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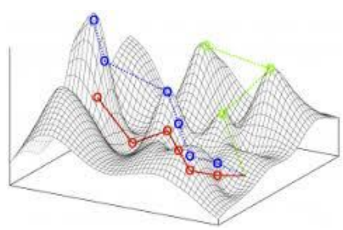
Journal of International Union for Interdisciplinarity and Transdisciplinarity in Complex Systems



1/2023

Content

Argument

The Journal of the "International Union for Interdisciplinarity and Transdisciplinarity in Complex Systems" - <<I.U.I.T.C.S.>> proposes the expert submission of some notifications and comments from the point of interdisciplinary and transdisciplinary point of view related to the current international results and having a scientific and humanist profile. The texts of the Journal are referring to the high-performance university and academic studies. In order to put into light the concerns for the XXIst century interdisciplinarity and transdisciplinarity and to evidentiate, at the same time, the significances of the respective fields, the journal will open with an argument review of the general issues and also of the structure related to them. In this edition, are shown and commented some interdisciplinary and transdisciplinary scientific aspects which find their place within complex systems, the forms which can be taken out from the results that have been granted the Nobel Prize in 2023. The current research is also accompanied by a glossary of scientific terms related to quantum phsyics and chemistry, medicine (biology) and physiology, as well as other two well-known essays (somehow visionary, at the time) essentially concerning issues referring to emergence and complexity by the remarkable physician granted with the Nobel Prize – Dr. Philip W. Anderson. In the end, are presented some current university and academic fields and concerns where are to be found the main forms of interdisciplinarity and transdisciplinarity of complex systems existing within an immediate context, also pertaining to the relationships among the latter (after UNESCO classification).

Interdisciplinarity and transdisciplinarity existing in complex systems – current aspects

Nowadays, within the international scientific segment, one may notice the continuous existence and requirement for a well-marked interdisciplinarity and transdisciplinarity, with pertinent significance. Thus, by means of interdisciplinarity, a “cross-fertilization” with epistemological level takes place; it pertains to the research and analysis of the knowledge hermeneutics obtained by means of an optimal redefinition of general concepts, logics, methods appplied to the scientific research and humanism, to the philosophy of the latter. It is to remark the “transversality” which characterizes interdisciplinarity, as well as the scientificity which is already to be remarked, making its presence still known within the transdisciplinary disciplines.

The complexity of the subject matters, as well as the considering of the close results among them, of the simultaneity in achieving the different research steps proper to the harmonizing of the languages used, of the limitations implied by the auxiliary aspects, sometimes having determinant influences on the scientific “targets”, are also useful in an (upward) modification the intellectual attributes of the Human beings, obtainable in an interdisciplinary and transdisciplinary way.

The knowledge supposes integrativity and convergence, as well as forms exercitated on the study and research of a subject matter by two or more disciplines having, most times, as an objective, also obtaining a local “wholism”.

Currently, some new methods are proposed to optimize the research field proper to interdisciplinarity and transdisciplinarity of complex systems, thus trying to avoid the possible redundancies, as well as heterogeneities, dissipations, non-integrativities, influences of the non-neighbouring results proper to non-harmonized langauges. Thus, a complementarity of interdisciplinarity and transdisciplinarity concepts takes place, implying the recent mechanisms of integrative research, but observing, however, the disciplines of an academic level, the requirements of the latter being maintained by means of an optimal reorganization and by means of specific intelligently built softwares. Thus, is generated the emergence of new disciplines, proper to the XXIst century. They imply professional competencies recently appeared, and no discipline will be superior to another.

Essentially, a number of six funamental complex systems are considered: a) physical and chemical; b) bio-molecular and cellullar; c) physiological; d) organisms and populations; e) social-human and economic; f) engineering. Within those systems are to be found different research subject themes, such as those referring to emergence, complexity and bio-complexity, self-organization. The current forms, proper to the concerns taking place within complex systems, consider the (mathematical, physical, chemical, biological) modelling (existing in cognitive disciplines), the evolution and adaption, the colective behavior, the non-linear dynamics and bio-dynamics, the theory of games, the theory of systems, the theory of networks, each having, in turn, numerous distinct components which interact among one another. At the same time, the number of the level of scale is considered; the primary level is proper to the common, non-structured behavior. There is an intensive (vertical) hierarchy of the former within which, at a certain moment, appears a structure that assures quality by means of its processes and mechanisms. Thus, the optimal development of functionality, proportional with the hierarchic growth of the level of structure (including the biological one) takes place. E.g.: within the living processes there are: the common molecular matter (non-structured) (level I), the bio-structured one (level II), the noesi-structured one (level III). As concerns the extensive (horizontal) hirarchy, are considered the interior relationships, proper to the system and exterior ones (with third complex system, such as the environment), as well as the forms of evolution (one can notice that they take place also within the intensive (vertical) hierarchy). When considering that, are taken into account the general concept of system, the necessity of some optimal flows of energy to exist, for its functioning, as well as Newtonian space and time, quantum processes, biological information (including genetic + epigenetic), bifurcation, space of phases, statistic aspects, adaptativity and evolution.

There are essays that concern interdisciplinarity, where it is remarked the fact that in some West-European states, such as U.K., Holland, Belgium, Germany, France (*University of Paris "Sciences Po"*), there are concerns regarding the field of interdisciplinarity, but also in the USA (*The Center for Studies of Interdisciplinarity, The Faculty of Graduate Studies of British University Columbia, Fairhaven College of Bellingham-Washington, Stanford University (software of the types:Bio-X-biology, medicine, bio-mathematics (modelling in genetics and evolutionist biology, bio-computational disciplines)), bioengineary – University of Pensylvania*). To be remarked, too, in the USA – *Association for Interdisciplinarity Studies, International Network of Inter.&Transdisciplinarity, Philosophy of/as Interdisciplinarity Network, Center for Study of Interdisciplinarity – University of North Texas*. And so on. Thus, it is generated a new modality of approach, what, in fact, the philosophy of interdisciplinarity considers to represent an "ontological unity of disciplines".

Interdisciplinarity and transdisciplinarity may be also found in humanist disciplines (general-theoretical philosophy, as well as theology – with its aspiration towards ecumenism, hermeneutics, semiotics, general antropology and antropology of culture, psychoanalysis, philology, linguistics and psycholinguistics, economy and bio-economy, legal disciplines, history, sociology, politology…), obtainable by means of establishing some connections existing among the classical domains and the new ones, which emerged in the XXth-XXIst centuries. It is also taken into account the perspective to come, by connecting the humanist disciplines with the non-humanist ones, some of those having a dominant actuality (artificial generative intelligence, computational legal studies and others).

For instance, it is to be remarked a domain with an interdisciplinary and transdisciplinary status + a great amount of instrumentalism, named "neuroscience", which also contain domains such as mathematics and bio-mathematics, physics and mathematical physics, theory of operators (existing within quantum disciplines), biology (cellular, molecular, synthetic), biophysics, biochemistry, philosophy of science and epistemology, neurophilosophy, neurolinguistics and psycholinguistics, bio-psychology, medicine, genetics and epigenetics, medical imaging, bio-complexity, sciences of computation, nanomedicine, neuroetics, neuroinformatics, neuroengineering.

One should also remark the major concerns of bioetics that include interdisciplinary and transdisciplinary elements (contributions) in the following fields: biology, genetics and epigenetics, medicine and biotechnology, artificial intelligence and mathematical, physical, chemical, teological, antropological, legal, philosophical, sociological modelling…

There are important subject matters and also considerations, in time, belonging to remarkable thinkers, philosophers and logicians, such as Georg Cantor, Gottlob Frege, Edmund Husserl, Martin Heidegger, Karl Popper, Rudolf Carnap…, who generated and claimed some scientific and philosophical ideas, very significant in our days, too, for the thinking and judgement (interdisciplinary and transdisciplinary direction), some of which having futurist attributes, too.

As compared to the period of about fifty years ago, currently, the situation of non-humanist sciences, but humanist ones, as well, has been much modifying; a feasible solution is the one generated by the approaches of interdisciplinarity + transdisciplinarity, since the functional framework of the latter is continuously optimally-rebuilt, based on significant ideas, intelligently applied.

As concerns the special significance pertaining to transdisciplinarity, one can distinguish three fundamental components. Transdisciplinarity is different from interdisciplinarity. The three components of transdisciplinarity refer to (I) the knowledge existing within disciplines, exterior connexions which may take place with other academically accepted domains (even border ones) (II), within the context (III) of some "evaluations" when (potentially) considering the levels of reality, where some of these are "felt" and "intuited" by the Human being, by means of some forms proper to neurophysiological perception, some others - not. Different forms of logics are used, too (in the superior-experencial, phenomenological, and not at all common, trivial situations) which do not fit into the forms of Aristotelian logics, but having, however, consistency (e.g.: logics of the third party included, third, polyvalent type of logics, the principles of tetralemma, others). In this sense, it has been accepted to include the issues of transdisciplinarity also in the category of those pertaining to complexity, biocomplexity, as well as chaordicity (appliable to situations when complexity and biocomplexity go beyond the human understanding). An essential requirement of transdisciplinarity is represented by the characteristic of the temporal simultaneity of the three forms - I, II, III -, a fact that cannot exist within a strictly interdisciplinary framework. Transdisciplinarity has also a methaphysical aspect (that goes beyond the common rationality of the human being, as it is, trivially known), an aspect which, sometimes, is no longer taken into account by the university and academic environment. This may, however, represent, in the context of the current period, but also in perspective, an interesting method of study, to be possibly considered also within the fundamental research which is complementary to logics, methodology and philosophy of science (sometimes, named classical). It is useful to remind, in the context of component III of transdisciplinarity the Borromean regions, too, which specially refer to the triad Real – Imaginary – Symbolic, where the Human being is at their intersection; the Real "zone" is not accessible to the latter, since it is different from the ontic reality (Heidegger).

To close the current essay, we also consider the situation of the systems of complex systems. In this context, a complexity of level 1 takes place, existent within each system and a complexity of level 2, more remarkable, which takes place among the (global) systems of complex systems, consequently including the systems of level 1. When thinking of interdisciplinarity and transdisciplinarity existing within complex systems of level 1, it is necessary to take into account, at the same time, the systems of systems that have this form, which consequently also implies the intersystemic analysis of the relationships among the systems that include complex systems of level 1. This aspect makes a difference between some of the current concerns of the <<I.U.I.T.C.S.>>, and the series of the objectives proper to the analysis of common complex systems. The interdisciplinary and transdisciplinary relationships existing within complex systems of level 1 and among the systems of complex systems of level 1 represent modern concerns that sometimes also have phenomenological aspects. Example: Social systems of a complexity of level 2, containing systems with a complexity of level 1, are currently represented by the European Union, as well as the United States. In the first case, the component states of the European Union represent complex systems of level 1 of complexity and in the second case, the complex systems with level (degree) 1 of complexity are represented by the states composing America. Between the two multinational forms, multistatal-regional respectively, (each having a complexity of level 2), containing systems of complex systems of level 1 of complexity, some relationships also take place. One can also remark examples in cosmology, as well as in other third domains. The category of complex systems of level 1 of complexity also may include the big systems (current scientific name), having numerous sub-systemic components. It is useful to remind, however, the fact that big systems can sometimes constitute systems of complex systems.

PS: The current text concerning interdisciplinarity and transdisciplinarity of complex systems also contains some useful directions, the results being, at the same time, that the differencies between them are marked. Extensions are necessary, if we think prospectively; (probably, within future steps) there will be referencies to thinkers who have contributed to the analyzed landmark issues.

<<I.U.I.T.C.S.>> Scientific Board

Bibliography: 1. Martin Heidegger, *Science and Reflection*, 1954, pp. 155-182; 2. Julie Thomson Kleine, *History-Theory-Practice*, 1990; 3. Jan C. Schmidt, *Towards a Philosophy of Interdisciplinarity*, 2007.

