity in such a mechanism of "compensation", i.e. a majority of intermediate states is unstable and only selected, definite configurations of structures are metastable. The compensation of the magnitude of a maximum by its bigger distance from the center of symmetry of a complex structure "works" in a discrete, quantized field of possibilities of integration.

When maxima of intensity increase, a distance between them decreases (the model of "converging waves of burning" is developed and studied by our scientific school), and, on the contrary, when they decrease, the distance increases. One can integrate structures with different powers of intensity by arranging them at different distances from the center and by observing certain forms of organization.

The factor of unification of parts into a whole structure is chaos, dissipation, fluctu–ations or—for social structures—their analogue (exchange processes of various kinds). The chaos plays a constructive role not only in choosing a further evolutionary path, but also in the processes of assembling a complex evolutionary whole. The chaos leads to the establishment of the coherence of development in all parts (substructures). To put it demonstratively, the chaos serves as a "glue" that binds parts into a united whole.

If a complex structure is organized from more simple ones in a right topological way (that is, if there are a certain degree of interaction and overlapping of substructures and a certain symmetry of "architecture" of an emerging united structure), the united structure finds itself on a higher level of hierarchical organization, i.e. a step towards a super-organization is taken. Thereby, the rate of the development of structures, which are integrated into a complex one, is being picked up. The rapidly developing structures "pull to themselves" by their tempo of life the slowly developing structures. In the case of right unification, a ratio of maxima of more developed structures to maxima of less developed ones remain constant, i.e. small, underdeveloped structures do not fall out into another tempo-world, they do not become a simple background for development of structures with bigger maxima, there is no decay of tempo-worlds.

Besides, if an evolutionary whole is organized in a right topological way, the whole begins to develop at a rapid pace, which is higher than there was a pace of the most rapid developing structure before the unification.

The path of unity and of integration of different parts into entire structures is not steady, permanent and monodirectoral. The evolutionary ascent towards more are more complex forms and structures passes through a number of cycles of decay and integration, of tearing off from the whole and inclusion in it, the slowdown of the processes and their acceleration.

From the theory of self-organization, it follows that all open systems with strong nonlinearity are most likely to pulse. They have natural cycles of development: the stages of differentiation of parts alternate with the stages of their integration, scattering alternates with rapprochement, the weakening of bonds changes into their strengthening. The world

seems to go towards a universal unity, a super organism. Yet, it moves forward not monotonously but through certain fluctuations and pulsation. The stages of decay, even if partial, are followed by stages of more and more powerful unifications of structures. This modern scientific notion of complexity reminds us of the eastern images of "rhythms of life" that are peculiar to our world, first of all, of the Chinese symbol Yin-Yang.

The cycles of increase and decrease of the intensity of processes, of decay and unifications of parts indicate regularity of nonlinear processes; the cycles are determined by the very nature of nonlinear processes. Any complex structures at the moment of maximum of accretion, or at the culmination of development (at the moment of peaking of processes), are subjected to the inner instability with respect to small perturbations, they are under the threat of decay.

The history of humankind testifies that the world empires increased in size and became stronger to the maximum extent and in the end they came asunder, sometimes disappeared completely without leaving a trace. But if the beginning of decay of some geopolitical system is observed, it is reasonable, from the synergetic point of view, to put the question: is the nonlinearity of the system sufficient to turn the evolutionary processes back, to switch them to another regime of the renewal of bonds, the attenuation of processes in the central domain and their stirring at the periphery of the structure? If the nonlinearity is not sufficient, then the former intensive processes may be simply extinguished, and eventually they come to naught.

Thus, the fundamental principle of behavior of complex nonlinear systems is the periodical alternation of stages of evolution and involution, the unrolling and the rolling, the explosion of activity, the increase of intensity of processes and their fading, weakening, the converging to the center, the integration and the disintegration, at least the partial decay. There are profound analogies here to the historical testimonies of the downfall of civilizations and the break-up of great world empires, to the cycles of Nikolai D. Kondratiev, the oscillatory regimes of John K. Galbraith, the ethnogenetic rhythms of Lev N. Gumilyov.

