Correlation and Order in Bio-Complexity

SORIN BAICULESCU[1] ADRIANA GODEANU METZ[2]

Abstract

Grégoire Nicolis and Ilya Prigogine argued that macroscopic phenomena occur as a result of their initiation through fluctuations within microscopic molecular processes. In studies of the dynamics of macroscopic phenomena, correlations are established either exclusively at the macro level or between this level and quantum biological processes (including analyses of stochastic aspects), moving from instability to a stable regime[3], through constraints and bifurcations. Coherence arises within this framework. Quantum theory also considers probability amplitudes. Noteworthy is the inclusion of irreversibility and Markov processes, which take place within macrostructural processes. There is a correlation between macroscopic and microscopic forms, as well as order relations. This can be observed both at the macroscopic level due to the emergence of bifurcations (toward which certain bioprocesses evolve at a given moment), and at the microscopic level. These aspects are supported by Poisson distribution calculations, variance (statistical estimation of fluctuations), and covariance (estimation of fluctuation correlations). This essay analyzes the correlation and order inherent to bio-complexity processes, also considering certain chaordic forms that emerge when bio-complexity can no longer be correctly understood (a process generated by a very high increase, beyond the levels at which bio-complexity remains comprehensible, in the number of components). We also make references to the "Space of Experience" (SE), whose components include metric spaces (subspaces) (MS), quantum spaces (subspaces) (QS), symbolic spaces (subspaces) (SS), and spaces (subspaces) of consciousness (SCo.) which contain two fundamental properties that will be stated. Within these spaces, various forms of correlations are identified, generating order and organization.
The essay concludes with a series of final observations, outlining future perspectives.

Keywords: Biocomplexity, Correlation, Order

1. Correlation and Order Occurring Within Bio-Complex Processes

In the case of biological connections, there are certain strongly correlated forms, as well as a category in which such correlations are not observed. They express the degree of dependence of one process's functioning on another, aspects that statistics sometimes treat as stochastic relationships. Usually, the connection between two processes is considered (simple correlation). When three essential processes occur, one of them is kept constant, and when four processes occur, two of them are kept constant (partial correlation). In partial correlation, the influence of the third variable is determined within the process involving the other two. Correlations are established between phenomena that both share a similar scale of observation, or between microstructural and macrostructural phenomena. For example, correlations that arise between the

[1]International Union for Interdisciplinarity and Transdisciplinarity in Complex Systems; Romanian Committee for the History and Philosophy of Science and Technology – Division of Logic, Methodology, and Philosophy of Science, Interdisciplinary Research Group – Romanian Academy; French Society of Philosophy: bio-mathematician. E-mail: s.baiculescu@gmail.com.
[2] International Union for Interdisciplinarity and Transdisciplinarity in Complex Systems; bio-physicist, E-mail; info@iuitcs.org
[3] Grégoire Nicolis and Ilya Prigogine, 1989, *Exploring Complexity – an introduction*, W.H. Freeman and Company / New York, [1989], pp.75-79.

microstructural and macrostructural levels can be distinctly identified in prionic disorders[4]. Some pathological forms are generally observed in the unfolding of macrophysical processes, often having genetic causes. A modification of the relationship between the (biological) microphysical region and the macrophysical region belonging to a human being occurs beginning at the level of the genetic "construction," through the existence of mutations, resulting essentially in genetic "alteration" (for example: Creutzfeldt–Jakob disease). Order is associated with entropy and with the Boltzmann measure. This measure considers the probability of a microphysical phenomenon existing within a macrophysical one, or the existence within it of a state with thermodynamic stochasticity. Fluctuations determine a certain relationship between these two domains (microphysical–macrophysical), and Boltzmann's principle of order explains equilibrium structures, while nonequilibrium becomes a source of new order. Instability can generate a certain level of long-range order[5]. There is a linking relationship between Function, Fluctuation, and Biostructure.

Function ↔ Biostructure
↕ ↕
Fluctuation

There exists a connection of the form order–organization. Certain invariant parameters are associated with order, both within hierarchical levels and within the transition phases of a phenomenon, indicating its stability. For example, in the genetic process of transcription (the first stage of gene expression), the information belonging to the DNA located in the nucleus of the eukaryotic cell—as a measure of order—is initiated through the production of RNA, where it will be stored in the form of three molecular components (messenger, transfer, ribosomal), with the associated parameters being invariant in all situations. This RNA then becomes part of another process (translation), which results in proteins. The process unfolds with full adherence to self-organization and order, thereby maintaining its stability. Certain transcription factors, in the form of protein compounds, also intervene in this process[6]. Therefore, the level of order in a biosystem characterizes its degree of organization. Order can also be understood by considering self-organization. Correlations and order in the (bio)macrophysical domain can also commonly be identified in various biomedical conditions.

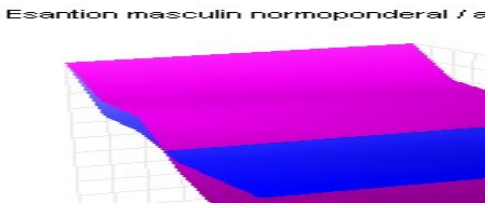
Obs.: In the sense presented, one can mention a study conducted by the first author at the symposium "Francisc I. Rainer Days" of the Romanian Academy on April 23, 2010. In this study, a medical condition was considered, for the analysis of which certain representative anthropometric, biochemical, and hemodynamic parameters were previously taken into account, recorded within affected and healthy population samples (also called biostatistical units). The Pearson correlation coefficient, as well as other (bio)statistical indicators, were determined, revealing the existence of six significant biological correlations at the macro-physical level, potentially present within the respective condition. The

[4] "The term prion means an "infectious protein." It was introduced into molecular biology by Stanley Prusiner at the University of San Francisco in 1982. Prions (previously also known as protoviruses, virinos, latent viruses, etc.) represent a class of subviral infectious agents unique in their kind, resistant to all inactivation processes that degrade nucleic acids. Prions remain an enigma, a "perplexity" of molecular biology, because acknowledging their existence as infectious agents, lacking any nucleic acid and composed solely of proteins, would challenge the central dogma of molecular biology. This is because it would imply that the infectious prion protein can be encoded and replicated not through the nucleic acid of the prionic agent itself, but through the nucleic acid of the host cell." (Dr. Anca-Michaela Israil, *Molecular Biology – Present and Perspectives*, p. 418, 2000, Humanitas Publishing, Romania)

[5] *Ibidem*, pp. 209-210.