Interdisciplinary and transdisciplinary aspects existing in complex systems identified in the results granted the Nobel Prize in 2023

Sorin Baiculescu[1]

General introduction (references to the Nobel Prizes, to the reasons for granting the former)

In the period 2nd – 9th October 2023 the Nobel Commitee *(in Sweden: Royal Swedish Academy of Sciences din Stockholm – the institution designed to grant the Nobel Prizes for Physics, Chemistry and Economy; Karolinska Institute in Stockholm – institution designed to grant the Nobel Prize for Medicine and Physiology; The Swedish Academy in Stockholm – institution designed to grant the Nobel Prize for Literature and Norway: Norwegian Nobel Committee, Nobel Peace Prize – Norwegian Nobel Institute in Oslo – institution designed to grant the Nobel Prize for Peace)* presented the Nobel Prizes for the year 2023. Those were granted for the following domains: Physics, Chemistry, Medicine and Physiology, Literature, Peace, Economy *(a prize funded, since the year 1968, by the Central Bank in Sweden (Sweriges Riksbank in Stockholm))* granted by the Royal Swedish Academy of Sciences in Stockholm. The structure is described as follows, for the year 2023..

Physics

Pierre Agostini (Ohio State University, Columbus, USA); Ferenc Krausz (Institute Max Planck for Quantum Optics, Garching, Germania; University Ludwig-Maximilians, Münich, Germany); Anne L`Huillier (University of Lund, Sweden).

Reason: “For experimental methods that generate attosecond pulses of light for the study of electron dynamics to matter”.

Chemistry

Moungi G. Bawendi (Institute for Technology (MIT), Cambridge, Massachusetts, USA); Louis E. Brus (Columbia University, New York, USA); Alexei I. Ekimov (Nanocrystals Technology Inc., New York, USA).

Reason: “For the discovery and synthesis of quantum dots”.

Medicine and Physiology

Katalin Karikó (University of Szeged, Hungary); Drew Weissman (University of Boston, USA).

Reason: “For their discoveries concerning nucleoside base modifications that enabled the development of effective Mrna vaccines against Covid-19”.

Literature

Jon Fosse (Norway)

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[1]President <<I.U.I.T.C.S.>>, the Romanian Committee for the History and Philosophy of Science and Technics (CRIFST), Division of Logic, Methodology and Philosohy of Science (DLMFS), the Group for Interdisciplinary Research (GCI) – The Romanian Academy, Société Française de Philosophie.

Reason: "For his innovative plays and prose which give voice to the unsayable".

Peace

Narges Safie Mohammadi (Imam Khomeini International University, Qazvin, Iran).

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Reason: "For her fight against the oppression of women in Iran and her fight to promote human rights and freedom for all".

Economy

Claudia Goldin (University of Harvard, Cambridge, Boston, USA).

Reason: "For having advanced our understanding of women`s labour market outcomes".

The Nobel Prizes (Nobel medals and diplomas) are effectively granted to each laureate, by the King of Sweden (Physics, Chemistry, Medicine and Physiology, Literature), always at the same date of the year – 10^{th} December –, in "Stockholm Concert Hall" and – according to the same principles – by the "Royal Swedish Academy of Sciences" in Stockholm (Economy). On the same day, in Oslo (Norway), in "Oslo City Hall", is held the ceremony of granting the Nobel Prize for Peace by the "Chairman of the Norwegian Nobel Committee", in the presence of the King of Norway. In 2023, there were eleven Nobel laureates, six of them from the USA, one from Germany, Sweden, Hungary, Norway and Iran. Each one, as per the Nobel statutes, has he right to have a single "Nobel lecture", referring to the subject for which they were granted the distinction[2].

Abstract

In the following text, there are comments for each of the fields mentioned in the introduction, the significancies of the subjects for which were granted the Nobel prizes in the year 2023. In the second part, there are references to interdisciplinary and transdisciplinary aspects existing within complex systems, which also include the results granted the Nobel prize, for the respective period. In the context, are put into light the importance and their perspective, in relationship with the border and futurist disciplines. It is useful to remark, when putting those aspects into light, the structure of the expertise of the Nobel Committee (specially) created with a view to identifying the Nobel distinctions granted in 2023 (theoretic and experimental physics (applied physics), computational biology, physical biology, molecular physics, quantum physics, nanostructural physics, physics of materials obtained by nanotechnology, geophysics, mathematical disciplines, biology of molecular systems, endocrinology, immunology, neurosciences, neurology, molecular biologic development and theoretic/applied chemistry, medical chemistry, organic chemistry, structural chemistry, chemistry applied in biology, universal literature, legislation, universal human rights, economy, finances, history of economy, sociology, economic statistics, others).

[2]For the mathematical sciences, the equivalent of Nobel is represented, since the year 1936, by the Fields Medal granted by the "International Mathematical Union".

Physics

The Nobel Committee - 2023 for physics which established, according to analyses, reports and references, the granting the Nobel prize - 2023 for physics was composed of the following ten specialist-experts: teoretic physics (Dr. Ulf Danielsson), experimental physics (Dr. Eva Olsson), computational and physical biology (Dr. Anders Irbäck), molecular physics (Dr. Mats Larsson), applied and quantum physics (Dr. Gőran Johansson), physics of nanostructures (Dr. David Havland), physics of materials (Dr. Ellen Moons), general physics (Dr. Mark Pearce), theoretical physics (Dr. Olle Eriksson), geophysics, teoretical mathematics and pshysics (Dr. John Wettlaufer).

In conformity with the theory of the quantum mechanics, rapid processes take place within atoms, with a very short duration in time; they are governed by the Werner Heisenberg non-determination relationship. In the context, within the quantum interactions, takes place the non-commutativity; the status of an electron modifies according to the order of measurements (step 1 – position of the electron, step 2 – speed of the electron) or vice versa (step 1 – speed of the electron, step 2 – position of the electron)[3]. The modification of the status of the electron is, accordingly, dependent of the order of measurement. Thus, there is a complex physical system with a quantum nature, which may be analyzed by a non-commutative algebra. Alain Connes (a French mathematician granted with Fields in 1982) is the author of non-commutative geometry[4], also used in a quantum context. The time for vizualization of the processess proper to the electron, is running on the background of short light impulses which may put them into evidence, with values of the order of attoseconds (1as.=10^{-18}sec.)[5]. The quantum fluctuations cannot be perceived by humans (including the precise parameters of the dynamics of the electron). In conformity with the researches of the physicians de Broglie and Bohm, the position of an electron cannot be identified with precision, and the respective sizes are, in fact, considered to be some hidden variables. Matter has a granular (discontinuous, not at all continuous) form. In this situation, are considered the probabilities of the positions of the electron (electronic cloud). It is considered that, by the interaction of the electron with the physical form, the former will obtain materialization.

Note: In the text, there is a short “brace” of knowledge, in order to put even more into light the resultat obtained by the three physicians. Further on, we shall explicitate it and refer to its importance for the interdisciplinarity and transdisciplinarity of complex systems.

The dynamics and the position of the electrons of matter atoms can be found out in an experimental way, too, in real time, by means of short light impulses with a unitary duration of 10^{-18}sec., named attoseconds. The respective pulses are accepted since their existence duration is under the level of the times required for the electrons to achieve a new positioning, generated by the burden and chemical links proper to the atom. The procedure is from the field of spectroscopy related to the emission and absorption of light by matter. Pulses are electromagnetic waves. For a correct identification, it is necessary that the latter be characterized by parameters with a size of the same level as the one of the researched entity (the electron) (optimal resolutions – spatial and of impulse). Very short light pulses, measurable in attoseconds, are,

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[3]$A_{c.}$ x $B_{c.} \neq B_{c.}$ x $A_{c.}$ | $A_{c.}$, $B_{c.}$ – sizes proper to quantum aspects.

[4]In the context of non-determination which takes place in quantum physics, by means of a short SF essay named “Le théâtre quantique”, dr. Connes (also a co-author) introduced the person of a woman-physician (Charlotte Dempierre), who has a complete perception of the Universe (an impossible aspect) without having the non-determinations and limitations of the general perception of the Human being. She enjoys all the possibilities of knowledge accepted by the Universe.

[5]Taking into account, for the comparison sake, the Planck time ($t_P=10^{-44}$sec.) (known as the extreme limit under which there is no sense to exist time in the Human being’s perception), also result the relationships $t_P=10^{-26}$as., 1as.=$10^{26}t_P$. The Planck length (the extreme limit under which there is no sense in considering any length, within the same perception) is $L_P=10^{-33}$cm.

generally speaking, obtained by the interference and composition of some monocromatic waves. In 1988, Anne L`Huillier presented a method to obtain some light waves with different wave lengths, using a laser which was sending light into the molecules of a gas, while at the exit it resulted the group of harmonic waves belonging to incident light from the laser. In 2001, Pierre Agostini presented a method to focus light pulses directed towards a gas (argon), thus quantifying the photoelectrons emitted by means of a photoelectric process, and resulted from the initial sending of the laser light. In 2010, Ferenc Krausz presented the result of his remarking the delay of the photoelectronic processes of the electron dynamics belonging to an electronic cloud. To remark that the time of orbitation for the electrons within the neon atom is approximatively 100as.; the measured parameters had about the same order of size with the one of the researched entity (the electron).

Thus, a new method of effective observation was initiated ("in vivo", in real time) of the dynamics of the electrons of matter atoms, by means of the laser light and light pulses, with a unitary duration of the order of 10^{-18} sec., what had been previously achieved only by a theoretic estimate. One can vizualize, by means of what the three researchers granted the Nobel prize achieved, the behaviour of an electron, although the Heisenberg incompletitude principle limits one in calculating precisely – just the impulse or just the speed of the latter.

The result of the research granted with Nobel-2023 will determine remarkable interdisciplinary, but also transdisciplinary scientific implications existing within complex sytems. We should remark several connections, first from the intedisciplinary point of view: a) a clarification of the understanding of the dynamics of atoms orbitated by electrons, existent within materials and methamaterials, their implications in nanotehnology (nanorobotics) and in superconductivity (including achieving some superconductive materials that will optimally operate at the temperature of the environment); b) an understanding the biomolecular processes (dynamics of the atoms of biomolecules, as well as molecular robotics): c) a superior understanding of the dynamics of atoms within the devices with semiconductors; d) an optimization of the ELI Project ("Extreme Light Infrastructure") existent at Măgurele; e) achieving some photonic crystals; f) putting into evidence the current chalenges existing in physics, proper to the results obtained within the "Large Hadron Collider" (LHC) – CERN Geneva; g) achieving optic computers and computers with biomolecules; h) obtaining optimal scanning results in biology, medicine, psychology; i) a supplementary understanding of the processes taking place in the cerebral matter, analyzed also in "neuroscience", as well as by mathematic oncology, also representing knowledge from the charting of the human brain; j) a supplementary understanding of cerebral behavior; the brain also has some quantum peculiarities (the superposition of the possible quantum states of components belong to the brain and to thinking, with implications also as concerns consciousness, considering the de-located quantum states (microtubes + macromolecules of tubuline, nanotubes of carbon)). The considered interdisciplinary connections may be included into the category of complex systems, among which, we essentially mention the following ones: a) physical and chemical; b) biomolecular and cellular; c) physiological; d) organisms and populations: e) social-human and economic; f) engineering. As transdisciplinary aspects of the form III[6] within some levels of reality, we would like to remind some claimings, in conformity with which, time, in fact, doesn't exist. That opinion is, probably, justified by the fact that, since time intervals within which quantum events are taking place have extremely small intervals of time, of the level of attoseconds, and, since quantum phenomena (considered to be events) compound one another, the (illusory) situation occurs when the limited perception of the Human being can no longer perceive time, considering it, by an extension of thinking, as non-existing. From the macrostructural point of view, at the level of attoseconds, time cannot be perceived by humans, as an entity that they can understand quite well. However, the former exists. Quantum time is unique and universal. Some opinions claiming that time does not exist have also been in the previous period. Robert Matthews (University of Aston, Birmingham), referring to

