LOGICAL AND METHODOLOGICAL ANALYSIS AND THE FOUNDATIONS OF THE TRANSITION FROM THE STUDY OF THE BRAIN'S PHYSIOLOGY TO SYNERGETIC PRINCIPLES

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Abstract: The article aims to establish the significance of studies of the physiology of the brain as the epistemological sources of the emergence of the synergetic paradigm. In this regard, the author, for the first time, carried out a systemic study of the principles and categories of synergetics encountered in the basic concepts of physiologists from Sechenov to Anokhin in chronological order. He assessed the completeness of each definition's conceptual content, carried out an initial generalization of the analytic-synthetic method based on the existing definitions, substantiated the contribution of physiological science to the methodological foundations of synergetics. The scientific achievements of higher nervous activity physiology in this area do not yet have their final philosophical generalization. Physiological and synergistic methods mutually complement each other, and contribute to a complete knowledge of the surrounding nonlinear world.

Keywords: Coherence, Functional System, Integrity, Nonlinearity, Self-Organization.

1 Introduction

The synergetic paradigm as an interdisciplinary scientific methodology is widely used in natural science and the humanities since. One of the synergetic paradigm's main methodological principles is the unity of the nature of the material and spiritually ideal worlds, which allows one to study the processes taking place in them by general methods.

The research task includes:

- Explore the principles and categories of synergetics considered in each physiologist's works in chronological order;
- Evaluate the completeness of the conceptual content of their definitions and the initial generalization;
- Determine the ways of the formation of these principles and categories.

In synergetics, the problems of evolution of a complex nonlinear system are considered with categories as integrity, nonlinearity, attractor, coherence, and self-organization. The principles of self-organization extend from morphogenesis in biology, and some aspects of brain functioning, to the flutter of an airplane wing [11, p.16]. Synergetic principles and categories have a long history of formation and different epistemological origins. The study has philosophical and methodological significance.

It is known that the works of natural scientists created the synergetic paradigm – physiologists [4, 21, 27, 28, 31], mathematicians [13, 14, 17, 20, 23], physicists [11,12], and chemists [8, 9, 24, 25], but a historical excursion shows that for the first time physiologists faced the problems of synergetics when they began to study the reflexes of the brain. The word "synergetics" was introduced into science by the English physiologist C. Sherrington at the end of the 19th century noted that synergetic is a coordination of the nervous system's effects (spinal cord) in controlling muscle movements [29, p. 174]. The famous synergetic theorist Kurdyumov identifies three sources of synergetics, one of which is biology. Synergetics went from at least three sides. Not only from the side of calculations of thermonuclear fusion but also from the side of biologists [15, p. 193].

As an open, nonlinear system, the human brain is the most complex and perfect synergistic research object. The science of brain functioning laws, particularly of higher nervous activity, was created by the works of physiologists. Although in the scientific works of physiologists there are no names for such synergetic categories as "attractor", "dynamic integrity", "fractality", "coherence", nevertheless, all the processes associated with these categories fully take place in the brain, and physiologists in the process of studying such processes created the necessary prerequisites for the scientific formation of these categories. Some of their ideas anticipated some ideas of cybernetics and synergetics.

Physiologists' ideas and concepts have found their application in biology, neurocybernetics, neurophysiology, mathematics, intelligent control systems, pedagogy, philosophy, psychology, and literature. Covering the natural, social and spiritual spheres of human existence, they reflect the dialectic of interaction between society and nature, the development of which is still ongoing.

Numerous studies [16, 19, 26, 34] have considered only certain aspects of physiologists' contribution to the formation of a synergetic paradigm and, mainly, from the standpoint of physiological problems. However, there is no systematic study of this problem's philosophical aspects, which determines the relevance of the proposed work.

This work is an integral part of the research of folk poetry by the methods of the synergetic paradigm, the joint application of which in unity with the theory of the whole person is preferable, since the theory of a holistic person that "reveals the main natural and socio-historical sources of human development, the diversity of the relationship to objective reality" [1, 25].