[6] There are simulated images showing the phases of transcription (http://www.scientia.ro).

conclusions of the study were considered useful for biomedical and order analyses within the studied biological system. Nine forms of (bio)variability and six forms of correlation were obtained, along with their 3D representations (according to the figure below). The results were also accepted at an international specialized congress (Sweden, 2010).



(red – unaffected cohort; blue – affected cohort)

Academician Paul Constantinescu, in his book "Synergy, Information and the Genesis of Systems – The Foundations of Synergetics" (1990), noted the existence of a relationship between complexity and order (p. 39), introducing the observation that "organization is a rate of order." He considered "the generation of order, organization, and synergy through resonance and coherence, for example, in cases of resonance in which conditions arise within positive-feedback regulation, conditions of instability and amplified oscillations, an increase in the amount of information (negentropy), an enrichment of the system's structure, therefore an increase in complexity and in order, in higher hierarchical organization, in the genesis of a new synergy."
Order becomes directly proportional to organization, with negentropic values increasing. Certain parameters can be associated with order. These acquire invariance within hierarchical levels and transition phases present in biological networks characterized by stability. The nonlinearity of hierarchical evolution is also described within the network formed by multidimensional hierarchical evolution through different ranks, using models with nonlinear differential equations. These generally model biological processes for determining order parameters. Ilya Prigogine, in fact, referred to situations in which order is obtained through the existence of fluctuations that generate organization. In both microphysical and macrophysical processes, whether stabilized or not, a form of organization (or self-organization) emerges, involving order. This is in a determined relationship with bio-complexity, their observation depending on the scale allowed by the experiment through which the phenomenon manifests. A "maximum" level of ordered bio-complexity is obtained through the multidimensional organization of the biological system, in the sense of achieving order—becoming stable or in a state close to such stability. In this case, the (bio)information corresponding to the given situation must have maximal communication with both the internal and external environments. Order, which also appears in situations analyzed within bio-complexity, can likewise be exemplified through processes occurring in cellular phenomena (the bio-microphysical level) and through certain ecological processes (the bio-macrophysical level). Relevant in this sense is the predator–prey process. The time variations belonging to prey individuals and predator populations have reciprocal, interlinked dependencies, self-organized and ordered spatially and temporally, within macrophysical domains. Their reciprocal dependence is currently described using both linear and nonlinear differential equations. These represent an adaptation of the linear Lotka–Volterra differential equations to the same type of process. In this context, the reproduction rate of the respective species, the prey consumption constants, the migration of predator–prey species, and the disappearance (through competition) of certain predator species also intervene. These interdependencies generate stability and order.

Based on the aspects presented, one may admit that the level of order existing in a biosystem characterizes its degree of organization. Simple correlations, generally of a priority–anthropological level[7], are usually linear (Pearson), whereas correlations belonging to pronounced bio-complexity (complex biological processes tending toward the chaordic) are nonlinear (Spearman). We mention, as a difficulty, the determination of the correlation within a bio-complex process between one of its quantities at a quantum level and another of its quantities (within the same biosystem) at an accepted and measurable macrostructural level[8]. Phenomena of decoherence and quantum "entanglement" arise, making it nearly impossible to determine correlation with quantities belonging to the (observable) macrostructural realm. This is caused by the different scales of the two quantities. If the differences in scale were to disappear, all linear and nonlinear correlations could be determined—like a theory of the whole—using acceptable values. Otherwise, highly complex mathematical and physical methods are required, sometimes generating significant deviations from reality. Similar observations, involving indeterminacies, arise when estimating the correlation between two quantum quantities belonging to the same bio-structure. The quantum universe is at times difficult to compute. One must also consider the bio-complexity generated by quantum biology, as well as a psycho-complexity generated by general psychology and quantum bio-psychology.Both types of correlations (Pearson and Spearman) have numerical values in the interval [–1, +1], linear and nonlinear, respectively—positive (when both quantities involved in the computed correlation are similarly monotonic), negative (when one increases while the other decreases, and vice versa). Quantum correlations involve short existence times, while classical (macrostructural) ones involve longer times of stability and evolution. Absence of correlation yields a value of zero. A possible overlap (even partial) between two biological processes creates difficulties in calculating their correlation. Such an intersection may appear artificially favorable, yet is entirely incorrect precisely because of the overlap, which becomes misleading at the level of scientific research. According to reference [4], p. 12, and to what Dr. Robert Zimmer noted in 2006 in the book Philosophy – From the Enlightenment to the Present (ALL Publishing, p. 18), French mathematician René Thom (Fields Medal, 1958) "considers the existence of the ideal space also called the Logos (Heraclitus), signifying 'a universal region standing behind all changes' (denoted S_1), whose (formal–philosophical) 'projection' represents another space (denoted S_2), in which, in fact, the morphological phenomena identified by humans take place. In the ideal space S_1 there exists the quality of the state of a 'point' or domain belonging to the morphological space S_2. If the 'point' (domain) has the particular characteristics of the state perceived within S_2, the parameters (otherwise understood—the quality of these characteristics) lie within the (ideal) space S_1. Morphology takes place in S_2, in fact, for all domains 'immersed' within it. A dynamic system formed in such a manner depends, for the actual perception of the human being, on what occurs within S_2, which thus becomes a 'support space' well understood by humans, proper to the dynamics through which it is expressed." Motivated by this observation, we hold that the form of correlation—regardless of how it results (linear / nonlinear / positive / negative)—will always, in fact, be the significant philosophical "projection" of space S_1 into S_2, expressing the numerical

[7] Example: in humans, the correlation, in the most representative cases, between their weight and height.