At the initial stage of formation of a complex structure, its right topological organization is of great importance. When the process of integration occurs, the structures are not simply put together; they do not simply become parts of the whole in an unaltered, undistorted form. They become somehow transformed; they form strata on each other and intersect, and at the same time some of their parts fall out. As the physicists say in such a case, there exists an overlapping with energy loss. This means that the unification leads to the economy of energy, to the diminution of material expenses and human efforts.

The topologically proper organization of structures in an entire evolutionary structure results in an approach to the moment of peaking, the moment of maximum development. The whole develops faster than its integral parts. It is more profitable to develop together, since the joint, co-evolutionary development is connected with a saving of material (in particular, energetic), spiritual and other resources. Every new way of the topologically proper integration of structures, the appearance of successive layers (with bigger exponent of nonlinearity) of hierarchical organization picks up speed of development of the whole as well as its integral parts. Therefore, the evolutionary path to the building of more and more complex organizations of structures in the world is to a certain extent pre-determined. We

should lend our ears to Eliot's advice: "We must be still and still moving / Into another intensity / For a further union, a deeper communication"[5].

Co-evolution is *per se* "the art to live together". To follow the rules of co-evolutions means to construct a preferable and sustainable future. An important task can be set as follows: to define order parameters of evolution of states that determine a corridor of their sustainable co-evolution. General rules of co-evolution of complex social, economic and geopolitical structures on national, international and global scales, which arise from the methodological analysis of mathematical models, can be summarized in the form of the following key notions:

a) it is *a common tempo* of development that is a key indicator of connection of complex structures into a single whole;

b) *non-uniqueness and involuntariness* of ways of assembling of a whole from parts;

c) structures-parts enter the whole not in an invariable form, they *are transformed and became deformed* in a certain way in accordance with the peculiarities of an emerging evolutionary whole;

d) for the assemblage of a new complex structure, for the re-crystallization of a medium, one need to create a situation *"at the edge of chaos"* when small fluctuations are able to initiate a phase transition, to throw down the system in another state, and to set another course to the process of morphogenesis, another way of assembling of the complex whole. "The very nature of co-evolution is to attain the edge of chaos"[6];

e) to make a dynamically evolving integral structure, a *proper topology* of combination of structures is of great importance;

f) in the case of right, resonant unification of complex structures into the whole, a united super complex structure begins to develop at a higher rate ("it is profitable to live and to develop together").

Co-evolution is not simply a process of the adjustment of parts to each other by formatting a complex whole, of their resonant positional relationship and of the synchronization of tempos of development, but it is the enactive cognition of the world by a human being, synergism of cognizing and constructing subject and of a medium surrounding him. This is also an interactive connection between human organizations and single individuals, the universal collaboration, complicity and solidarity, concerted efforts in construction and rebuilding of the world, and thereby of one's own mentality. This is the disclosure of the universal affinity of all with everything and of a mysterious connection between the past, the present and the future.

Enactive cognition. The integrity of bonds subject—object, subject—other subjects

The holistic vision is essential for the application of models of nonlinear dynamics and of synergetics in cognitive science as well. In that case, it is the matter of epistemological dimension of synergetics. In the frames of the conception of enactive, embodied or situated cognition[17] developed by Francisco Varela (1946–2001), a cognizing organism is

[17] F.J. Varela, E. Thompson, E. Rosch, *The embodied mind. Cognitive science and human experience*, Cambridge: The MIT Press, 1991.

considered together with its environment, the cognitive act is being broadened into some situation possessing certain topological properties. There is a nonlocality, profound mutual determination of the external and the internal, of an object and a subject. "The world, which surrounds me, and that, which I do in order to find out myself in this world, are inseparable (...) The global is both the cause and effect of the local actions"[18]. A subject and an object of cognition interact with each other in a nonlinear way, and there is a complex cohesion of feedbacks of different kind in the process of its interaction. Enaction, the building oneself into the world signifies the awakening of the world as a result of actions of a subject of cognition. When awakening the world, the subject itself wakes up. When changing the world, it changes itself.