The article attempts to conduct a complex analysis of studies of the physiology of the human brain in order to study the conditions for the emergence and stage-by-stage formation of synergetic principles and categories and, on their basis, indicate the contribution of physiologists to the formulation and solution of the formation of philosophical and methodological problems of the synergetic paradigm.

The theoretical basis of the research is formed by the basic principles and philosophical understanding of the achievement of synergetics as an important criterion for assessing the contribution of physiologists to this area, and the principle of historicism, which ensures the significance of physiological research in the ontological and methodological aspects and the conditions of their occurrence, and the scope, as well as by comparing them, to expand the completeness of the available definitions.

The principle of correspondence characterizes the continuity of the relationship of scientific theories in their historical development, and the principle of complementarity, asserting the complementarity of the rational and irrational sides of reality and their relationship to each other, which is necessary for the holistic reproduction of reality, are used.

The synergetic principles and categories developed by physiologists are universal in nature, allow you to penetrate into the essence of processes of various natures, and have an important methodological value in the process of research not only in the field of physiology but also in biology, biophysics, cybernetics, psychology, pedagogy, and control theory.

2 Literature Review

2.1 The Beginning of Scientific Research on the Physiology of the Brain

The first scientific research in brain physiology is associated with the name of the founder of the physiological school in Russia, the materialist philosopher Sechenov, who developed the reflex theory of the brain. He, proceeding from the principle of materialistic understanding of the processes occurring in nature, took the natural scientific direction as a basis, particularly the principle of the unity of the organism and the environment, i.e., conditions of its existence.

In his fundamental work, "Reflexes of the Brain", Sechenov established that the brain's reflex activity is a single principle of the entire central nervous system because the reflex covers physiological acts and mental phenomena. According to the mode of origin, all acts of conscious and unconscious life are reflexes [27, p. 124]. According to Sechenov, physiological and psychological processes are organically connected in the reflex. The relationship between mental and nervous acts is expressed in their dynamics, procedural, which should be taken as the initial axiom. Developing this idea, Sechenov explains the integrity of the body by "the coordination of both manifestations - feeling with movement" and believes that the main content of the physiology of the spinal cord and the brain is the doctrine of the combined activity of the sense organs and movements in the bone skeleton [28, p. 663].

He interprets the reflex as an act consisting of feeling and movement, and "on the basis of the discriminatory and regulatory function of the mental and feeling as a signal" [34, p. 21-22], introduced the idea of self-regulation into the reflex scheme, which is consonant with the principles of cybernetics.

The significance of the reflex theory for psychophysiology lies in the fact that reflex of the brain is, according to Sechenov, a memorized reflex, i.e. not congenital, but acquired in the course of individual development and depending on the conditions in which it is formed [26, p. 175].

Sechenov has deep research in cognition, in whose opinion, cognition begins with observation, i.e., with experience; then there is the processing of experimental data and the analysis of the results. The transition of thought from the experimental area to the extrasensory one is accomplished through continued analysis, continued synthesis, and continued generalization. Sechenov has a synthesis. "The ability to combine together facts separated by space and time" [27, p. 84] plays the main role for an adequate reflection of the world, and allows to create a holistic image of an object and phenomena. This idea of Sechenov was later developed by Pavlov (afferent department) and his student Anokhin in the form of an action acceptor.

Sechenov offers his criterion for the adequacy of reflection, which he calls a "compromise": "The following provisions should be recognized as the cornerstones of a compromise. The identity of sensory signs from external objects must correspond to the identity of realities, and, finally, to the difference of signs - the difference in reality" [27, p. 449-450], in the form of strict correspondence between the laws represented and valid.

By the word "represented," he means a model of an object and proposes a new criterion of adequacy, so to speak, functional adequacy, i.e., strict correspondence between the laws of the course of processes in the object and their expression in the model. And by this criterion of adequacy, it is many decades ahead of its time.

2.2 The Doctrine of the Activity of the Central Nervous System

A systemic study of the functioning of the brain begins with the works of the great Russian physiologist Pavlov, who was the first to start researching higher nervous activity, applying the method of a holistic study of physiological processes, using strictly objective criteria for the natural scientific investigation of phenomena in this area.