[8] We note the differences between the quantum and classical "universes," also taking into account the logic in philosophy. In the classical "world," the law of distributivity applies to classical quantities p, q, r $[p\wedge(q\vee r)=(p\wedge q)\vee(p\wedge r)]$, which cannot be admitted in the quantum world for quantum entities (quantities) p, q, r $[(p\wedge(q\vee r))\neq((p\wedge q)\vee(p\wedge r))]$, highlighting the distinctions. It follows that these are represented within different "universes," which is also supported by the previously introduced notion denoted SE, separating SM from SC - spaces (subspaces) associated with the Human Being, which are, however, separate (distinct). We recall the notable achievement recognized with the Nobel Prize in Physics in 2025: "The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2025 to John Clarke, Michel H. Devoret and John M. Martinis for the discovery of macroscopic quantum mechanical tunneling and energy quantisation in an electric circuit" (announcement of the Nobel Committee 2025ff).

(statistical) form of human understanding for the formal relation in S_1. We introduce the idea of expressing possible new forms of correlations, which may also be applied to correlations previously determined within the same biosystem. Through a positive extension of thought, applicable both now and in the future, these new correlations could be automatically realized (obtained) even between large systems, complex and bio-complex, with numerous components structurally different from one another, taking into account the estimates of frontier disciplines and the performance of artificial intelligence, generative artificial intelligence, Big Data systems, scientific transhumanism, and others. We conclude this subsection by recalling the possible existence of hidden (invisible) correlations generated by certain models (generally biophysical and bio-mathematical[9]. In the same sense, we mention another study[10]. In modeling, there arise certain correlations that cannot be directly, empirically observed—yet they do exist, resulting theoretically from the obtained model. This characteristic is generated by its "power" (generally from systems biology), by its correctness, describing—through so-called stages (or steps of approximation)—the biological reality of Nature, also employing scientific interdisciplinarity and transdisciplinarity. The process can be simulated computationally, Nature's reality being, in a way, revealed (the projection occurring from S_1 toward S_2). The analytical form of the theoretical model directs research toward the effective (humanly understood) reality, which cannot be distinguished solely empirically, through experiment alone, and for this reason some new forms of correlations become invisible to humans (hidden). What is at stake is the reality of the human Being, implicitly its correlations—not the Real, which differs from reality. Otherwise understood, the biological phenomenon may in fact exist in space S_1, while in human reality it will be represented only through a "projection" (into S_2). In this regard we also recommend the works of the French psychiatrist and psychoanalyst Jacques Lacan, where, through philosophical distinction, the domains of the triad Real–Symbolic–Imaginary are considered, situated— for clarification—within an "interweaving," and in explanatory relation to the Borromean rings. Reality, in the Lacanian sense, is formed from the Symbolic domain (which in fact sustains the human Being in its many forms within S_2), as well as the Imaginary domain, while the Real is almost inaccessible (it contains pure forms, even unintelligible to the human being) directly. In S_1, human geometry (as understood by humans) can no longer be applied (that space is not dependent on normal distances or measurements). The correlations of the aforementioned triad must be sought within the symbolic spaces, sometimes vaguely connected to the imaginary ones, but very little (almost not at all) within the Real S1, primarily due to humans' inability to understand it.

2. Bio-complexity and Chaordicity: New Forms of Correlation and Order

In the following, punctual references will be made to the field of bio-complexity and to its concerns (at present and in perspective), as well as to the domain of chaordicity. The conditions under which the transition from bio-complexity to chaordicity takes place will be analyzed, as well as the new emergent forms belonging to correlations and to order, which may appear within this latter domain. At present, in some scientific publications, a series of researchers use the term "bio-complexity" (bC), analyzing, in this context, the complex behaviors having a biological (biochemical, biophysical) level, as well as the interactions between living organisms and the

[9] Dan Teodorescu, *Engineering of Biosystems – An Introduction through Models*, Facla Publishing House, 1978 (distinguishes deterministic anatomo-physiological models from probabilistic, statistically optimized ones, mentioning, at the end of his book, the necessity of correctly identifying biosystems and the unknown model (p.178)).

[10] Z Z. Simion and F. Schneider (eds.), *Current Aspects of Molecular Biology and Physiology*, "Viața Medicală Românească" Publishing House, 1998, pp. 107–113 (G.I. Mihalas and Z. Simion, chapter *Mathematical Modeling*).

environment. Concerns regarding the study of bio-complexity are new compared with those of other disciplines, incorporating knowledge from related domains, while models with generally quantitative valences are produced, generated by biological processes, for the purpose of correct interpretation. Theories of bio-complexity tend to form a new, distinct interdisciplinary, even transdisciplinary, domain, constructing their own methods and models. At present, there is also the need for certain requirements, such as: 1) the usefulness of knowing and studying bio-complexity, as well as the use of its mathematization, modeling, and axiomatization; 2) the usefulness of the fact that certain methods of analysis of bio-complexity may be evidenced within the history of science, its methodology, and logic; 3) understanding the fact that the mechanisms of study specific to bio-complexity do not represent a sum of scientific analyses having an exclusively biological level, sometimes cumulative, as they selectively utilize the accumulations realized by other disciplines; 4) the constitution of a theory of bio-complexity that should include its own specific properties and mechanisms of study, including mathematically and informatically developed; 5) considering the fact that, indeed, the incommensurability of the theories through which bio-complexity is analyzed also determines extensions of these theories, which are sometimes independent of a series of previous biological theories; 6) the importance of the fact that research in bio-complexity can no longer be realized, to a great extent, using the methods existing until the period 1967–1970, the necessity being distinguished of analyzing, through modern possibilities, the current body of biological knowledge. H.I. Hartwell, J.J. Hopfield, S. Leibner şi A.W. Murray specify[11]: "Biological systems differ greatly from the physical and chemical systems analyzed by statistical mechanics and hydrodynamics. Statistically, mechanics usually deals with systems containing many copies of a few interacting components, whereas the cells of living organisms contain from a few copies to several million of each of thousands of different components, each having specific interactions. In addition, the components of physical systems are often just simple entities, whereas in biology, each of the components is often itself a microscopic machine capable of transferring energy and activity under conditions far from equilibrium." This point of view shows that the methods by which bio-complexity is analyzed are close to those belonging to the science of complexity; however, there are also situations in which they are only slightly similar, requiring the particularization of analyses in the study of this field. The domain of the complexity of the "living" differs from that of the complexity of the physical sciences, the latter not determining that specific to bio-complexity. The constitution of bio-complexity is not similar to the constitution of complexity. The properties of complexity and of bio-complexity are different, involving methods and mechanisms of research similar only at the "surface," but not in "depth," in fact, through the "target" considered, they are not identical. There are limits and borders of approach, life being different from the inert. "The theory of bio-complexity represents the study of bio-structures, as well as of the complex behaviors that arise from the interaction of biological entities (cells, molecules, organisms). While physical and chemical processes give rise to a variety of spatial and temporal structures, even the complexity of the simplest biological phenomena is infinitely richer" (The Interdisciplinary The Center for Study of Biocomplexity-University of Notre Dame, Indiana, USA, http://www3.nd.edu/~icsb/, p.1). ""Why bio-complexity? The accumulation of molecular information in biology, permitted by tireless innovations of the last decades in molecular biology and in genomics and proteomics (the study of proteins, Marc Wilkins – 1997), has led to the undeniable habit in understanding life sciences: almost implicitly, explaining a phenomenon by invoking a material cause at a lower level, such as a gene or a protein, a molecular interaction or regulatory pathway. Systems biology has extended the search for mechanistic explanation to massively parallel, exhaustive measurements (including the genome). It has systematized the 'collection of molecular stamps' through the creation of useful databases, mapped networks and relationships, and launched complicated processes within