[6]As per the mentionings in the introduction (the text ref. to "Interdisciplinarity and transdisciplinarity existing in complex systems – current aspects"

the significance of the notion of time, shows that, in the context of the relationship Wheeler-DeWitt, which describes the quantum birth of the Universe, the "real" time did not exist. In the mathematical form proper to that relationship, one may remark its non-existence, the sizes that occur being just the wave function, the ray of the Universe, the constant of the Planck scale (to which even the "mergings" that make the structure of the Universe would become detectable), the scalar field of forces that had occured at the Big Bang singularity, the (future) scalar potential for the expansion of the Universe. That is to be "expressed" by means of a differential ecuation with partial derivates of the second order and limit conditions (Yong-Chang Huang – Institute of Theoretical Physics, Beijing, Popular Republic of China (http://arxiv.org/ftp/arxiv/papers/0705/0705.2083.pdf). The English philosopher and physician Julian Barbour (University of Oxford) supports the idea of the irreality of arithmetic time, claiming that this is just an illusion generated by the metrical perception of the Human being, evaluated from the past towards the future (Julian Barbour, (1999), *The End of Time: The Next Revolution in our Understanding of the Universe,* Oxford Univ. Press.). The author refers to the fact that "The Universe would be, in reality, an ensemble of static, "nows", snapshots situated on a cosmic film roll. With any moment or any "now", time is not a necessary factor to explain the functioning of the Universe. The perception of the passing of time would come from the way the human mind is processing those snapshots – or "time capsules", as Barbour calls them. However, time in itself, he claims, does not exist (Robert Mathews, *The Truth About Time,* Science World, September-October 2013, University of Aston, Birmingham, p.2). The American physician Lee Smolin claims that "time is, however, the most important characteristic of reality – one so fundamental, that its existence transcends the one referring to our Universe" (same publication as the previous, p.3). It is probable that, by the expression "fundamental reality" Smolin understands, in fact, only a metrical reality, not a complex, symbolic and a reality of consciousness that, together with the former, form what represents the Being, what makes the latter completely exist in the Universe, that is the Being's "Space of Experience". If we refer also to the way we may understand David Bohm's expression ("non-fragmented plenitude"), a certain degree of it would no longer be necessary to exist. The level "degree" is, from the beginning, that of the whole of the Human being, globally existent, since only within the respective framework, all processes and phenomena proper to the former, taking place within the "spaces of projection" (metrical, complex, symbolic, of consciousness) are wholly "understood", by merging. Explicitation is achieved, in this case, within the "projections", the implicit form taking place within the "Space of Experience", and, thus, it is no longer necessary its winding or unwinding. They can obviously, sum up, but not form together series towards the infinite. A certain similitude with the ensemble of static "nows" descricbed by Julian Barbour can be noticed. The dynamics of the Human being results by superposing some forms of "now", which are put into evidence within a "cosmic roll". Robert Matthews remarks: "… […] time surely seems real" (but only seems..., since it is considered to exist, generally speaking, exclusively by its arithmetic form within the metrical space). Barbour refers to such a global, complet time, excluding the existence of the common time. While putting into evidence the behavior of electrons within matter will also clarify the uncertainties on time reality, existing at the primary (matter) level; this achievement is, for the moment, sufficient. Within the general theory of relativity, time can be considered as having several forms. As Lee Smolin was writing in his book *"Einstein's Unfinishes Revolution: The Search for What Lies Beyond Quantun"*, 2019, USA, p.34 "… there is, somewhere, a transition from the quantum world (where an atom can be several places, at the same time) and the common world (where any thing will be, always, at a certain place). An answer to the issue of measuring would tell us where is that line and would explain the transition". From the epistemologic point of view, it is also relevant the (determined) way scientific knowledge occurs, an aspect that is reflected also in the research we referred to. There is, in fact, a hermeneutics, within which quantum mechanics find its place, too, by its different interpretations, in the spirit of: Copenhagen (main promotors - Niels Bohr (complementarity) and Werner Heisenberg), or of the wave and Schrödinger's observations, the triad Einstein-Podolsky-Rosen (EPR – 1935), Born (probability wave), Bohm (in search of the transcendent forms of the quantum field), Bell (introducing the term "beable" (which can exist), existent no matter of having made or not a measurement, apart from some theoretical results), others. As Bohr thought, "science is in a permanent dialogue with Nature". Personal remark: "not dominating it, but only discovering it, as far as the latter permits, at certain times, and, in this sense, introducing also the remark in conformity with which "The Space of Experience and the Being exist within an open / closed / open-closed / closed-open domain"[7]. In fact, it is necessary to put prioritarily into evidence the knowledge of some relationships existing between the Human being and Nature, not only of Nature itself (a process which is beyond us, in terms of significance). Mathematicians, philosophers, physicians and chemists have still been analyzing the significance of the results of the quantum theory; the current achievement, that we have referred to, still needs continuous clarifications.

Chemistry

The Nobel Committee -2023 for chemistry, which established, upon analyses, reports and references the granting of Nobel - 2023 in chemistry, was composed by the following eight specialists-experts: biochemistry (Dr. Peter Brzezinski), applied chemistry (Dr. Olof Ramstrőm), theoretical chemistry (Dr. Johan Åqvist), organic chemistry (Dr. Peter Somfai), nanophysics (Dr. Heiner Linke), structural chemistry (Dr. Xiaodong Zou), biologic chemistry (Dr. Pernilla Wittung-Stafshede), medical biochemistry (Dr. Andrei Chabes).

The quantum dot, with the "diameter" of the order of a reduced number of nanometers ($1nm = 10^{-9}m$), is a nanocrystal, where there is also a small dimensional space containing only a few atoms, similar, in terms of dimension, to the wave length of an electron. Its electrons have reduced levels of energy generated by the process proper of a quantum confinement. As concerns small dimension materials, of the level of nanometers, the process of quantum confinement generates the difference between the levels of energy proper to electrons and their band gap. Quantum points represent nanoparticles of very small dimensions, also when obtaining some semiconductors (dimensionally reduced) with particular characteristics (electronic/optical). Electrons may be influenced by generating a certain state of excitation, in order to determine them to emit a quantity of light, obtained according to the characteristics of crystals, and that is what makes them able to be manipulated. The emission process of the light by the electrons is generated by the fact that the size of a quantum point is quite close to the sizes of the electron, the characteristics of the latter being, in general, of the order of the sizes of molecules/nucleous/electron/atom. The properties of the quantum dots put into evidence by the three Nobel laureates are situated between those of the atoms and those of the semiconductors (electronic devices). The (reduced) "geometry" of the quantum dots implies the modification of some essential characteristics of materials, the quantum field (by behavior) being much different from the classical (macroscopic) one, the "passing" line from micro. to macro. being still, searched for (Lee Smolin's observation, previously mentioned). To remark the fact that the Nobel granted for chemistry for the year 2023 is part of the series of concerns that are proper to the concerns of quantum chemistry, too[8] (classical phyisics and chemistry are insufficient).

Important disciplines of the XXI[st] century, implied in interdisciplinarity, which benefit, by their structure also from the properties connected to quantum dots, are also represented in medicine and biology (latest generation of biomedical imaging, with a visualization of cancer tumors, too), constructive technology of different industrial devices – that have solar cells mounted on them (photovoltaic devices), domains related to lasers,LEDs and monitors of rigid and flexible computers, TV sets of the "plasma" type, sensors with nanometric sizes and, in perspective – quantum ordinators and crypted quantum communications. Quantum points have minimal sizes; their characteristics, generated by their size, are useful to

[7] Sorin Baiculescu, *Space of Experience*, bilingual edition, Bucharest 2013 (cover 2).

[8] As per Schrödinger, in quantum physics, the wave function, which does not have, in fact, a strict physical sense belonging to the electron, represents the solution of an equation with partial derivates of the form $H\psi = E\psi$ ׀ H – operator (Hamiltonian) correlated to the E total energy of the system, ψ – the wave function (whose value in the module, at power 2, shows the probability by means of which a complex quantum system, at time t, is within an "electronic cloud", being positioned, within this frame, in fact, around the point of coordinates (x_1, x_2,...). By integration, the wave function ψ is obtained, determined according to E energy.

mechanisms appliable to nanotechnologies. An auxiliary observation is that we can notice the fact that, lately, the Nobel prizes for physics/chemistry have been granted also for the concerns existing in vizualizing the behavior of the ”world” of electrons (in general, of the quantum and sub-quantum particles). Currently, some new experimental methods and organizations (quite sophisticated) are searched for, by means of which may be avoided the phenomenon of decoherence (which occurs at the interference of the quantum (microscopic) ”world” with classical devices (macroscopic) necessary to humans for measurements). Human beings, as macroscopic entities, find themselves at the impossibility to observe, in a real way, what takes place in the quantum region, unless they measue. However, that whole “world” disappears, by decoherence, when we try to evaluate it by classical measurements (observation). This allegation can be exemplified also by a result granted the Nobel in 2012, when Serge Haroche (France) and David Wineland (USA) obtained the respective prize thanks to their remarkable results named:“*Revolutionary experimental methods allowing to measure and manipulate individual quantum systems”* (avoiding the issues generated by the decoherence, o.n.). Analyzing the decoherence from the transdisciplinarity “angle”, we may estimate that it has profound implications (thought of by the quantum science philosophy, too) for issues proper to quantum information, to “quantum entanglement”, communications, quantum coding and teleportation, the (presumptive) existence of superluminic speed (impossible – as per the Einsteinien theory). Quantum points, also analyzed by transdisciplinarity, have some complementary implications in elucidating the misteries of Nature, too, helping to its understanding by the Human being, but also to correctly elucidate the described elements (still unsufficiently) by means of quantum physics and chemistry.

Medicine and Physiology

The Nobel Committee - 2023 for medicine and physiology which established, upon analyses, reports and references, the granting of Nobel - 2023 for medicine and physiology, was composed by the following six specialists-experts who work at the Karolinska Institute: biology of molecular systems (Dr. Sten Linnarsson), endocrinology (Dr. Olle Kämpe), immunology (Dr. Gunilla Karlsson-Hedestam), neurosciences (Dr. Abdel El Manira), neurology (Dr.Per Svenningsson), molecular biological development (Dr. Thomas Perlmann).

In order to have a correct perspective over the significance of the research achieved by the two Nobel laureates in medicine in 2023, we first introduce a short preamble concerning some important notions of molecular biology, inspired by the essay of Dr. Anca-Michaela Israil – “*Molecular biology – present and perspectives*, Ed. Humanitas, 2000, pp. 27-29, 31, 35, 39, 52.