Pavlov studied the physiological processes of a living organism in relation to it with the external environment, that is, in the human-nature system, and most of all paid attention to the integrity of the organism and developed the doctrine of its integrity.

Opening of Pavlov's unconditional reflex activity led to the creation of a new branch of science - the physiology of higher nervous activity. Conditioned reflexes associated with the concept of temporary (conditioned) nerve connections, the principle of the formation of which is the universal principle of the cerebral cortex, that is, "a temporary connection is the universal physiological phenomenon in the animal kingdom and our one" [21, p. 325]. Pavlov believed that temporary connections, in particular, associative connections, differ from the usually conditioned reflex: "In other words, we have [both] positive conditioned reflexes and negative ones, that is, associations of both categories" [33, p. 99]. At the same time, Pavlov notes the complete fusion of psychological and physiological phenomena, the complete absorption of one by the other, and their identification.

Pavlov, summarizing the results of numerous experimental studies, establishes that nervous activity consists of the phenomena of irritation and inhibition, which in the cerebral hemispheres go with mobility and complexity characteristic only of them. At the same time, I.P. Pavlov writes that the cerebral hemispheres are the most reactive and the upper part of the central nervous system. As a result of studies of nervous activity physiology, he determines the department responsible for the brain's creative work. Pavlov concludes the cerebral cortex as an isolated afferent department; the higher analysis and synthesis of the brought stimuli occur exclusively in this department. For this reason, the afferent department is an active, creative department, and the efferent is only passive, executive. This scientific concept of Pavlov was further developed in the theory of functional systems of Anokhin.

Pavlov introduces the concept of "dynamic stereotype," which is "a well-coordinated, balanced system of internal processes." This is a kind of attractor because "we observe and study this continuous systematization of processes in a normal animal on our conditioned reflexes, one might say, continuous striving for a dynamic stereotype" [21, p. 422]. In other words, the brain strives for its attractor for the best mode of operation. Dynamic stereotypes capable of change increase the nervous system's flexibility, provide a better attitude to reality, and develop the ability to predict the result.

Pavlov, in his famous article "On the mind," notes the significance of the joy of discovery as a new positive impulse that inspires the researcher to new heights: "For the mind, it is necessary to look at the truth, to rejoice at it. Real mind is a clear, correct vision of reality, knowledge of the number and composition of this reality. Such knowledge allows us to predict it - this reality and reproduces it to the extent possible by technical means" [33, p. 24].

Pavlov pays special attention to the surrounding reality's numerical characteristics and structure. A numerical characteristic is a more accurate and specific assessment that allows you to reproduce this reality further. Thus Pavlov anticipated the great importance of mathematical methods in the study of the physiology of the brain. He spoke about this back in a speech at the XII Congress of Naturalists and Doctors in Moscow: "The time will come - let distant - when mathematical analysis, relying on natural science, embraces all these equilibria with majestic formulas of equations" [21, p. 87–88].

Pavlov was right because three decades later Ukhtomsky and his students applied nonlinear oscillation models to study physiological processes. For Pavlov, "the condition of disequilibrium" is the normal mode of functioning of nervous activity. "More precisely, in the relative norm, there is a certain disequilibrium" [21, p. 497]. Several of Pavlov's works contain "an assumption about the" core "and" cortical periphery "of the analyzers" [19, p. 121], which was later developed and brought to the level of a scientific concept by Anokhin.

3 Materials and Methods

3.1 Dominant Theory

Based on the doctrine of Pavlov's "temporary connections" and the parabiosis of Vvedensky, Ukhtomsky developed the dominant theory, which outgrew the framework of physiology and found wide applications in other scientific fields: biology, physiology, psychology, philosophy, sociology, and ethics. The dominant theory explains the nature and laws of the organism's

vital activity and physiological behavior as a whole, showing the indissoluble unity of the biological and social in humans.

According to Ukhtomsky, the dominant is the dominant focus of excitation in the cerebral cortex, which reinforces its excitement with extraneous impulses, and as the excitement develops in itself, it inhibits other current reflexes encountered along the common final path [31, p. 120]; is a chained reflex aimed at a certain permissive act [31, p. 32].