[11] H.L. Hartwell " et all.", (1999), *From molecular to modular cell biology*, Nature, nr. 402, pp.47-52, http://www.cs.princeton.edu/~chazelle/courses/BIB/Hartwell.pdf/.

mathematical models. Nevertheless, something is missing. The description of molecular pathways, however comprehensive and quantitative, does not explain what makes the whole more than the sum of its parts and why the creative force of the biosphere, both in development and in evolution, appears inevitable. Bio-complexity aspires to fill this gap. With the approach of bio-complexity, IBI supplements the efforts of systems biology. Ultimately, our mission is to improve human health, well-being, and the life of people throughout the world" (Institute for Biocomplexity & Informatics (IBI), Calgary, Faculty of Science, Canada, http://www.ibi.ucalgary.ca). "The theory of bio-complexity represents the study of the emergence of self-organized and complex behaviors resulting from the interaction of numerous simple agents. Such emergent complexity is a hallmark of life, from the organization of molecules into a cellular machine, through the organization of cells into tissues, to the organization of individuals into communities. Another key element of bio-complexity is the inevitable presence of multiple scales. Often, agents organize into much larger structures; those structures then organize into even larger ones. And so on. A classic example is the primary, secondary, tertiary, and quaternary spiraling of DNA into chromosomes, which allows the coiling of filaments several centimeters long, without tangling or losing their function, into a chromosome approximately one micron in length.
The theory of bio-complexity has its own methodology and its own philosophy, being a distinct domain of study. It also focuses on biological networks." http://biocomplexity.indiana.edu/institute/biocomplexity.php,p.1). *"Bio-complexity itself, as a unique entity generated by biostructures, may be interpreted, besides the study of the manner in which it is formed, the identification of the properties it possesses, and the references regarding the procedures in which it is necessary to be studied, also through the manner in which it is and must be observed and thought by the Human Being, through its exterior consciousness (as a priority) and its interior one, directed toward the foundation (the grounding) of living structures, polarized, through the connections in which it participates, toward certain domains belonging to Nature"* (general synthesis of the first 3 descriptions of bio-complexity (definitions), belonging to the epistemological, philosophical, and scientific considerations of the authors of this essay).

The term "chaordic" was proposed by Dr. Dee Hock during the years 1990–1993–1999[12], having application also in the context of the organization of large complex systems, with many variables, which, however, may still be functional, avoiding their disappearance when chaos (which, sometimes, may be deterministic) and order coexist (in the analyzed situation – only when bio-complexity has extremely large values, which can no longer be understood by the Human Being (ontic level)). In chaordic systems, emergence is also accepted (the appearance of new systemic states and mechanisms, resulting from local behaviors), as well as self-organization. The bio-system situated at the chaordic level is (most of the time) nonlinear (as, in fact, is bio-complexity), but it may have, through correct modeling, hidden components (invisible to primary research, having an empirical level). Its logic is not predominantly binary; non-classical logic must also be considered. Therefore, correlation and order are generated (at the chaordic level) by the mechanisms of the process of biological self-organization, the results being emergent as well.
An example of bio-complexity that tends to transform into chaordicity is constituted by the bio-complex ecosystem called the Danube Delta Biosphere, having subsystems composed of lakes, flora and vegetation (specific), fauna (mammals, fish, birds), and processuality (biological–energetic fluctuations, sometimes impossible to control by humans), climatic and hydrological variability, and others. In this context, correlations exist between the biological structures of the fauna, but also between hydrological levels useful to the flora and vegetation, maintaining adequate states regarding the water of the lakes. One may also determine the optimal trajectory through which this true "gift of Nature" may be preserved (through objective functions). When a bio-complex system takes extreme forms, its manifestation may also be extreme, existing also

[12] Dee Hock, *Bird of the Chaordic Age*, 1999, Ed. Berrett-Koehler, USA.