The molecule of rhibonucleic acid (RNA) exists under three essential forms: a) rhibonucleic acid messenger (mRNA); b) rhibonucleic acid for transport (tRNA); c) ribozomal rhibonucleic acid (rRNA). All those are implied in the proteic synthesis achieved at the ribozomal level (translation of information from the mature mRNA in the sequence of aminoacids in the proteic molecule takes place at the level of ribozoms). Ribozoms are multienzimatic cellular organites with two sub-unities containing rRNA, as well as different proteins. For the first time in the world, a scientific group granted the Nobel prize, that included the Romanian George Emil Palade, identified ribozomes, microscopically. The DNA segment that codifies a protein is transcripted into mRNA. From the dezoxirhibonucleic acid (DNA) the genetic message is transported in order to achieve the proteic synthesis, by means of two main processes: a) transcriprion of the genetic information (sent from DNA towards mRNA), b) sending the genetic information from mRNA towards the rhibozoms, and then towards proteins, by tRNA (of translation). Within mRNA occur groups of three bases, named codons. Viruses represent a distinct group, composed of infectious agents existing both in their structure and in their way of multiplying. Viruses include mRNA (policistronic), which, represents, in fact, the mRNA molecules which have got some forms of intracitoplasmatic self-replication (that is the origin of the smallest molecules with authonomous replication). In the case of infecting some eucariot cells (with cellular organization of maximum quality, representing cellular organisms with a nuclear membrane (splits the nucleous from the citoplasma), belonging to superior animals and to humans), the genetic message of the virus is sent by mRNA, by means of the (biological) mechanism of transcription-translation of the host cell (of the eucariot type), under the form of monocistronic mRNA. "Both between the procariot cell (without a nuclear membrane, o.n.) and the eucariot one, parazitated by the RNA virus, there should be compatibility, in fact, between the viral mRNA and the translation system of the host cell. Thus, the viral RNA, in order to operate as mRNA should, before, arrive to the nucleous of the host cell, in order to transform itself into RNA, under the action RNA-polimerasys in nucleoplasma of the host cell". Vaccines, generally speaking, constitute the domain of concern for medical biotechnology, and are currently obtained by different genetic recombinations, the effect being the capacity to obtain a therapeutic immunization, necessary in the case of some infectious diseases (self-immune, neoplasms, allergies…). The two researchers managed to modify the nucleotidic base of the eucariot cell, a result that was the base for obtaining vaccine with rhibonucleic messenger. This will interfere with the immune system of humans, implying it in repelling some viruses and bacteria, which may have an impact on their health, including by the occurrence of some cancers.

Interdisciplinary aspects of those research may exist between the area of concerns for biochemistry, medicine and molecular biology, as kindred disciplines, and distinct at the same time, on the general background of bioetics, necessary to exist in tests - determined, time-fundamented by means of results and security, of antiviral vaccines. From the "angle" of transdisciplinarity, we consider there are connections only with its forms I and II, and not at all with form III (in this spirit, we remind and recommend consulting the initial part of this Journal, the text named "Interdisciplinarity and transdisciplinarity existing in complex systems – current aspects".

Literature

The Nobel Committee - 2023 for literature which established, upon analyses, reports and references, the granting of the Nobel prize - 2023 for literature, was composed of the following six specialists-experts: universal literature (Dr. Anders Olsson), writer (Dr. Per Wästberg), writer (Dr. Steve Sem-Sandberg), writer (Dr. Ellen Mattson), writer (Dr. Anne Swärd), universal literature (Dr. Mats Malm).

Jon Fosse is a Norwegian contemporary writer and playwriter (40 plays) who describes some social relationships in his volumes, the texts being, generally, elaborated in the dialect named "nynorsk" (a new Norwegian literary language). As Radu Afrim – the director of some of Fosse's plays, claims, one may find the "essence of the texts of a playwriter – as representation of the cosmos within us, by means of a few contour lines", Afrim considering Fosse's plays as part of "a theater of relationships". We may also remark the description of some states of alienation, melancholy, halucinations, sometimes even depression, anxiety and incertitude, generated by the phenomenon of misunderstanding by the others (even very close). Fosse also wrote poetry, essays, short prose, made translations and wrote books for children; the seven volumes of the series named "Septology" were decisive for his being chosen for the Nobel prize – 2023 (in fact, for his entire creation). Thus, we may find the existence of a certain monologue of solitude, with philosophic reflections and spiritual inflexions. His texts were compared to those of Kafka (the Kafkanian universe). Other relevant writings of Fosse are "The Other Name", "Melancholy" I and II, different other literary creations that were edited, in time, under his name, as a (unique) author.

In Fosse's texts, one may find a certain degree of interdisciplinarity with a humanist spirit, in relationship with the (religious) hermeneutics, the psychology of (literary) Freudian phychoanalysis (including by focusing on humans' sexual nature and impulses), sociology, bioetics and ohers. From the transdisciplinary "angle", we remark the fact that, within each of us (as intellectual and thinking persons) there is a certain degree of the "cosmic tension", and we are, thus, implied in transcendentalism

(Immanuel Kant – Criticism of Pure Thinking) and transcendence (trandisciplinarity of level III) (as per the text in this Journal - “Interdisciplinarity and transdisciplinarity existing in complex systems – current aspects”).

Peace

The Nobel Committee - 2023 for peace, which established, upon analyses, reports and references, the granting of the Nobel prize - 2023 for peace, was composed of the following six specialists-experts: international law and attorney (Dr. Berit Reiss-Andersen), human universal rights (Dr. Anne Enger), human universal rights (Dr. Asle Toje), human universal rights (Dr. Kristin Clemet), human universal rights (Dr. Jorgen Watne Frydnes), international law (Dr. Olav Njølstad).

Narges Mohammadi, granted the Nobel in 2023, first militates for the women’s rights in Iran, taking into consideration that, curently, there is a strong islamism in that state, with distructive effects on the woman’s personality, on human rights, in general.

Some interdisciplinary (humanist) and transdisciplinary (I + II) aspects (again, we recommend the attached text - “Interdisciplinarity and transdisciplinarity existing in complex systems – current aspects”) may be found in connection with issues of sociology and bioetics of human relationships proper to feminism (socially applied philosophy).

Economy

The Nobel Committee - 2023 for economy, which established, upon analyses, reports, references, the granting of the Nobel prize - 2023 for economy, was composed of the following eleven specialists-experts: economy (Dr. Per Krusell), economy (Dr. Peter Fredriksson), economy (Dr. Jakob Svensson), economy (Dr. John Hassler), finances (Dr. Ingrid Werner), economy (Dr. Tommy Andersson), sociology (Dr. Christofer Edling), economic statistics (Dr. Per Johansson), economy (Dr. Timo Roppart), history of economy (Dr. Kerstin Enflo), economy (Dr. Randi Hjalmarsson).

Claudia Goldin refers, in the economic texts and those concerning the history of economy (belonging to her), to the current (sociological) differencies between the activity of men and that of the women, who are in the field of the labor market. In her studies, we remark the analysis of the current modifications of requirements as concerns classical technologies and biotechnologies implying the participation of women, active in the development for those fields, in education, issues related to family and the building of the latter, analyzing the pecuniary inequalities (still) existing between men and women, in the immigration politics and of the social diffusions, others. She is the third woman granted the Nobel for economy, individually. We may make some collateral connections with the concerns of the activist Narges Mohammadi, also granted the Nobel, in 2023, for peace.

From the interdisciplinary (humanist) and transdisciplinary (I + II)) ”angle” (for which we recommend reading the text - “Interdisciplinarity and transdisciplinarity existing in complex systems – curent aspects”) we may remark, likely to Narges Mohammadi, the clear connection with isssues of sociology and the bioetics of human relationships, even transhumanist and posthumanist. Those ideas are also proper to the current feminism (socially applied philosophy), but analyzed from the current/future social perspective of economic levels.

Bibliography: Nobelprize.org: *the Official Website of the Nobel Prize*.

Complex approaches of biological sciences processes, translated through mathematical and physical models. Existing mathematical models within biocomplexity frame

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Abstract

Currently, in some scientific publications, a number of researchers have started to use the term "biocomplexity" to analyze, in this context, complex behaviors at a biological level that implies various biochemical and biophysical processes, as well as the interactions between living organisms and the environment. The interest for the study of "biocomplexity" is relatively new. The knowledge is taken from related fields and helps to create models having valences generated by biological processes, for the purpose of a correct scientific interpretation. The theories of so called biocomplexity tend to form a distinct interdisciplinary field, by building its own methods and models.

Nowadays, the presence of some requirements is expected, such as:

a) the usefulness of knowing and studying the field of biocomplexity, as well as the use of mathematization, modelling and (eventually) the axiomatization of its study methods;

b) the usefulness of the fact that some methods of biocomplexity analysis can be used and combined within the methodology and logic of science, the philosophy of science, and of epistemology;

c) the understanding of the fact that the study mechanisms of biocomplexity do not represent only a sum of scientific analyses exclusively done at biological level, sometimes cumulatively, they also use, selectively, the accumulations made by related disciplines;

d) the establishment of the theory of biocomplexity, in the sense that it must also include specific study mechanisms, including those that are mathematized and computerized, as well as those identified, in this period, by artificial intelligence, and by other disciplines such as neuroscience, biopsychology, cognition and others;

e) the consideration of the significant fact that the incommensurability of current theories, through which biocomplexity is analyzed, determines some of their extensions, which, sometimes, are independent in relation to the series of previous classical biological theories;

f) the importance of the current context through which biocomplexity research can no longer be carried out, to a large extent, with the methods and possibilities existing until the period 1967-1970, distinguishing the necessity and acceptance of the analysis of the current group of biological knowledge and through current, interdisciplinary possibilities, specific to the 21st century[9]

In the 2011 online edition of Encyclopedia Britannica, John Casti, in an article about the theory that analyzes the complexity[10], opines that it represents "a scientific theory that states that some systems display behavioral phenomena that are completely inexplicable through a conventional analysis taken only by constituent parts of the systems. These phenomena, which we usually think of as having emergent behavior, also seem to occur in many complex systems involving living organisms; ... consciousness is seen as an emergent property of a complex network of neurons in the brain".

H. L. Hartwell, J.J. Hopfield, S. Leibner and A.W. Murray specify[11] : "Biological systems are different from physical or chemical systems analyzed by statistical mechanics and hydrodynamics. Statistical mechanics typically deals with systems that contain multiple copies of a few interacting components, whereas cells contain from a few to several million copies of each of thousands of different components, each of them having their specific interactions. In addition, the components of physical systems are often simple entities, while in biology, each of the components is, itself, a microscopic machine, capable of transferring energy and activity, under conditions far from equilibrium". Yaneer Bar-Yam[12] gives examples of biocomplex systems, highlighting some of their essential attributes, as follows.

System	Element	Interraction	Formation	Activity
Proteines	Amino acids	Bonds	Protein folding	Enzymatic activity
Nervous System	Neurons	Synapses	Learning	Behaviour
Neuronal networks				Thinking
Physiology	Cells	Chemical messengers		Biodynamics
				Developmental biology
				Physiology
		Physical Support		

[9]Text released (partially) in the introduction of the paper “BIOCOMPLEXITY AND COMPLEXITY – SIMILARITIES, DIFFERENCIES, INTERDISCIPLINARY ASPECTS”, pp.49-58, Sorin Baiculescu (from the publication “ANTHROPOLOGY AND SOCIETY”, collection “RAINER DAYS”), presented by the author S.B.
[10]http://www.britannica.com/EBchecked/topic/130050/complexity / (29.03.2013).
[11]H.L.Hartwell “etall.”, (1999), From molecular to modular cell biology, “Nature”, no. 402, pp.47-52, http://www.cs.princeton.edu/~chazelle/courses/BIB/Hartwell.pdf / (29.03.2013).
[12]Yaneer Bar-Yam, (1997), Dynamics of complex systems, Addison Wesley Longman.Inc., p.8.