The complexity and nonlinearity of feedbacks, which accompany every act of cognition, mean basically that a subject and an object are in the state of mutual determination, they use opportunities given mutually to each other, wake up and create each other, change in a cognitive action and due to it. The path is not given to a searching and cognizing man *a priori*, it is laid in the course of advancement along it. Not only a running lay a path, but the path makes the running. When passing this path, he/she turns into another man/woman.

Besides, the process of cognition of an individual occurs in the mutual relationship, *co-determination of Me and Another*, in their mutual and synchronous becoming. The notion of intersubjectivity is key one in the new conception of enactive cognition. Boundaries between Me and Another, even in the processes of perception, are not outlined exactly, with the full certainty: to be oneself, to manifest the Self and to create Another, these events accompany each other[19]. The Self is not localized; it is in the process of becoming, co-determination with Another/Others.

5. SYNERGETICS: IS IT AN ABSTRACT OR CONCRETE THEORY?

The nature of synergetics lies in its interdisciplinarity. The main advantage of synergetics is universality: the discovery of general patterns of evolution and self-organization within complex systems of any kind. The synergetic assertions can apply to many scientific disciplines. They are functioning on the level from which a great scope of scientific disciplines can be embraced.

However, such an approach has also a negative side. The higher the level of the view is the less concrete details can be distinguished. On the other hand, the deeper we penetrate particular details the less place seems to remain for synergetics itself. We turn out to be within the traditional fields of physics, chemistry, biology, sociology, etc., and the latter do quite well without synergetics.

The theory which explains all explains nothing. Wolfgang Pauli once set for himself a rule: "If a theoretician says 'universal' it just means pure nonsense". Can it be that synergetics actually appears to be an abstract theory which explains nothing because it endeavors to explain all?

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[18] F. Varela, *Quatre phares pour l'avenir des sciences cognitives*, "Théorie – Littérature – Enseignement" 1999, no. 17 (Dynamique et cognition: Nouvelles approaches), pp. 9, 11.
[19] Ibid., p. 15.

Let us take as an example two scientific assertions being on the opposite poles of the concrete and the abstract. In one case, a nonlinear mathematical equation describes the processes in plasma in certain conditions of dissipation and of the creation of heterogeneities by a source of energy. In opposite case, general assertions are such ones: "The processes within natural and social complex systems obey some laws of self-organization", or "Chaos plays a creative role in evolution". Where is the place for synergetics proper between these two poles? The answer is that it is dealing with both things. However, some important corrections are necessary for this statement.

Synergetics uses mathematical models for the description of nonlinear processes, be it processes of self-organization in laser radiation or in plasma. It is distinguished by the construction of some generalized theoretical models and their application as a *method* of investigations.

At the same time, synergetics is not only about *how to study*, but also about *what to study*, i.e. it has a scientific object of its own. The object is not given *per se*, but is a "cut out" of the reality corresponding to the method and the models applied. This object is somehow chosen by the used method or approach.

The above general statements acquire in synergetics some essential additions. Synergetics shows what kind of self-organization occurs in nature and society and what kind of laws of self-organization governs the processes and under what particular conditions. Synergetics investigates when, in what cases, and at what evolutionary stages, can chaos, or disordered elements, play a creative role as well as at what evolutionary stages is chaos undesirable and destructive.

The main checkpoint is that the results of synergetics, as well as of any other scientific field, should meet the requirements of the scientific principle of falsification. This condition is satisfied in Haken's synergetic model based on the order parameters and the slaving principle. The model is linked to the fulfilment of certain preconditions for the cooperative behavior of elements, the emergence of macroscopic spatial and temporal structures out of chaotic movements of elements on the microscopic level.

To be able to reach self-organization a system has to be open and nonlinear. It must have many elements or subsystems: the interactions between them are always subjected to small fluctuations, insignificant random changes. The system has to be in a state of instability, far from equilibrium. One should check up every time whether these pre-conditions for self-organization are available. We are not able to know *a priori* what order parameters will be for a considered system. It is also impossible to say beforehand at which hierarchical level of a complex system self-organization will occur. It may happen that we observe self-organization not on an expected hierarchical level, but only on a higher level of hierarchy, say, between subsystems of a given complex system. The synergetic theory can be empirically corroborated. It has a certain field of applicability: multi-component systems which are open, nonlinear, far from equilibrium. The theory fully meets the necessary criteria of falsification.