new attractors (which must be determined and analyzed), and a certain level of order, even approximate, which is sometimes difficult for humans to discern.
It is useful to underline (an aspect already stated in this essay) that the chaos of chaordism is not at all elementary-simple, approaching that of deterministic chaos (mathematized through the theory of systems, as well as of biosystems). In an evaluation system having only fuzzy form, outlined on a horizontal axis, at the left end one may imagine chaos (it may even be deterministic), and at the right end lies order. Between them, in chaordism, different intermediate levels of chaos and order may be considered. Chaos, having a maximum level, implies order of minimum level, while minimum chaos generates maximum order, with different intermediate levels (vague, very small, small, medium, large, very large, etc., also considering their opposites)[13] situated between them. Order, existent through strongly nonlinear interactions, may also be introduced artificially into the biosystem, while a pronounced level of chaos may also be extracted artificially[14]. The order existent within bio-complexity, tending (asymptotically–vertical or oblique) toward extremely large values (theoretically infinite), or obtained through artificial intelligence and through its "derived" forms, when chaos becomes small or even disappears (evidenced through continuous curves of exponential form, increasing or decreasing), represents aspects that the Human Being can no longer rationally understand, constituting a specific region within chaordicity. Is this, ultimately, in fact, an evolution or an involution relative to the mode of expression of Nature? We do not yet know a plausible answer, but one fact proves certain – that Nature dominates us. The previous considerations are justified also in the situation of artificial insertions of order (even numerically increasing the natural one), generating new correlations (even hidden, invisible – empirically, yet still existing, obtained also through the conclusions of a (bio)physical, mathematical/informational modeling, possibly realizable between natural domains and artificial ones). In a bi-orthogonal axial system, on the horizontal axis one may emphasize time (macroscopic), and on the vertical one may consider certain elements such as: bio-complexity, chaordicity (coexisting order and deterministic chaos), entropy and bio-information, emergence, considering also philosophical and mathematical categories, topologies, bundles, toposes, meanings, and others. By accepting the chaordic domain, the emergent bio-complexity belonging to large bio-systems—such as that belonging to the Danube Delta Biosphere, mentioned earlier—is anticipated to have another level of order, belonging to Nature, toward which the Being, through understanding and an intelligent extension of its thinking, attempts to advance. Order, in chaordism, is also implied by fluctuations superior (in quality) to the initial ones. We also quote a text: "According to "The Chaordic Alliance (World Wide Web http://www.chaordic.com), the term "Chaordic" means: "1) Anything simultaneously orderly and chaotic; 2) Patterned in a way dominated neither by order and chaos; 3) Existing in the phase between order and chaos" (Frans M. van Eijnatten, *Chaordic Systens Thinking - Chaos and Complexity to Explaun Human Performance Management*, 2003, First International Conference on Performance Measures, Benchmarking and Best Practices in New Economy, University of Minho, Guimaras, Portugal, Parallel Session: "Chaordic Performance Measures", Annual Meeting of ECCON). Taking into account what the previous definition accepts, there also exists the problem of identifying, within a chaordic bio-complex system, the degree of existence of order and chaos (sometimes deterministic), situated through the correct estimation of the quantity belonging to each of these two components. If, in classical situations, order and chaos were analyzed independently, considered, in general, phenomena adjacent to the bio-process, at present, through their "interweaving" in chaordism (even antagonistic), it is distinguished that each has a certain participation, estimated effectively under acceptable conditions. Thematic

[13] However, a maximum level of order, of imposed constraints, can lead to blockage and increased rigidity, while a maximum level of chaos (even if deterministic) can generate a significant lack of (bio)stability.
[14] n conditions treated with certain medications (an artificial approach), in the case of human bio-structures, order is introduced and a certain amount of disorder (chaos – both random and deterministic) is removed.

questions: May a new form of metaphysical thought be developed within the chaordism of chaos and order? Is knowledge excessively forced, thus making disappear the mystery of all that is natural, fascinating, and unknown, through the introduction of a binomial represented by these? Does the unfolding of the processes of bio-complexity represent, in fact, hazard or necessity? Do the constraints imposed (within the applied framework of advanced scientific studies) by the boundary and frontier conditions effectively existing in bio-complexity direct the complex bio-system toward chaordism? Might the absence of bio-systemic constraints generate, in fact, to the extent that humans can understand and accept it, the existence of chaos? On this foundation, considered, in fact, empirical, of certainties/questions, we estimate that new chaordic correlations must be sought.

3. Auxiliary Aspects

Motto:

Human thought and being are one, through all that Nature allows [15].
(inspired by the teachings of the Apostle Paul, Parmenide, Immanuel Kant)

Currently (Dr. Sorin Baiculescu) the idea of the "Space of Experience" (SE) has been introduced, having a series of distinct component spaces (subspaces), different from each other, as well as an instrumental-epistemological, ontological, and phenomenological nature, implicated by the spaces (subspaces) introduced within the SE and attached to the Human Being. These must therefore be admitted when SE is considered. Within SE, it is accepted that Experience is not an attribute solely of the 'segment' of matter (empirical) (measurable in the physicalist sense in the Metric Space (SM)). Simultaneously, starting from the birth of the Human Being, its Quantum Space (SC), the Symbolic Space belonging to it (informational-formal and phenomenological) (SS), and the Space of Consciousness (interior and exterior) (SCo.) also appear[16]. . These are, in fact, its fundamental spaces (subspaces), inherent to its existence (observable through the five fundamental senses), though sometimes not directly observable.[17]. SE = {SM, SC, SS, SCo.} (1). Beyond the simultaneity of SE component emergence, a third property of these spaces (subspaces) is that they are nested in increasing order: SM is included in SC (considering exclusively the real part corresponding to the complex functions inserted therein, with the imaginary part being null), both are included in SS, and finally, the three SM, SC, SS are included in the Space of Consciousness (SCo.)[18]. SE is therefore considered not merely a geometric and

[15] In what will be described below ("The Space of Experience"), the entirety of the human Being, at different (chronological) stages of age (physiological, of consciousness), is dynamic, having no static forms, being one with thought and consciousness at the respective age. The Being, in fact, remains invariant. For example, at different ages, the Being possesses, at each of these ages, a somewhat modified (dynamic) mode of thinking, primarily through external and internal consciousness, but also through the accumulations it acquires, while nevertheless remaining invariant, without a fundamentally different identity.

[16] In the conditions in which SM, SC, SS, and SCo. did not appear and exist simultaneously, SE could not exist.

[17] Bernard d'Espagnat states: "[…] whoever says 'there are in Nature laws that…' thereby postulates that the notion of a 'Nature' endowed with 'structures' is meaningful. And if the said 'laws' or 'structures' are assumed to exist even when unknown, this implies that the 'Nature' that carries them is somehow external to us," *On Physics and Philosophy*, Princeton, 2006.