In this definition of Ukhtomsky, the synergetic properties of the dominant are laconically expressed: the multi-stage formation of the dominant as a chain process, the attractor properties of certain centers that intensify their excitement about a random impulse, the integrity of the functional constellation of centers as a dynamically functional organ that gives the body unity of actions at the moment.

The dominant is formed in a non-equilibrium mode of the brain, and Ukhtomsky considers the cerebral cortex as a special organ of "renewal and brief experience of the previous dominants with less inertia and with the aim of their economic combination," i.e., the brain tends to the optimal mode of operation [31, p. 28]. The formation of a dominant is a long process and corresponds to a synergetic - nonlinear principle, according to which at the initial stage its excitation is reinforced by extraneous impulses through inhibition of other current reflexes encountered on the general final path to as long as the threshold of its excitability has not become at least equal to the magnitude of the arriving indifferent impulse, only after that, the dominant begins to form.

Note that the nonlinearity of the nervous organ's functioning was established by the teacher Ukhtomsky Vvedensky [32, p. 194]. Ukhtomsky was also familiar with the theory of nonlinear oscillations, which had been developed by physicists since the late 1920s and used the analogy between nonlinear oscillations and physiological processes. In particular, the presence of a "threshold" for the occurrence of oscillations and a "ceiling" for their manifestation; the tightening of frequencies (i.e., inertial insistence on the once evoked rhythm) of the transformation of the rhythm of variable lability, with its influence on the current result of the assimilation of the rhythm (synchronization of oscillations). Thus, it can be concluded that his students were among the first to apply the theory of nonlinear oscillations to study physiological rhythms [30, p. 123].

The irreversibility of the process and the formation of a new structure after the attractor's point, considered in synergetics and in the theory of dominants, thus have their own specificity associated with memory. More precisely, at the point of branching, the choice of a certain branch (or dominant) is influenced not only by random or purposeful influences but also by the memory of which path the system chose earlier, during previous branches [35, p. 18]. It should be noted that the principles of the dominant encompass all human activity from the molecular level up to the organismic and socially social, and here the organism is thought of as a certain unit that reacts entirely, as an integral whole. It is a unit capable of acting entirely on current stimuli [31, p. 82].

According to Ukhtomsky, the nervous system is a single whole. This unity is determined by the coherent behavior of active centers, expressed by synchronization in the nerve pathways. Ukhtomsky named the properties of coherence as "mutual attunement," "sympathetic rhythm," "sympathetic rhythmic action."

In studies of the organism as an integral system, he used the principle of historicism. He studied physiological processes as processes of formation in the form of an integral of a person's current behavior, and the integral, according to Ukhtomsky, is an accumulation process that began from the depths of the past. Thus, he created a unified concept of physiological time, in accordance with which time acts as a factor in the organization and determination of physiological processes [16, p. 33]. Thus, it should be noted that the dominant theory is one of the ideological sources of Anokhin's theory of functional systems, which organically enters into the basic principles of synergetic science.

4 Results

4.1 Modern Scientific Ideas about the Organization of the Practical Activity of Living Organisms

The principles of organizing the practical activity of living organisms developed by Anokhin, which form the basis of his theory of functional systems and a new approach to understanding the functions of the whole organism, became possible due to the development of the ideas of Sechenov, Pavlov, and Ukhtomsky.

According to Anokhin, functional systems are objectively existing apparatuses for self-organization of the human body's adaptive functions, which determine the prospects for studying their organization and formation. In relation to a living organism, a functional system is a unit of integration of the whole organism, which develops dynamically to achieve any of its adaptive activities and always on the basis of cyclical relationships. It selectively unites special central-peripheral formations [4, p. 154]. This definition covers all the properties of a synergistic system – integrity, dynamism, selectivity, adaptability, and integration. Synergetics is the science of interactions. The interaction of functional systems in the body is complex, which considers the principles of hierarchical domination, system genesis, and systemic quantization of vital processes, multiparametric, and sequence.