One should proceed from the general criteria for scientific research. There is no automatic, universally pregiven synergetic description. In every concrete case, one should check whether the general prerequisites for self-organization are available. It is not possible to know beforehand, for instance, what are the order parameters for a given complex

system, and what stable, long-living modes exist determining the general picture of the behavior of the system.

Synergetics can provide us only with *general frames of consideration*, a *mental scheme* or a *heuristic approach* to a concrete scientific investigation. Concrete applications of synergetic models to complex human or social systems presuppose further detailed scientific investigations. Such investigations can be carried out only by the use of a profound knowledge of a certain disciplinary field and/or with a close collaboration with specialists in a corresponding scientific discipline. Thus, synergetics gives a certain *approach* or a *direction of research*, or, to put it in terms of psychology, a *scientific attitude*. The rest is the matter of every concrete investigation.

That is why synergetics is dissimilar to the conceptions of the former philosophy of nature—*die Naturphilosophie*—which prescribes, according to some speculative outlook on the world how nature must behave in this or that field. Synergetics does not invent speculatively general evolutionary laws; it discovers them and puts boundary conditions on their application. There is no compulsion from the side of synergetics towards nature how to behave. To use the synergetic models is likely to get into the inner mechanisms of evolution and self-organization of complexity in nature.

6. SYNERGETICS: BETWEEN REDUCTIONISM AND HOLISM

A book written by Hermann Haken together with his daughter Maria Haken-Krell, who is a biologist, contains an important note concerning the place that is occupied by synergetics as a new universalism with respect to two other important trends in the modern scientific cognition—reductionism and holism. "Synergetics, they note, occupies a middle position with respect to them, to be more precise, plays a role of a mediator. The fact of the matter is that it is not only interested in the processes which occur on the microscopic level or on the macroscopic level; it rather tries to establish a connection between these two levels. And it succeeds in this, because it introduces the notions of order parameters and of the slaving principle"[20]. This thesis was discussed in the article published in "*Philosophia Naturalis*"[21].

When considering the question of relation of synergetics to reductionism, one should take into account that there are different types of reductionism, namely: ontological reductionism and epistemological reductionism (sometimes called also the methodological reductionism), and—if we discern them on other grounds—the mechanistic reductionism and the dialectical reductionism.

The ontological reductionism is based on the conviction that complex structures are a simple assembly of their parts. For instance, a living organism "is not something other than a conglomeration of atoms and molecules (...) True, one could hardly find today a serious specialist in natural sciences who would adhere the position of the ontological

[20] H. Haken, M. Haken-Krell, *Erfolgsgeheimnisse der Wahrnehmung. Synergetik als Schlüssel zum Gehirn*, Stuttgart: Deutsche Verlagsanstalt, 1992, p. 242.

[21] H. Haken, H. Knyazeva, *Synergetik: zwischen Reduktionismus und Holismus*, „Philosophia Naturalis" 2000, v. 37, no. 1, pp. 21–44.

reductionism"[22]. The epistemological reductionism is founded in the conviction that properties of complex structures can be explained by the properties of parts or substructures, which form them. It is claimed that laws discovered in all fields of knowledge, which have an empirical basis, can be finally reduced to corresponding fundamental laws. The position of the epistemological reductionism in its full and comprehensive form is the following: in its frames, it is assumed that "there exists a certain fundamental theory, which fully describes behavior of all layers of reality and can be completely reduced to the whole set of laws, which are specific for the level organization of being"[23].

The essence of synergetics consists in the description of macroscopic emergent properties of systems, i.e. such properties, which are not derivable from the consideration of the level of their elements, being a result of their cooperative interaction. As it was shown by H. Haken, synergetics concentrates its attention on the study of interaction between the level of elemental building of a systems and the level of its dynamical properties as integrity. The order parameters, which characterize behavior of a certain system on its macroscopic level, and the movement of parts of this system on the microscopic level set conditions for each other. Parts engender order parameters which exert a backward influence upon parts and determine their behavior, so it is impossible to establish what is here primary and what is secondary. That is why one speaks here about the circular causality.