[18] With regard to consciousness (through SCo.), the introduced idea (sometimes considered a concept) states that "the '*Space of Experience' is not a place where consciousness resides, but where it is configured*" [3]. Its dynamic nature is evident, not static in any way. It appears through a configuration

measurable domain (as evidenced by the exclusive existence of the SM component); it also contains the other components mentioned above, which appear simultaneously with SM. In this context, the entire Space of Experience (SE) can be considered a potential domain, becoming, at a given moment (generally through SM, but not exclusively…), an actualizable possibility. A biological process of the Human Being, within the accepted existence of SE (considering SM, SC, SS, SCo.), is strongly correlated within each of these fundamental components. An example of internal correlation within SM from SE will be presented below.[19] Generally, these spaces (subspaces) are lacking correlations (vaguely correlated), if one accepts that for different spaces, identical or even similar theories cannot exist. At birth, the Human Being, being observable (primarily in SM), can be considered to possess some incipient bio-formative mechanisms (slightly empirically observable), also existing in the accompanying spaces/subspaces SC, SS, SCo. (according to some hypotheses from quantum psychology, and also according to the assumptions of the distinguished English mathematician and Nobel laureate Roger Penrose and collaborators, e.g., Prof. Stuart Hameroff), a.o.)[20]. in fact only rudimentary forms lacking effective macrostructural perceptibility, considered to be present at birth, with approximately null values (not entirely null), implicated in the initial earthly existence of the Human Being.[21]. In this context, there is a vague minimal resemblance to the notion of 'Universal Grammar', where a biologically innate ability is considered, not an attribute of an embryonic-infinitesimal form of consciousness. This possible ability is believed to derive from the genetic 'history' of the Human Being, representing only an original hypothesis of the American thinker Chomsky, formulated for linguistics. Between these two considered forms, no identity exists, though some interweaving with SCo. is possible; SE is therefore not a completely closed space.

---

imposed by Nature, already from the emergence of the "Space of Experience" (SE), at the moment of the human being's birth, with consciousness initially having minimal forms—essentially almost nonexistent (at most embryonic-infinitesimal, about which, at present, within specialized scientific knowledge, there is no fundamental certainty, but also no absolute denial). It is also stated that "*the 'Space of Experience' as well as the human being exist within an open / closed / open-closed / closed-open domain" [4]*

[19] This idea-concept was also presented and published in the USA by the first author, being delivered at a conference on system complexity, alongside the relevant mathematical considerations. Additionally, with some supplementary auxiliary elements, the topic was revisited and further developed in Argentina, during an international conference on the theory of complex systems, as well as in India in 2010, at the Congress of World Mathematicians, when the Fields Medal for mathematics (equivalent to the Nobel Prize) was awarded to the French mathematician Cédric Villani.

[20] However, in the article published in Science ("Intercellular communication in the brain through a dendritic nanotubular network," October 2, 2025, by Minhyeok Chang et al.), the authors do not mention the existence of possible cellular quantum structures within the analyzed tubular structures.

[21] The human being initially possesses only a so-called "neuronal tube" with a few neurons and an extremely limited number of synapses, as well as minimal bioelectric activity, almost nonexistent. These structures can be effectively developed only with the actual formation of the nervous system, between approximately 3–3.5–4 years of age. The incipient forms of human neurons develop after the embryonic phase, towards the end of the fetal stage, just shortly before birth. Under these conditions, at the moment of its emergence into the general natural human existence, the human being has a form of consciousness that is approximately null (though not completely null), as is also considered in SCo. within SE. This is, therefore, almost null (an aspect caused by the incomplete anatomical formation of human neural circuits), rudimentary, but not entirely null. For this reason, it is accepted that within SE, the space SCo., accompanied by its particularities, appears in macrostructural forms, perceptible only after the age of 3–3.5–4 years, and subsequently reconfigures continuously from birth until death, together with the other three fundamental components—SC, SS, and SCo. At the end of its normal earthly existence, or when extended by age, the consciousness of the Human Being may become somewhat altered due to the emergence of neurodegenerative biological forms, with cognitive implications, analytically justifiable within SM, but not exclusively (also within SC, SS, SCo.).

Note 1: One can also consider the form SE = {SC, SM, SS, SCo.} (2), with SC as initiator (different from SM in (1)). Both forms preserve their fundamental, distinct structures and are by no means competitive. The unity of the idea is invariant with respect to forms (1) or (2), In (2), SC is considered a fundamental ontological domain fundamental, with quantum information as a component, whereas in (1), SM is considered an ontological domain with classical information as a component. In (1), one can admit the direction determinate → indeterminate (from SM to SC and onwards), while in (2), one can consider the direction indeterminate → determinate (from SC to SM and onwards). In the latter direction, Emergence plays a significant role (as referenced by one of the authors in [5]). Considering SM as initiator implies the existence of macrostructural-empirical emergence, while considering SC as initiator implies quantum and subquantum emergence. In both SE forms, the fundamental domains SM, SC, SS, and SCo. exist, generating order, from which organization arises. Numerous detailed considerations regarding SE are found in [3] and [4], noting that SE, through its components, is heterogeneous, not homogeneous. The component spaces (subspaces) are sometimes vaguely contiguous (vaguely tangent), never fully overlapping. The order of consideration (SM or SC) is not essential, since both appear simultaneously from the birth of the Human Being.

Following is an example where the triad of coexistent molecular matter, bio-structured matter, and noesi-structured matter (first identified by Acad. Eugen Macovschi) has significance, with correlations existing within it (example: within SM). Notations in Fig. 1 are linked to strictly biological considerations and accompanying nonlinear mathematical relations, including numerous nonlinear differential equations, applicable in intensive and extensive evolutionary developments (vertical-evolutionary and horizontal, respectively). Biological-level considerations were estimated by the late Prof. Dr. Gavril Acălugăriței.In this essay, the existence of correlations, both horizontal and vertical (visible in Fig. 1) is emphasized, resulting in a level of order, organization, and self-organization. Within Macovschi's theory, correlations also occur between the three groupings (coexistent molecular matter, bio-structured matter, noesi-structured matter), at the molecular, functional-structural, evolutionary, and informational levels.The disappearance of one grouping, along with its correlations, implies the loss of order (homeostasis) of the entire bio-system, which ceases to exist in the form of life as understood by humans. Conclusions were obtained using formal-level methods. Loss of bio-structure (and its internal/external correlations) implies the disappearance of the entire bio-system, losing biological and even mathematical coherence if the bio-structure vanishes. Probabilistic approaches are also possible.Within the physicalism of the Human Being, correlations are generated (and even triggered) by the existence of minimum-energy mechanisms of life, bio-informational-functional and open. It is observed that noesi-structured matter has ontic support from bio-structured matter, which in turn is optimally generated through organization and self-organization by coexistent molecular matter.Observation: Both coexistent molecular matter and bio-structured matter become subsystems of level one and two, respectively, of noesi-structured matter, maintaining the bio-structure necessary for life, which depends on coexistent molecular matter (without relevant structure). A hierarchy exists in bio-structural theory.The Space of Experience (SE) considers, besides the strictly measurable forms in SM (as in Macovschi's bio-structural theory), the other fundamental spaces/subspaces that the Human Being possesses throughout life, from birth, constituting the superiority of the SE concept over purely empirical levels. Once again, we recall that the bio-structural theory, within SE, holds a relevant position, but only inside the Metric Space (SM), which is geometrically measurable (sometimes even restrictive), and not universally present. In this context, correlation (C) and order (O) become, through this mode of thinking, functions of SE, determined by the components that SE comprises (CO = f(SE), SE = {SM, SC, SS, SCo.} – with the meaning as previously explained). Currently, it is also accepted the fact[22] that "the S*pace of Experience represents a place where consciousness is not located but configures itself continuously*, along with it", with corresponding correlations and dynamics. Consciousness, both internal and external, is dynamic rather than static. Conștiința (atât cea interioară cât și cea exterioară), în fapt, nu este o entitate statică, ci dinamică. One note that a perturbed form, SE(*) = {SM(*), SC(*), SS(*), SCo.(*)}(3) can be identified,