All functional systems have essentially the same architectonics. Functional systems are characterized by invariance of laws, which is determined by the fact that all these systems, regardless of the level of their organization and the number of their constituent components, have fundamentally the same functional architecture, in which the result is the dominant factor that stabilizes the organization of systems [3, p. 39].

The concept of a functional system, combining analytical and synthetic functions, determines the whole's organic unity and the part.

Based on the theory of the functional system, Anokhin offers a new, more complete definition of the system, where the interaction of components is of particular importance. The property of coherence is obtaining a useful result. A system can only be called a complex of selectively involved components, the interaction and relationship of which acquires the character of interaction of components to obtain a focused, useful result [2, p. 19].

Further, Anokhin developed the concept of system genesis, which is based on three principles:

1. The principle of heterochrony, which expresses the selectivity and acceleration of maturation of the functional system's morphological basis, thanks to which the main requirement for the survival of the newborn is ensured. The harmonious relationship of the structure and function of this newborn organism with environmental conditions;
2. The principle of consolidation of elements into a single functional system, which is a process when morphological elements are combined into functional systems while achieving adaptive results useful for the body;
3. The principle of minimum provision of functions, expressing the optimality of combining morphofunctional units into a functional system.

Based on this position, it should be noted that the essence of system genesis is reduced to "a set of embryonic processes that, through the morphogenetic patterns of maturation of individual structural elements, lead to selective systemic connections" [5, p. 136].

Selective systemic connections are a coordinated and accelerated development of structural formations of different localization, which determine their analogy in terms of synergetics' resonant effect.

Anokhin also owns a new idea of the integrative activity of neurons, which consists of the fact that convergence is the central mechanism, without which afferent synthesis cannot occur because convergence provides interaction, juxtaposition, and synthesis excitations in the axoplasm of nerve cells.

In addition, Anokhin also developed the concept of advanced reflection, which is of particular importance for the theory of knowledge. According to this concept, in the process of afferent synthesis, the subject of reflection identifies and correlates the necessary environmental conditions and the corresponding action programs. The acceptor of action results is programing the impacts of future events. It makes a decision and, having received some result, encodes all its properties before it is implemented.

The brain, thanks to the special ability of living matter, among other things, accumulate the experience of the past. The human brain's property is expressed in its ability, based on the space-time continuum, to build an anticipatory reflection of events [5, p. 47-48]. Putting forward and substantiating the ideas of "reverse afferentation", "afferent synthesis," Anokhin anticipated the cybernetic concept of "feedback" [10, p. 203].

5 Discussion

5.1 Self-Organization Problems

Synergetics is the science of self-organization, and the analysis of physiologists' research on this problem is of great importance for modern science. Within the framework of this article, it is important to carry out a comparative scientific analysis of the research of Bernstein and Anokhin. Bernstein's name is associated with the concept of "Physiology of Activity", which is the object of research in physiology, psychology, biology, and philosophy.

According to Bernstein, an organism is an active, purposeful system developed in the course of evolution, continually striving for the future. His concept of "Physiology of Activity" expresses the specific features of self-movement of a living system in its interaction with the environment [22, p. 328].

Proceeding from the fact that the brain can "look into the future," into the reality that has not yet matured, Bernstein offers modeling of the surrounding world in two forms: a model of the past-present and a model of the future, the first is unambiguous and categorical, and the second is probabilistic. The process's activity is reflected in the "model of the future" and requires the actual implementation of the process of converting probability into an accomplished fact.

Bernstein expresses the problem of activity as a process of overcoming the environment through the concept of self-organization – "negentropy", since "the organism ... in all manifestations of activity moves negentropically along the way" [7, p. 455], where denegentropy denotes the measure of orderliness and organization of the system, and at the moment the measure of the organism's activity.

He presents activity in the form of "living movement" as "integrity and structural complexity" of movement, and since movement is multicomponent, "unity and mutual conditioning of its parts, in space and time" is necessary. The problem of the integrity and structural complexity of the "living movement" noticed by Sechenov was reflected in the principle of the dominant of Ukhtomsky and became the subject of deep research by Bernstein [7, p. 469]. Anokhin, under the concept of a functional system, means "systems that have the ability of emergency self-organization, dynamically and adequately adapting the body to a change in the external environment" [5, p. 54].