Life	Organisms		Evolution	Survival
		Reproduction		Reproduction
		Competition Rel. Prey-predator		Consumption
				Entropic balance
				Life-like entities
Human economies and societies	Human being	Communication	-	Social evolution

Complexity	Bio-complexity
Non-living physical system (partially closed, sometimes open, linear/non-linear)	Biosystem (always open, anti-entropic, non-linear/with probabilistic priority)
Time (Newtonian physics, special/general relativity, quantum science and cosmology)	Time (chronological, physiological, subjective-psychological, entropic Prigogine type – dissipative phenomena)
Input options/variables	Input options/variables
Class of functions attached to input variables	Class of functions attached to input variables
State variables	State variables
Transition functions	Transition functions
Output options/variables	Output options/variables
Class of functions attached to output variables	Class of functions attached to output variables
Entropic increases	Integrity (maintaining an optimal entropic level)
Informational character (quantitative priority, qualitative reduced)	Bioinformational character (quantitative medium, qualitative priority)
Ranking	Ranking
Functional balance (static/dynamic)	Bio-dynamic balance
Technologies	Confrontation/Cooperation Bioexploration

Self-regulation (robotics and artificial intelligence), external regulation	Self-regulation (self-organization, feedback/feedbefore (anticipation)
Internal heterogeneity/homogeneity	Internal heterogeneity
Passive and standardized reflection	Active and non-standard reflection
Preservation (executed externally)	Self-preservation
Self-reproduction (robotics and artificial intelligence)	Self-reproduction (DNA, heredity)
Self-development (robotics and intelligence)	Artificial self-development

The dictionary[13] definition of the word "complex" shows that it represents something "composed of interconnected parts", "characterized by a complicated organization of its parts", being "difficult to understand or use".[14] There are works in which the term "entwined" is used, similar to the word "interconnected", to show the connection that is made between the parts of a system (interconnected/interwoven parts). Considering a "field" composed of fundamental disciplines, such as physics, mathematics, chemistry, biology, astronomy, computational sciences, neurosciences, ecology, geology, linguistics, history, psychology, biopsychology, sociology, economics, finance, intended to be simple, but converging towards a larger system (a system of systems), it can be observed that to obtain a biocomplexity simply by making interconnections/entanglements of their parts, it appears in fact, through various correlations, the development of scientific knowledge obtained through the creative participation of all of them, within the resulting biocomplexity.

We can also refer to the dynamics of complex systems, which originates, through convergence, from the complexity of simple systems, in which the respective disciplines address areas such as: biocybernetics, hyperspace, general theory and system dynamics, deterministic chaos... Each of these represents, in turn, subsystems included in a certain supersystem, whose complexity is superior to theirs. The theory of biocomplex dynamic systems includes, in its turn, the study of other systems, within which some scientific fields operate, such as: analysis of bifurcations, stochastic calculation, fractal geometry, reconstruction of attractors, catastrophe theory, time series analysis, periodicity... "The European School of advanced studies in the field of management of complex systems" identifies a network of complexity, composed of ten fundamental fields of science, among them being also the previously mentioned ones.[15]

As it can be seen, in order to identify the difference between what represents the non-living physical system and the biosystem, representing the core elements of the theory of complexity (respectively biocomplexity), it is useful to analyze, first of all, the way in which they are defined and, also, what essential characteristics do they have. The non-living system, in a general sense, presupposes the existence of the values of the "time" variable, of the set of input quantities in the system, described by a

[13]Corneliu Stanciu, (2006), Introduction in Psychophysiology, Ed. Fundaţia România de Mâine, p.16.
[14]Webster's Encyclopedic Unabridged Dictionary of the English Language, (1994), Dilithium Press, Ltd., p.301 (complex).
[15]www.visual-chaos.org/complexity/www.gaianxaos.com/chaos_complexity_pdf_library.htm/ (01.04.2013).

class of functions, of a set of state variables and of the transition function, of the set of values of the output variables from the system, also described by a class of functions.

Biological systems are, in general, dynamic and non-linear, while physical systems can be dynamic, linear (the elastic spring works according to Hooke's law, the electrical resistance works, in direct current, according to Ohm's law...), non-linear (the hysteresis characteristic of ferromagnetism, the use of a rectifier diode...). Their operation is described by differential equations or by systems of linear differential equations (linear systems), respectively by non-linear differential equations, called "dynamic equations" or "equations of evolution", having different boundary conditions, located on the border of the environment where the process takes place . Sometimes, for biological phenomena that can be sufficiently described by nonlinear differential equations, their form is reduced to linear differential equations, the approximation being acceptable. This procedure is preferred due to certain methodological considerations related to mathematical modeling methods, which are often used with better precision, in a linear regime.

Biological systems are situated within the category of open systems, having a permanent exchange of substance/energy with the outside, including "the chains", biological chains of a simple to a complex form, having complex informational characteristics, self-regulatory capacities, self-preservation, self-reproduction, self-development. They are obtained through the organization of their anti-entropic finalist behavior, determining their global stability as well as their temporal existence, within some modelling biosystemic relationships.

The self-control capacity, involving some self-regulatory properties, places them in the set of bio - cybernetic systems having reverse connections. They have fundamental properties, such as completeness, bio-informational character, programming, biodynamic balance, self-regulation, internal heterogeneity and hierarchy, also having auxiliary characteristics, such as: asymptotic behaviour directed towards a (so-called) "bio systemic ideal" (absolute yield), the existence of a determined form of the operational energy (adenosine triphosphoric acid - ATP), a.o.

The energy resulting from the metabolism, also obtained with the help of the participation of inorganic systems, determines the increase of their entropy, as well as the simultaneous decrease of the same size for the initial biosystem (developmental organization). Evolution implies an increase in integrity (phylogenetic and ontogenetic level), determining (within the hierarchy of higher biosystemic levels) the appearance of the homeostasis process (bioequilibrium). It follows that, in biological systems, biostructure plays an important role (the arrangement of molecules and atoms within biological molecules with high molecular weight (macromolecules) (proteins, nucleic acids...)). To the same extent, a determining role is played by self-reproduction and self-organization, and the existing systemic hierarchy within some levels of organization.

Centralizing the above mentioned statements, a significant definition of biological systems[16] can also be considered: "... they are informational, open systems; due to their way of organization, having the capacity of self-preservation, self-reproduction, self-regulation and self-development, from simple to complex forms of organization; they have an anti-entropic and completed behavior, which ensures stability in their relationship with other systems". Also, differences in organization appear between non-living physical systems and biosystems. Both admit a systemic organization having the general form previously described, but, unlike the non-living physical system, the living system has an organization and quality attributes that the non-living system does not have. This aspect represents a first argument for which biocomplexity is different from complexity, in terms of properties and mechanisms. A closed system achieves, exclusively, only an exchange of energy with the environment in which it exists, but it cannot also develop an exchange of substance. In fact, in reality, closed systems do not exist in nature,

[16]Nicolae Botnariuc, (1979), General Biology, Ed. Didactică şi Pedagogică, Bucureşti, p.61.

except approximately, while absolutely closed systems do not exist at all, since, in this case, they would turn into isolated systems, not exchanging energy/ substance with the environment. This aspect has only theoretical forms, necessary only for some approximations (solid, ideal gas...).

A particularity of the bio-systems, which distinguishes them from non-living physical systems, is the self-renewal, obtained through self-organization, thanks to a continuous exchange of energy and substance, which they have with the environment. It involves the exchange (transport) of bioinformation, the material biostructure being its substantial carrier. If there is a certain form of energy, needed (sometimes) in minimal quantities, the process can take place inside the bio-structure. Under the conditions in which the bio-dynamic balance must exist permanently, the exchange of substance, energy and bio-information (with the environment) must take place simultaneously, for all three components. Currently, references are made to the need to consider the fourth component: consciousness.

Some additional arguments are highlighted, as well as authoritative opinions, supporting the fact that biocomplexity is different from complexity. "**The biocomplexity theory** represents the study of complex structures and behaviors that arise from the interaction of biological entities (molecules, cells and 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"[17]."**Why the bio-complexity?** The accumulation of molecular information in biology, allowed by the tireless innovations of the last decades, in molecular biology and, more recently, in genomics and proteomics (the study of proteins, Marc Wilkins - (1997, n.a.), has led to the undoubted habit in terms of understanding in the life sciences: almost by default, we explain a phenomenon by invoking a material cause at a lower level, such as a gene, a protein, a molecular interaction, or a regulatory pathway. The biology of the systems has extended this search for mechanistic explanation to massive measurements parallel, exhaustive (involving the whole genome). It has systematized the "collection of molecular stamps" by creating useful databases, drawn maps of networks and relationships, launched complicated bioprocesses within mathematical models. However, it is missing one more thing... The description of molecular pathways, however comprehensive and quantitative, does not explain what makes the whole more than the sum of its parts why and why the creative force of the biosphere, both in terms of development and in terms of evolution, appears as inevitable. Bio-complexity aspires to fill this gap.

Along with the bio-complexity approach, the IBI (Institute for Biocomplexity & Informatics) supplements current, modern efforts within systems biology. Finally, its mission is to improve the health, well-being, and quality of life of people all over the world[18]. **The theory of biocomplexity** represents the study of the emergence of complex self-organized behaviors, resulting from the interaction of numerous simple agents. Such emergent complexity is an emblem of life, from the organization of molecules into a cellular machinery, through the organization of cells into tissues, to the organization of individuals into communities. The other key element of biocomplexity is the inevitable presence of multiple scales. Often, the agents are organized into much larger structures; these structures organize themselves into even bigger structures and so on. A classical example is the primary, secondary, tertiary and quaternary coiling of DNA in chromosomes, which allows filaments of several centimeters to be twisted, without tangling or loss of function, into a chromosome of about one micron (length).

Biocomplexity theory represents a methodology, a philosophy, a field of study. It focuses on

[17]The Interdisciplinary Center for the Study of Biocomplexity-University of Notre Dame, Indiana, USA, http://www3.nd.edu/~icsb/, p.1 / (05.04.2013).
[18]Institute for Biocomplexity & Informatics (IBI), University of Calgary, Faculty of Science, Canada, http://www.ibi.ucalgary.ca/, p.1 / (05.04.2013).

networks of interactions and on the general rules that govern such networks"[19].

We consider that **biocomplexity,** as unique entity - having also a structure, generated biostructures, can be interpreted, outside the he Interdisciplinary Center for the Study of Biocomplexity-University of Notre Dame, Indiana, USA, http://www3.nd.edu/~icsb/, p.1 / (05.04.2013). process in which it results by analyzing the mechanism in which it is formed, or through the identification of the properties it has, or according to references regarding the procedures in which it is necessary to be studied, by the way in which it is either/and must be observed. Also it can be thought and researched through the concept of the Human Being, by its consciousness directed towards the foundation of the living structure, through the connections in which it participates polarized towards the domains of Nature. One can recall Spinoza's thinking, who was influenced by Platon, Aristotle and Descartes, who influenced at their turn, Leibniz, Einstein... (Sorin Baiculescu's opinion)). The connections, in this context, are made through static and dynamic methods, in simultaneous domains – such as metric, quantum, symbolic, informational. The polarization underlines the process by which biological structures, through connections, are simultaneously found in these domains. Through such an interpretation, it can be observed that biocomplexity is, in fact, the place where a "game" of living forms takes place, and of the gathering of its results. Considering that, in the formation of new structures, there is a pronounced topological and structural variability of life, superior (by quantity + quality) to topology and inert spatio-temporal structures, it once again results that, in fact, complexity is different from biocomplexity, they "intersect themselves" only through some research methods.

Biocomplexity is different from complexity, the former only transferring from complexity certain mechanisms and methods of study, especially mathematized, adapted, however, to the respective situations, but also (corollary) mathematical and computer models. These transfers have as an argument the existence of a certain intuition, polarized meaning complexity → biocomplexity, motivated by the fact that the Human Being cannot be detached too easily from physicalist (Aristotelian) thinking, even if, at present, attempts are made to understand biocomplexity and through some limits scientific and philosophical, and could be adapted, at least in terms of consciousness, through some forms of polyvalent logic or even through another type of reasoning, with many arguments supporting this possibility.