[22] As presented in [3] and [4] (considerations belonging to the first author of this essay).

where (*) indicates loss of homeostasis, caused by (un)correlations generating cellular disorder, with physiological implications, potentially leading to the disappearance of the entire biosystem (pathogenesis). All component spaces (subspaces) belonging to SE will be affected, including their correlations and order; in this situation, there may even be distortions of correct psycho-neuro-symbolization in the Human Being (predominantly within SS). In SE, these phenomena can be explained better than in the singular-natural form SM, which is primarily used today, under bivalent logic. This also refers to neurodegenerative neoplastic forms, those determined by apoptosis, as well as deficiencies of the immune system[23], prion-related diseases, and others. It should be noted that all spaces (subspaces) belonging to SE and SE() are natural[24], however, through emergence, new spaces can also appear within SE and SE(). Within SE(IA), unknown forms of "quantum computing" occur, as well as the emergence of new codes and programming languages. In the network shown in Fig. 1, intensive (vertical) correlations are observed, such as those between proteins, enzymes, nucleic acids, and various chemical combinations within a single cluster, as well as intensive correlations occurring between bio-structured matter and noesi-structured matter. In the same network, extensive (horizontal) correlations can also be noted, existing across each of the three "segments." It is also useful to note that a system belonging to one level is considered to become a subsystem of the immediately higher level. The system of coexisting molecular matter becomes a subsystem of bio-structured matter (which is at a higher level), and this, together with the coexisting molecular matter, in turn becomes a subsystem of the noesi-structured matter system (which is at a higher level than bio-structured matter). The system of coexisting molecular matter becomes a subsystem of bio-structured matter (which is at a higher level), and this, together with the coexisting molecular matter, in turn becomes a subsystem of the noesi-structured matter system (which is at a higher level than bio-structured matter). In SE, given the existence of the components SM, SC, SS, and SCo., there is also a level of scientific hermeneutics necessary for the correct interpretation of correlations and order. In conclusion, it can be stated that every human Being possesses an SE from birth, through its component spaces SM, SC, SS, and SCo., which appear simultaneously and are hierarchically included as described. Therefore, when analyzing a Being (or intervening upon it), it is appropriate to consider the components of its existence within the "Space of Experience," and under normal conditions—all of them[25]. In this way, a range of mismatches can also be socially avoided, which could otherwise have long-term negative effects.

[23] In 2025, the Nobel Prize in Physiology or Medicine was awarded (according to the Nobel Committee) "for discoveries concerning peripheral immune tolerance," revealing clear correlations between T cells and cellular self-organization (including at a chaordic level), fluctuations, and (deterministic) chaos. It should be noted that in December 2025, the authors of this essay will also publish a detailed analysis of all the interdisciplinary and transdisciplinary aspects present in the topics distinguished with the Nobel Prize that year, as well as on the website of the International Union for Interdisciplinarity and Transdisciplinarity in Complex Systems (IUITCS), a scientific organization headquartered in Belgium.

[24] We propose, prospectively, the analysis of an "Artificial Experiential Space" (virtual) (algorithmic, classical, and quantum), denoted as SE(IA), generated with the aid of artificial intelligence. This idea could also be incorporated into the foundations of scientific transhumanist concepts. Through SE, a new topic is proposed for the future concerning what the "Experiential Space" (natural) becomes when considering SE(IA) (the rational acceptance of a form of artificial consciousness at a digital level), raising the following question: "How are the correlation and order within SE modified by SE(IA) (with its respective advantages and disadvantages)?" We consider that, in this context, ethical aspects must also be taken into account.

[25] Finally, we pose one more question, which will likely provoke reflection: What happens to SE when, for a living human being, SM is nullified (through the disappearance of that life)? Under such conditions, SC would function only through its imaginary components (the real parts of the Being becoming null), while

4. Conclusions and Perspectives

Correlation and order occur within cellular and molecular biological processes, as well as in mechanisms specific to bio-complexity. Aspects of correlation and order arising through self-organization have been identified within cellular processes (cellular communications) and within organic systems (subsystems) of the Human Being.The essay highlighted the importance of Emergence, the usefulness of considering ordered information states, derived from coexistent molecular matter, bio-structured matter, and noesi-structured matter, as in Macovschi's bio-structural theory. This was estimated to exist exclusively in SM, part of SE.SC was analyzed separately, emphasizing its distinction from SM, through the law of non-distributivity and distributivity, defining essential characteristics. The significance of chaordicity in bio-complex systems was evaluated, along with its role and timing in bio-complexity.As perspectives, fundamental guiding questions were formulated, potentially with plausible or implausible answers. Correlation and order were proposed to relate, in future, to artificial intelligence, including generative AI, as well as scientific transhumanism.

Observation: In Fig. 1, indices i, j, k, p and notations ↑, ↓, →, 0, 1, 2, 3, 4, 5 correspond to sets and subsets formed by coexistent molecular matter, bio-structured matter, and noesi-structured matter within SM of SE. These notations serve formal demonstration purposes, defining intensive (vertical) and extensive (horizontal) levels, as well as inter-set/inter-subset connections. Physico-mathematical relations being complex, only correlations and order within the network are highlighted, consistent with Macovschi's bio-structural theory, without mentioning accompanying analytical work, which has been presented in the USA, India, and Argentina, within a specialized meeting.