Such fundamental mechanisms provide the self-organizing properties of functional systems as afferent synthesis, decision-making, an acceptor of the results of an action, reverse afferentation, and the result of an action. The result is a determining factor in self-organization. The rest of the mechanisms contributing to obtaining a useful result: "Here is an unreliable system that receives a reliable the result, - notes PK Anokhin, - is a self-organizing plastic system" [6, p. 263].

The problems of self-organization associated with a systematic approach to the organization of the life of a living organism, and in particular a person, his relationship with the world, in the science of physiology received concrete development earlier than in psychology and philosophy, and earlier than in the general theory of systems and in cybernetics [18, p.26].

Analysis of the step-by-step development of research in the field of brain physiology shows the important methodological significance of the scientific achievements of physiologists in the study of the problem of the nature of complex nonlinear dynamic systems and their study, through which it is possible to identify certain stages of the formation of synergetic principles and categories. In particular, the concept of "nonlinearity" constitutes the synergetic system's ontognoseological basis, and this phenomenon is studied from different angles of view. Vvedensky established the nonlinearity of the nervous organ's functioning, and Bernstein connects the nonlinearity with the principle of feedback and notes that "physiology is increasingly revealing the greater universality of such a circular scheme of regulation with the help of feedback" [7, p. 395].

Anokhin’s nonlinearity is associated with the idea of inverse afferentation, which, if necessary, makes a correction in the decision-making. Physiologists have studied the concept of integrity as a multi-aspect problem; begun by Sechenov, it found its theoretical development in the works of Pavlov, as a doctrine of the integrity of the central nervous system; in Ukhtomsky as a spiritual-material unity; in Bernstein as the integrity of the living movement. According to Anokhin, this problem found its expression of integrity in the form of the integrity of the functional system, which is confirmed by the many-sided study of the problem.

As for the concept of attractiveness, physiologists have different interpretations: as a one-sided accumulation of excitement in a certain group of centers (Ukhtomsky), then as a desire for the future (Bernstein), the idea of which was later developed as follows: "the future attracts us more than we strive for it ". Anokhin considers two aspects of this problem: physiological and philosophical. In the first case, the attraction is expressed by the convergence of ascending excitations of various modalities on the brain's same neurons.

He developed the philosophical aspect of this problem in the concept of "advanced reflection," mentioned above. In his opinion, "adaptation to future events" - "anticipation of the future" is only the property of man. The phenomenon of attractiveness is considered by physiologists mainly from the perspective of the principle of invariance: from the physiology of the brain to the scale of human life.

Regarding the concept of coherence, which is characteristic only of dynamic systems, this idea runs like a red thread through all definitions of physiologists; in particular, "sympathetic rhythmic action" (Ukhtomsky), "mutual conditioning of parts of the movement, in space and time" (Bernstein), "the principle of consolidation of elements into a functional system" (Anokhin). This definition includes not only physiological processes but also the processes of the whole organism in motion.

Physiologists approach the process of self-organization from different points of view: Bernstein considers the problem of self-organization from the standpoint of the physiology of activity, "the living brain was evolutionarily constructed and programmed, the process was carried out in the order of active life and self-organization" [7, p. 404].

Being one of the systems approach theorists whose works have enriched the main areas of synergetic science, Anokhin investigated functional systems as self-organizing, using cybernetic and mathematical methods. Starting with the study of Sechenov, special attention is paid to the category of synthesis, the theoretical foundations of which are developed by him and completed in the concept of afferent synthesis by Anokhin. Today, synthesis is accepted as the methodological basis for the synergetic paradigm.

6 Conclusion

Based on the preceding, we can conclude that physiologists made a significant contribution to the formation of synergetic principles and categories and their philosophical interpretations, which had a noticeable impact on the cardinal change in the tradition of the culture of thinking.

The ideas of physiologists as essential components of an interdisciplinary approach are widely used in medicine, psychology, pedagogy, literary criticism, philosophy, cybernetics, bionics, and psychophysiology. They have become the methodological basis of a systematic approach to comprehensive human research.

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