The theory of complexity is deeply based on classical logic, while the theory of biocomplexity tries to follow some new, less conventional "trajectories", having, however, arguments. Biology is, in fact, a phenomenological discipline, in the sense that within it, first of all, it makes the analysis of different living systems, how these behave, describing and (still) classifying them. For the non-living physical system, there is a modeling that is close to the "reality" of a physical process, being, in general, quickly converging towards its description (sometimes, describing it completely). The speed of approaching the model to the non-living physical phenomenon is higher than that of a model specific to the biological phenomenon, which, in order to describe it as accurately as possible, carries out several stages. The causes of these aspects are determined by the probability and non-linearity of biological phenomena, by the fact that they are irreversible (fully open systems), operating, often, in conditions far from equilibrium, by the fact that they are dissipative, dominated by self-organization, of synergetic processes... These have a much greater weight than that existing in the unfolding of inert physical phenomena. Currently, in some treaties related to complexity theory there are references (somehow vague) to its specific methods, which can also be used in biology. There are not enough references to what is specific to biocomplexity analysis methods, as there is not (yet) a specific paradigm for it.

At the preparadigmatic level, however, mathematical methods with advanced creativity are outlined, adapted and inspired by third domains, there being, however, no scientific framework strictly attached to

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[19]The Biocomplexity Institute, Indiana University, USA, http://biocomplexity.indiana.edu/institute/ biocomplexity.php,p.1 / (05.04.2013).

a methodology specific only to biocomplexity. There are also some significant works related to complexity/biocomplexity, which can be mentioned: a) Sunny Y. Auyang, (1998), Foundation of Complex System Theories in Economics, Evolutionary Biology, Statistical Physics, Cambridge University Press; b) Cliff Hooker (coordinator), (2011), "Philosophy of Complex Systems", Elsevier (Handbook of the Philosophy of Science, vol. 10), others. In this context, images regarding the complexity/biocomplexity are attached. These are taken from the Yanner Bar-Yam collection. USA, 2006 (Fig.1-Fig.7), Fig. 8 belonging to the authors of this essay reffering to the general characteristics of complex systems/biosystems.

Characteristics of Complex Systems (graphics):

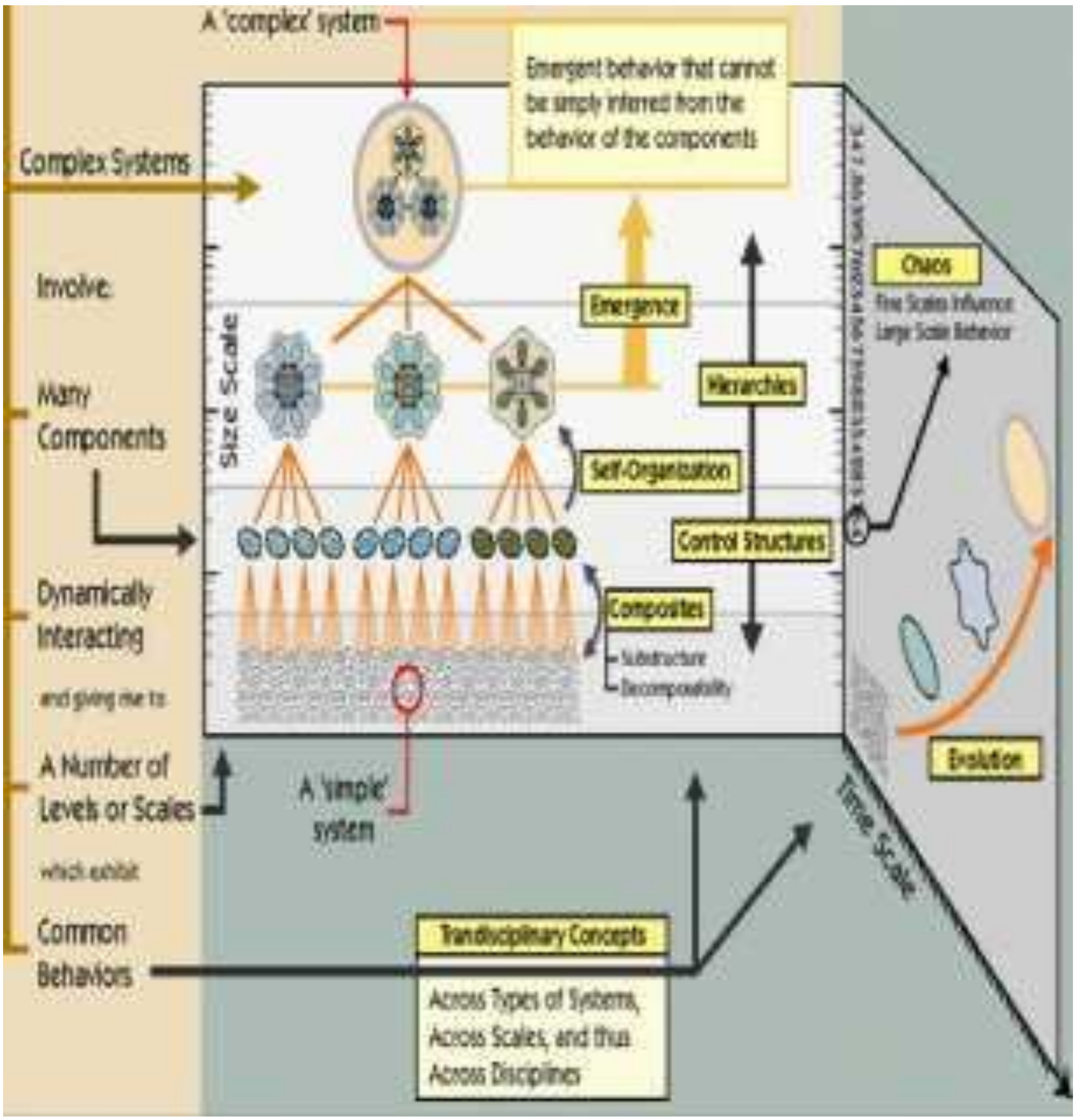

Fig.1 General characteristics of complex systems/biosystems.