Whereas the holistic way of consideration limits itself to the analysis of macroscopic, integral properties of a system as the most important for the understanding of its behavior, the synergetic approach embraces both levels, that is, the level of dynamical properties of the system as well as the level of its elements. The correlation between these two levels, the emergence of new unexpected system properties from the behavior of elements, turns to be in the center of attention. Whereas the reductionist way of consideration is satisfied with the study of main elements of a system as a general substratum of observed phenomena, the synergetic approach goes further and analyzes higher levels, interactions between different levels of the system organization and the hierarchy of various levels of complexity.

It is worth to underline that the detection of order parameters for a certain complex nonlinear system serves as a key for understanding its behavior. Order parameters allow us to radically reduce the complexity of the explored system, and in a relatively simple way allow to describe the functioning and the development of a multidimensional system with complex organization; those behaviors on the level of elements are extremely entangled and chaotic. Another way of the reduction of complexity, which is used in the presented here scientific school of Alexander A. Samarsky and Sergey P. Kurdyumov, is the study of developed, asymptotic stages of the development of complex non-equilibrium systems described by automodel laws, and the revelation of structure-attractors of evolution of these systems. The description of dynamical properties of systems as evolutionary integrities prevails in synergetics, and so the synergetic approach is closer to the holistic position.

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[22] B.-O. Küppers, *Einleitung. Inwieweit lassen sich die Lebenserscheinungen physikalisch-chemisch erklären?*, in: B.-O. Küppers (ed.), *Leben = Physik + Chemie? Das Lebendige aus der Sicht bedeutender Physiker*, München: Piper, 1987, p. 9.

[23] R. Hedrich, *Komplexe und fundamentale Strukturen. Grenzen des Reduktionismus,* Mannheim: BI-Wissenschaftsverlag, 1990, p. 31.

Besides, synergetics explores laws of co-evolution and of nonlinear synthesis of complex structures of "different ages" developing with different speeds. The theory studies laws of topologically right assemblage of the complex evolutionary whole. Thereby, synergetics makes steps towards the development of a new evolutionary holism.

If it is a question of the epistemological reductionism in terms of the "existence of a comprehensive, all-embracing fundamental theory", synergetics by no means can be qualified as a theory of such a type. Synergetics has an interdisciplinary status and cannot substitute the chemical, biological, psychological and social researches in concrete disciplinary fields. Synergetics has no such claims. It is rather a mental scheme showing how concrete researches of complex systems in this or that disciplinary field might be done.

In the scientific literature, sometimes the question of positive properties of the reductionist approach arises. For instance, Per Bak, one of the founders of the theory of self-organized criticality, wrote: "The reductionist approach has always been the royal road to the Nobel Prize"[24]. In what sense is reductionism useful? To what extent can it be justified and permissible in the scientific cognition?

An interesting answer to such questions is given by Daniel C. Dennett, a well-known philosopher of mind. He discusses the Darwinian evolutionary theory, especially dangerous Darwin's idea that the whole historical chain of biological evolution can be represented in a mechanistic, or algorithmic way that it submits to strict rules of natural selection. "We must distinguish reductionism, which is in general a good thing, from *greedy reductionism*, which is not. The difference in the context of Darwin's theory is simple: greedy reductionists think that everything can be explained without cranes [i.e. without reducing higher levels of organization and complexity in the world to lower ones – *authors*]; good reductionists think that everything can be explained without skyhooks [i.e. without speculative reflections – *authors*]"[25].

The strong mechanistic or physicalistic reductionism is entirely unacceptable since it consists in an immediate reduction of complex phenomena to the laws of simple structural formations of nature. In this case, peculiar features of complex forms and structures are, in fact, denied.