At the conclusion of this essay, we quote the remarks of a Romanian university professor of biochemistry, referring to the importance of the previously presented scientific research: "… cell biostructure is found under an altered abnormal state and the investigation of this state is essential to understand carcinogenesis. In addition, a mathematical hypothesis of networks of multidimensional hierarchic evolution with various ranks was advanced, and the self-organization of living was analysed in the frame of Macovschi's biostructural conception [291, 292].". The network's complexity varies horizontally, within the same level, and vertically from the lower io the upper level."[26].

SS would vanish, since even its symbolic "register" (which supports the living human) disappears. SCo.—specific to the previously existing human Being—could, at least theoretically, integrate after the actual disappearance of the individual into the vast domain of the Universe's Consciousness, but only through what remains of its existence, primarily in SC (which characterized it in the past). It is also useful to reflect on the Schrödinger wave functions, inherent to each of us.

[26] Works: 1**. Carcinogenesis; 2. Stresses; 3. Warburg Effect**, and others, uploaded on Academia.edu. Baiculescu, S. is cited in studies in Physics, Biology, Psychology, Consciousness, Genetics, Philosophy, and Biochemistry. *Propedeutics of the Essay "Space of Experience" – Prolegómena* is cited in publications in Consciousness and Biology and mentioned by Prof. Dr. G. Drochioiu (University of Iași). In Philosophy, it is cited in *Complexity and Transdiscipline: Epistemologies for Sustainability*, as well as in a work by Rudolf Klimek. All references are fully archived on Academia.edu.

NOESIS STRUCTURE (k=3)	3	3	4	-		-	framework relations (interface ANs(3)/psychic phenomena)	ANs(3)	BIOSICS	NOESICS
			3	-	-	-	sequences(noesic metabolism)			
			2	cortex	-	noesic disassimilation	time (non-linear biodynamics)			
			1	cerebral hemispheres	changes existing at the level of noesistructured matter;components movement	noesic assimilation	specific evolution (noesic assimilation)			
			0	ANs(2)	fundamental components ANs(3)	internal relations ANs(3)	external relations ANs(3)			
BIO STRUCTURE (k=2)	2	4	4	-	-	-	framework relations(interface ANs(2)/ANs(3))	ANs(2)		
			3	-	-	-	sequences(biosic metabolism)			
			2	intracapillary spaces	-	biosic disassimilation	time (non-linear biodynamics)			
			1	spongy mass	changes existing at the level of biostructured matter;components movement	biosic assimilation	specific evolution (biosic assimilation)			
			0	ANs(1)	fundamental components ANs(2)	internal relations ANs(2)	external relations ANs(2)			
COEXISTING MOLECULAR MATTER (k=1)	1	5	5	undissolved chemical combinations	-	-	-	ANs(1)		
			4	H_2O	-	-	framework relations(interface ANs(1)/ ANs(2))			
			3	auxiliary chemicalcombinations	undissolved chemical combinations and auxiliary reactions	-	sequences (metabolism)			
			2	nucleic acids	catabolism	dizassimilation	time(non-linear biodynamics)			
			1	enzymes	anabolism	assimilation	specific evolution (assimilation)			
			0	proteins	fundamental components ANs(1)	internal relations ANs(1)	external relations ANs(1)			
				SUBSETS $S_i^{j(k)}$						
(MBt) NIVEL	k ↑	p ↑	j ↑	FUNDAMENTAL COMPONENTS	INTERNAL RELATIONS	EXTERNAL RELATIONS	EVOLUTION RELATIONS	ANs(k) ↑	LIVING MATTER SPECIFIC OF THE HUMAN BEING	
				COMPONENTS SETS $S_i^{(k)}$ OF THE NETWORKS OF MULTIDIMENSIONAL HIERARCHIC EVOLUTION ANs(k)						
i→				0	1	2	3	4	5	

Fig. 1 The ANs(k) networks (k = 1, 2, 3) associated to the three levels of the living matter, identified within biostructural theory

Selective bibliography

[1] Grégoire Nicolis și Ilya Prigogine, Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order Through Fluctuations, 1977, Editura Wiley, vol.29, USA;
[2] Grégoire Nicolis și Ilya Prigogine, Exploring Complexity: An Introduction, 1989, Editura W,H, Freeman, USA;
[3] Baiculescu Sorin, ***SPACES AND IDEAS*** – Propedeutics of the Essay "Spaces of Experience" (Prologomena),2022, Scholars' Press, Editura Schaltungsdienst, Berlin, Germania;
[4] Baiculescu Sorin, ***Spațiul Experienței*** (ediție bilingvă), 2013, Editura Amurg Sentimental, România;
[5] Baiculescu Sorin, *Emergența*, Noema XIV, 2015, Editura Academiei Române;
[6] Constantinescu Paul, ***Sinergia, informația şi geneza sistemelor - fundamentele sinergeticii***, 1990, Editura Tehnică, București, România;
[7] Enescu Gheorghe, ***Dicționar de Logică***, 1985, Editura Științifică și Enciclopedică, București, România;
[8] Israil Anca-Michaela, ***Biologie moleculară-prezent și perspective,*** p.418, 2000, Editura Humanitas, România;
[9] Godeanu Metz Adriana și Baiculescu Sorin, ***Apologetica biocomplexității***, 2006, Editura Ilex, România;
[10] Proceedings of an International Conference held in Bari, Italy, July 18-22, 1983, ***Mathematics in Biology and Medicine***, Edited by V. Capasso, E. Grosso and S.L. Paveri-Fontana, 1985;
[11] Simion Z. și Schneider F. (coordonatori), ***Aspecte actuale de biologie și fiziologie moleculară,*** 1998, capitolul "***Modelare matematică***" (autori: G. I. Mihalaș și Z. Simion), pp. 107-112, Editura Viața Medicală Românească;
[12] Tassi Philippe, ***Méthodes statistiques***, 1989, Universités Francophones, UREF, Paris, France;
[13] Teodorescu Dan, ***Ingineria biosistemelor – o introducere prin intermediul modelelor***, 1978, Editura Facla, România.