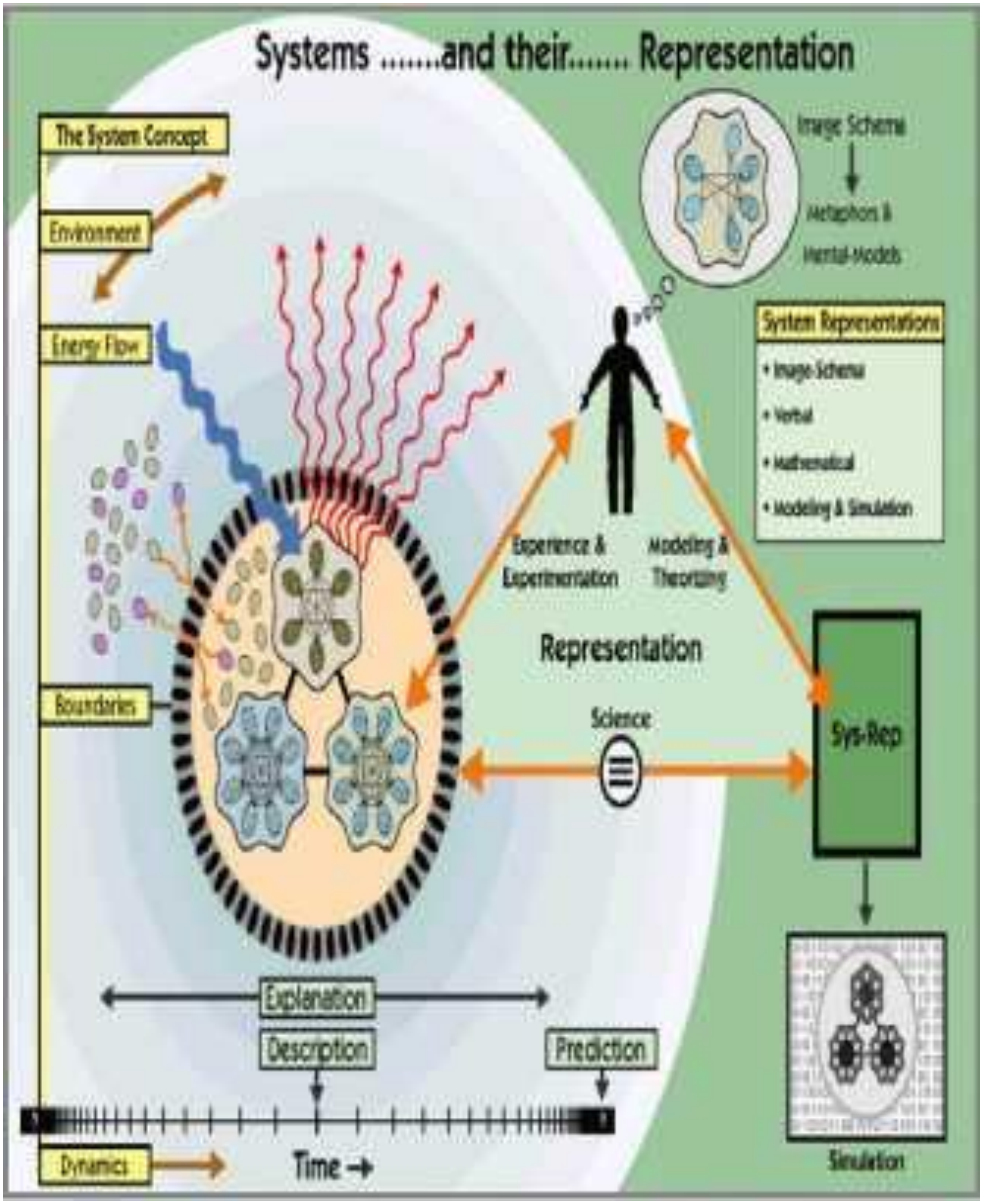

Fig. 2 Illustration of the systems/biosystems

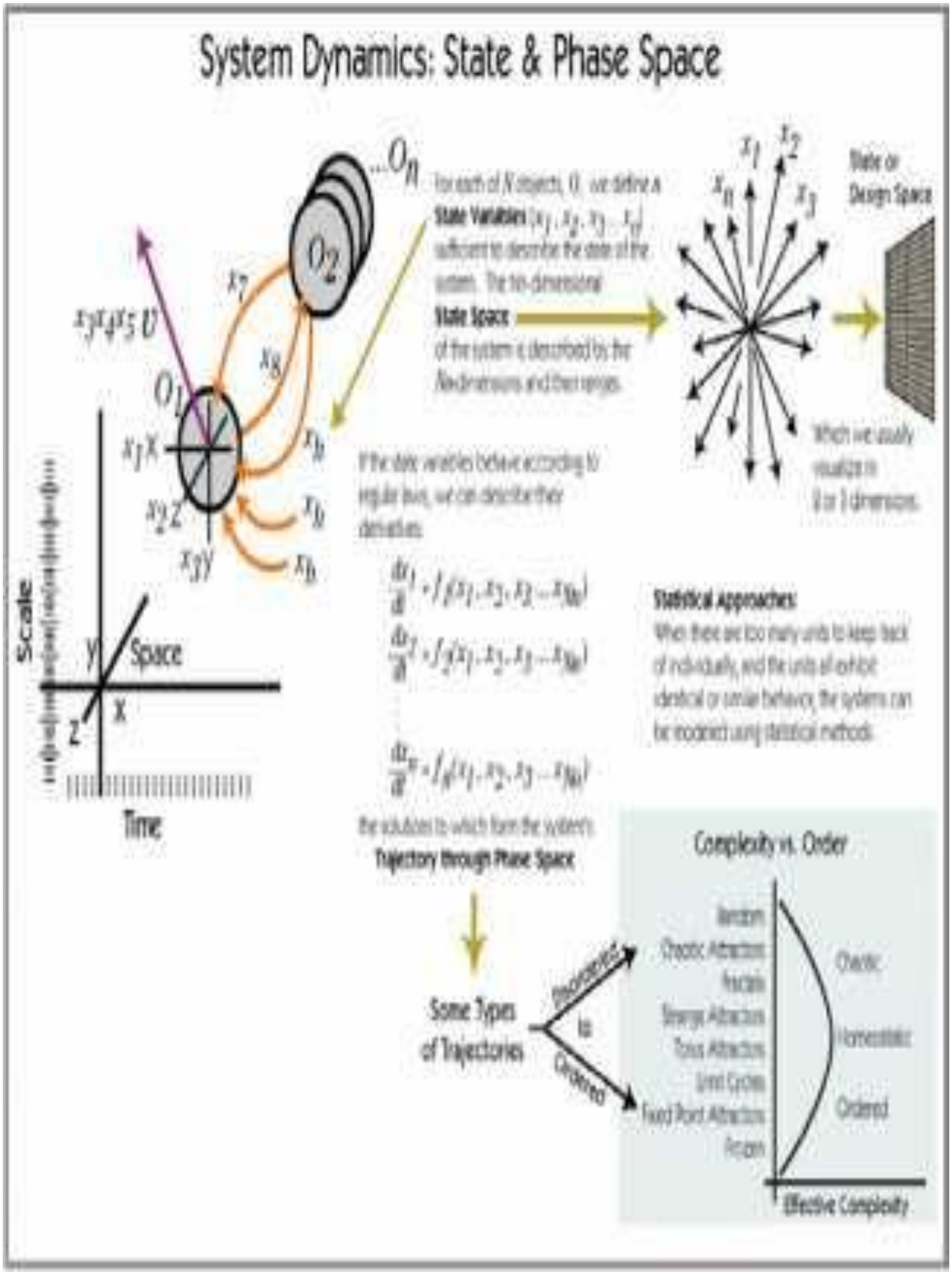

Fig. 3 State and phase space within the dynamic systems/biosystems

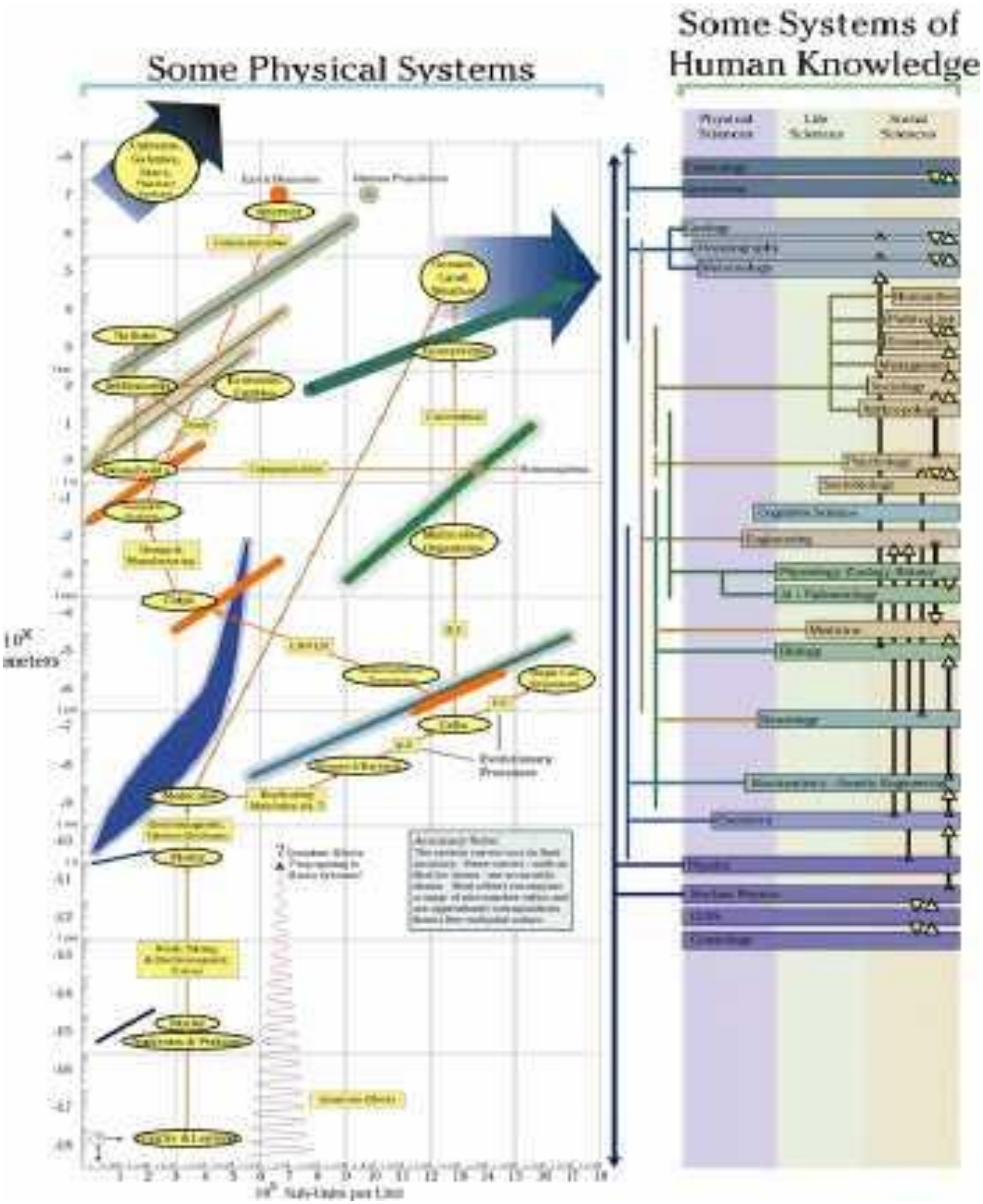

Fig. 4 Physical/bio-physical systems

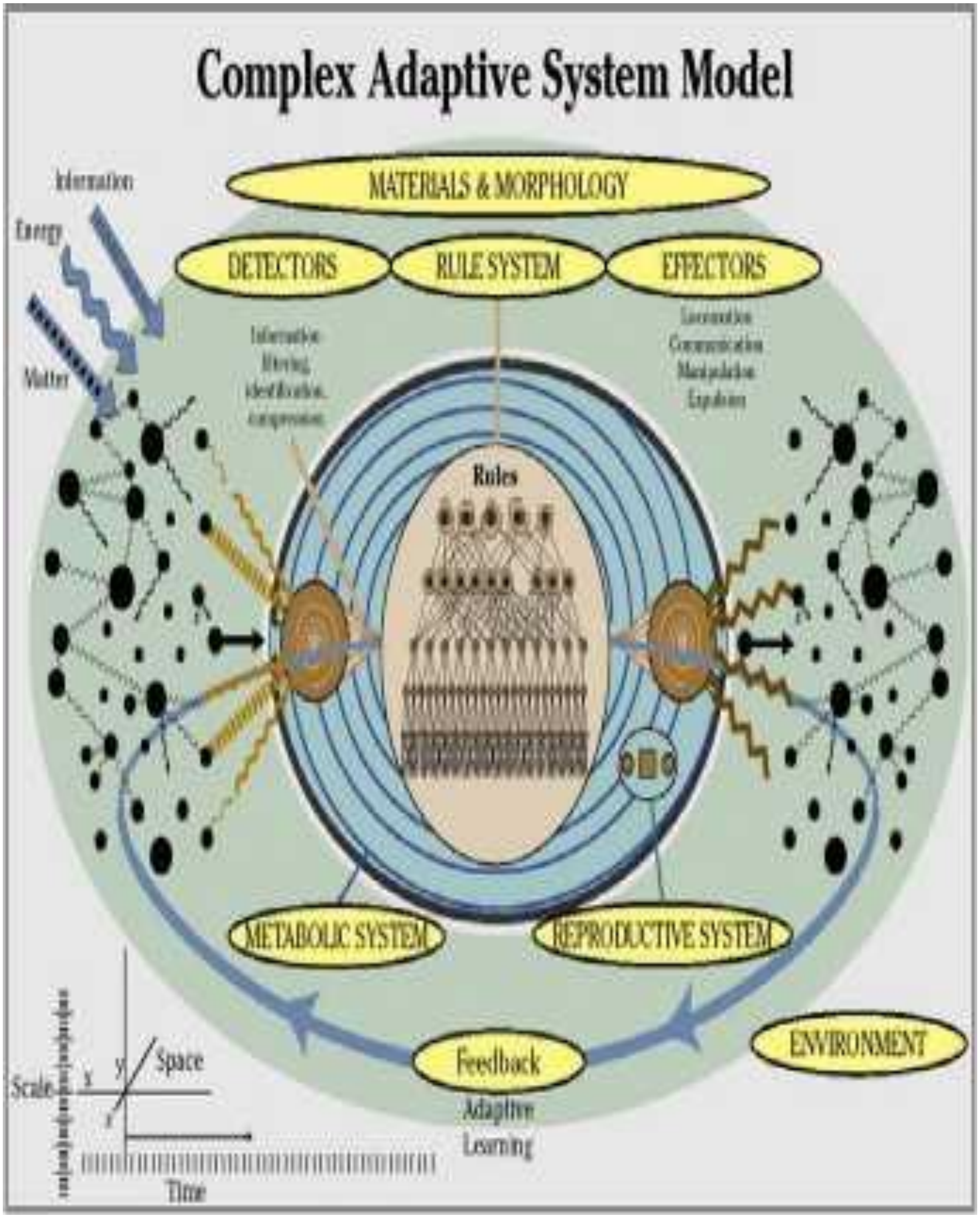

Fig. 5 Complex adaptative bio-systems

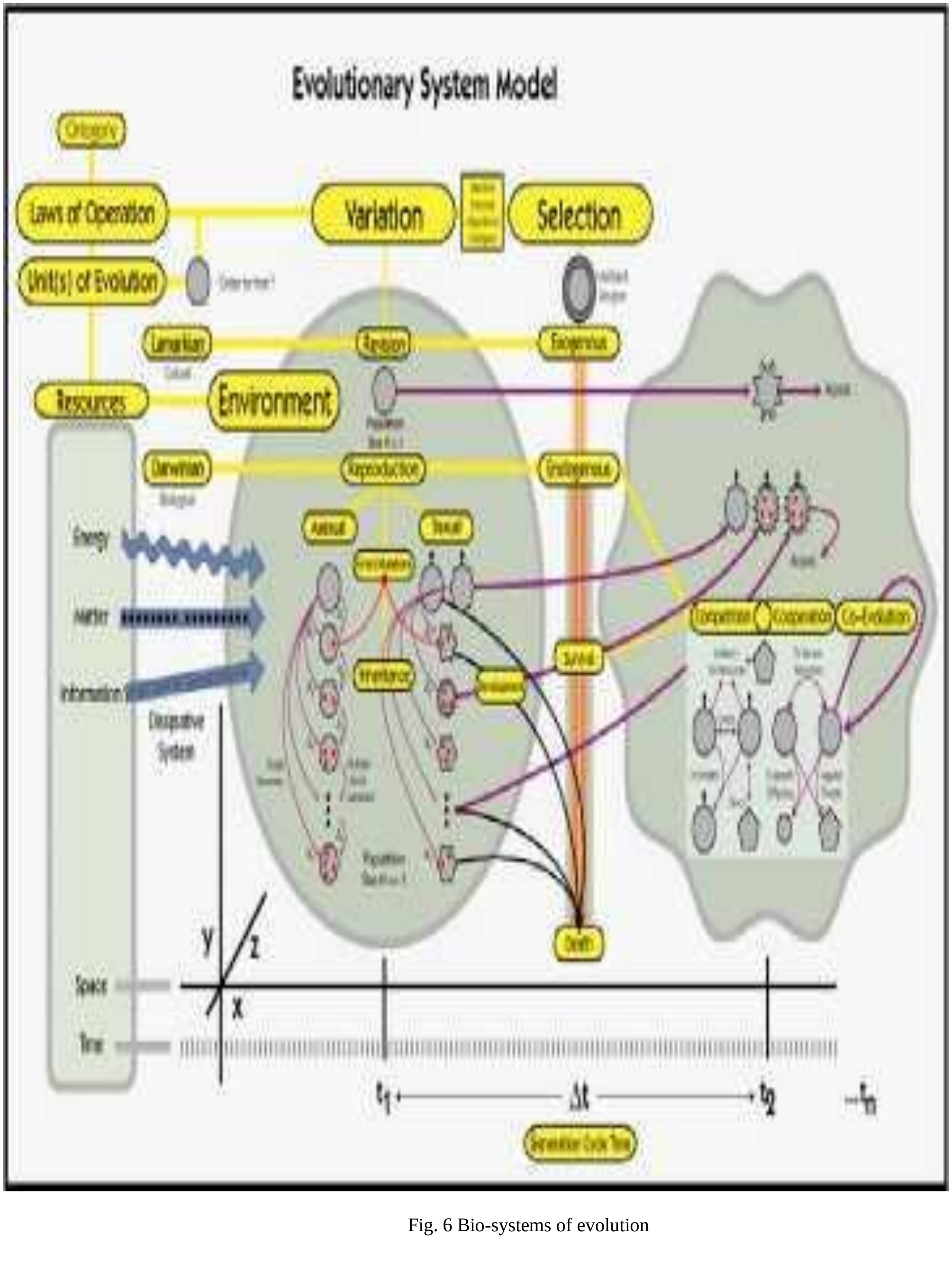

Fig. 6 Bio-systems of evolution

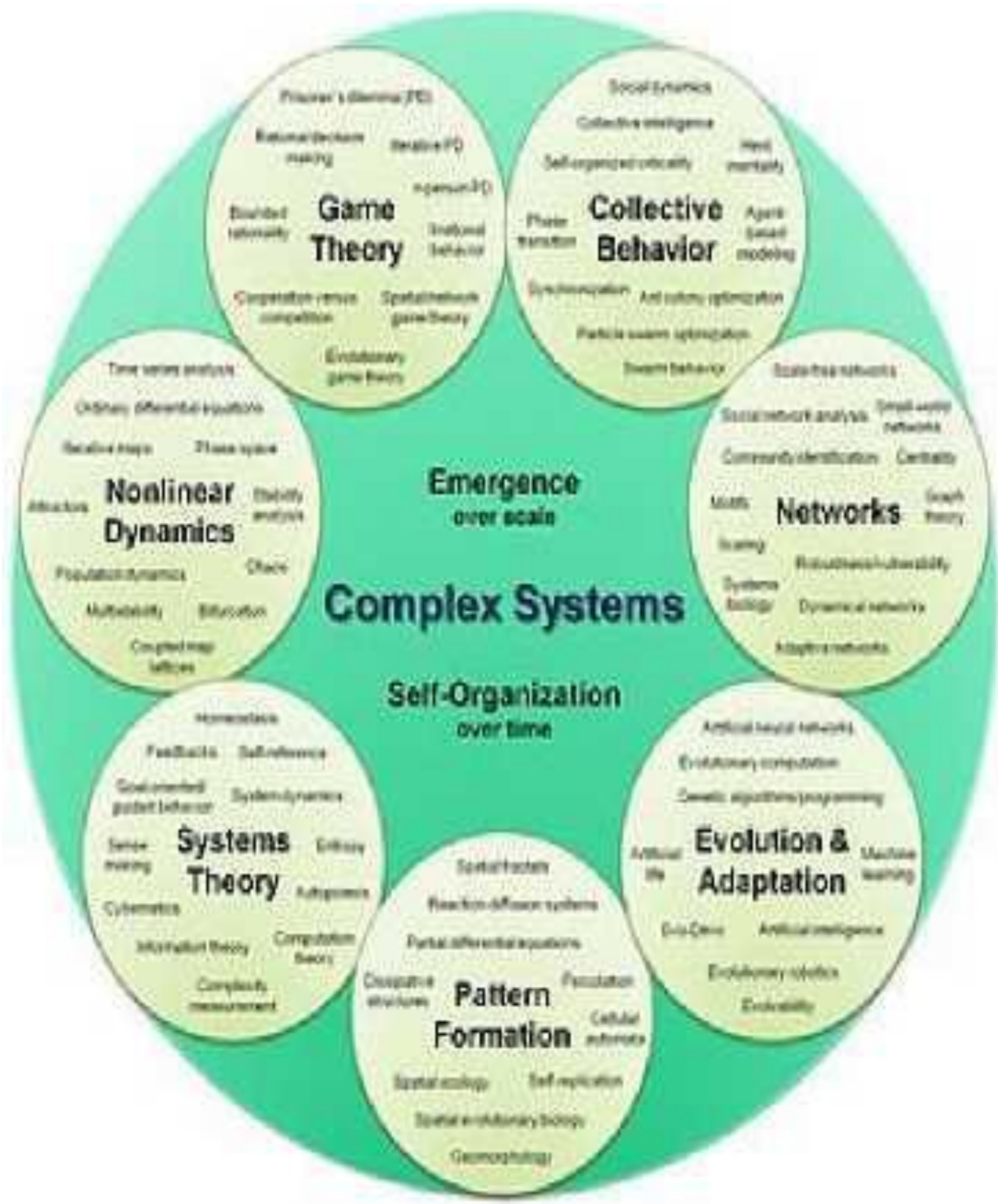

Fig. 7 Biocomplex bio-system

Observation → **BIO-COMPLEXITY** → ***Modelling***

Adaptation
Environment
Frontier
Network
Ecosystem
Development
Replication
Self-organisation
Selection
Evolution

↑
Bio-information
↑
← **Emergency** →
↓

Collective behaviour
Interdependence
Indirect effect
Biodynamics
Bio-feedback
Linearity
Non-linearity
Chaos
Fractals
Scale

Hazard ← **Biosystem** ← Disasters

Fig. 8 General characteristics of complex systems/biosystems

In this essay, in a very general context, references will be made directly to the method, then to the formal aspects involving mathematical modeling, in order to finally address the issue of biocomplexity models. "Dictionaire d'histoire et philosophie des sciences", PUF, Paris, 1999, defines the method as "the analysis of the relationship between a given theory and the set of facts it tries to explain; it concerns the justification or corroboration of theories with facts". The encyclopedic dictionary "Larousse" (Claude Augé), Sorbonne, 1936, considers that the method represents "the rational path of the spirit, necessary to be realized in order to reach the knowledge and demonstration of the truth". In the universal encyclopedia "Britannica", 2010, it is stated that the scientific method is generated by the grouping of "mathematical and experimental techniques used in the natural sciences". On the inductive and deductive aspects used within the method applied in science, there are some different approaches, including Aristotle, Descartes, Newton, Mill, Popper... In mathematics, conjectures are inserted into methods for which the verification is carried out in the situation of particular cases. Alain Voizard (University of Montreal, Canada) characterizes with the following opinion the determinism and probability of the natural law, implicit in the method: "maybe there is no law of Nature, maybe there are only statistical correlations that can be distinguished from laws, or only some symmetries ” ("Dictionaire d'histoire et philosophie des sciences", PUF, Paris, 1999). The infinitesimal methods, introduced through the infinitesimal calculus by Leibniz and Newton, consider small infinities, thus generating some algorithms used for different differential and integral forms. The status of infinitesimally small quantities, the transition from microphysical phenomenological forms to macrophysical processes, generalizations, form the subject of other separate analyses. René Descartes, in the work "Le discours de la méthode", Leyde, 1637, states that the method consists of "those certain and easy rules which whoever will follow without deviating from them, will never take anything false as true and without needlessly wasting the efforts of the spirit, but constantly increasing, gradually, the science, he will reach the true knowledge of all the things for which he will be capable...". Establishing the method is important in scientific research, representing one of its distinct stages. Its general framework currently includes seven sub-stages, most of the time taking place successively: a) identification of interrogative problems on the surrounding "space", which can have different forms; b) selective retrieval of information on him; c) establishing profitable assumptions; d) elaboration of the mental model; e) experimental or theoretical verification of working hypotheses (the stage being necessary, but not always possible to achieve, especially in the case of macrophysical (cosmic), microphysical (quantum), anthropological, prebiotic evaluations,,,); f) the development of a theory, provided that