The modern scientific knowledge is built to a considerable extent on the application of highly abstract models reflecting amazing properties of open nonlinear systems on different levels of organization of the world. The mathematical modelling begins to grope after a such class of complex objects, for which the principal similarity of the course of processes on qualitatively different levels of complexity is revealed, some bridges between the lifeless nature and the living nature (between the self-completing of nonlinearly evolving structures in nature and the highest manifestations of the productive imagination and creative intuition of a human being) are built. On a certain level of abstraction, some fundamental generality of processes, which occur, it would seem, in completely incomparable areas of reality, starts to ooze. In this connection, the content of the very concept of "reductionism" changes. Reductionism, which is understood in a dialectical way, consists in the fact that fundamental

[24] P. Bak, *How nature works? The science of self-organized criticality*, Oxford: Oxford University Press, 1997, p. 114.

[25] D.C. Dennett, *Darwin's dangerous idea: evolution and the meaning of life*, New York: Simon & Schuster, 1995, pp. 81–82.

laws, which are valid on more basal levels of organization of the world, are used for the explanation and theoretical representation of some peculiarities of complex formations.

It is generally known that the biological science in the 19th century aspired to introducing everywhere the idea of evolution and to applying the evolutionary mechanisms discovered by it. It served as a constructive basis for the worldview of that time. The computational experiment (with the help of computers) and the mathematical modelling of the processes of self-organization in complex nonlinear systems play nowadays a similar role. They promote the appearance of new ideas and the formation of a new worldview; they show eventual behavior of complex systems and possible ways of the effective management. This is a kind of reductionism, reductionism in a constructive sense of this word.

7. THE FUTURE OF SYNERGETICS AS A NEW UNIVERSALISM

Synergetics has to be self-critical towards its own future development. Synergetics in H. Haken's sense was born approximately 40 years ago, and was developing very fruitfully during the last three decades. But what is to happen further? What is the destiny of synergetics?

According to one point of view that we share, synergetics is a modern and quite close analogy of cybernetics which passed its highest point of development in the fifties and sixties; the systems theory was actively developing one decade later. As it was mentioned above, the development of cybernetics was accompanied by a quite enthusiastic mood of the scholars involved. But what happened then? Cybernetics was replaced first with the general systems theory and later with synergetics. What is the future of synergetics? Although during these three decades synergetics proved to be a highly promising field of scientific research, we should admit its possible limitations.

In our opinion, cybernetics as well as synergetics can be considered as certain "constellations" of developments, conclusions and arguments collected from some basic scientific disciplines, such as mathematics, physics, engineering science and technology, biology etc. Both of them are interdisciplinary theories. Cybernetics with its principles of feedback, purposive behavior and information processing is closer to technology, studies of ways of construction of automatic devices and apparatuses. Synergetics is immersed deeper, because it tries to reveal profound evolutionary mechanisms of complex systems in general.

Such a "constellation" is determined by the logic of historical movement of science. A certain form of this "constellation" may be created, it may transform itself and may even scatter for a while, thereby enriching the basic disciplines. The "constellation" may be assembled and fall apart, may be re-assembled later in a different way, whereas the basic disciplines remain in their frameworks.

Proceeding from the analysis of the historical development of cybernetics, systems theories and synergetics, one may assume that in the second half of the 20th century, a new, quite unknown type of scientific research starts to form. It is not simply an interdisciplinary or multidisciplinary research. This is a kind of "ferment" or "catalyst" which does not replace the basic disciplines, but stimulates the development of knowledge within existing

disciplines frames. Then the "ferment" pioneering approach may dissolve giving the way for another one which is to be a new igniting stimulus.

It is a new phenomenon in the development of science. The focus of interdisciplinary investigation may change in time, other problems and means of their investigation may turn to be in the center of attention. However, the essence of such an interdisciplinary structure based on the sciences of complexity remains, in general, the same.

As enthusiastic scholars in the field of synergetics, we hope for successful and prolonged perspectives of synergetics as a theory of self-organization and co-evolution of complex systems. Perhaps, a culminating point in the development of synergetics has not yet been reached. But only history will put all the things in their due places. The future is charming because of its uncertainty and openness.