the verification confirms the hypotheses and the model, it must also possess predictive characteristics; g) scientific appropriation of the theory established in stage f), in case of reconfirmation of the veracity of stages e) and f). In contrary situations, there are only scientific assumptions, supported by knowledge and intuition, but insufficient for the definite establishment of a stable theory, supported by methods. There is also a possible influence from mental experiments (eg: the Einstein-Podolski-Rosen experiment - EPR). The emergence of some scientific paradigms totally or partially modifies previous scientific methods and theories. In order to be able to analyze the essence of formalism, it is necessary to consider one of the requirements imposed on the method, also stipulated by Spinoza in the work "Treaty on the direction of the intellect and on the best way that leads to the true knowledge of things". He affirms the need for the existence of "clear and distinct ideas, that is, ideas that come only from the mind, not from the random senses of the body. "The formalism considers, implicitly, through the concepts of its doctrine, the influence of some mental constructions that develops and are realized inside the system, having "the knowledge" as its support. Mathieu Marion (University of Montreal, philosophy of mathematics) believes that the formal system, within which there is a formalism, as well as an abstract thought, implies the existence of "a list of symbols, terms, rules for constructing formulas, as well as axioms, the inference rule or rules that allow obtaining theorems starting from the latter ». This situation is due to the conception of Haskell Curry (American mathematician, 1900-1982), according to which mathematics itself represents the study of formal systems. He, however, does not consider the concept of the consistency of arithmetic, which represented, in Hilbert's thinking, the necessary and sufficient condition for the existence of a formal system.

David Hilbert, through his program, supported the formalist doctrine, which, however, proved to be limited, by the results of the incompleteness theorems obtained by Kurt Gödel in 1931. However, during the 1920s, the German mathematician distinguished real sentences from ideal ones . The first were considered to be "meaningful", relating them to "perceived reality", while the second category is "lacking real meaning", having to be eliminated from the demonstrations of real sentences. The Bourbakian school supports the fact that the formalism of systems cannot fundamentally "overlap" mathematics, considering that within it the sets of mathematical objects are, in fact, the ones that have priority, the theory of sets not being contradictory, in the real sense, possible contradictions can be avoided. This doctrine does not consider the problem of consistency, in Hilbert's sense. "Mathematical objects" cannot have a specific nature, they can be considered arbitrarily, the common language of theorems ensuring them this property. They are, thus, "desubstantiated". The physicalist conditions, existing, in general, within the applied sciences, cannot consider this particularity either, as it can be accepted, within certain limits, only within pure mathematics. In the framework of the theory of formal languages, there are notions such as: alphabet, symbol, word, concatenation, general and genetic language, grammar, terminal and non-terminal symbol, closure properties, decision, automatically finition... It results from the fact that within formal systems artificial, specific languages are used, building formal models, having, in most cases, a level of abstraction, generating understanding, analysis, implying proximity to "reality". The notion of a formal model involves the general analysis and some aspects related to modeling, to its heuristic forms. In the work of Werner Heisenberg - Le manuscrit de 1942, Ed. Allia, Paris, 2010, the model is considered to be "the theoretical scheme, generally unmaterialized, which, in principle, does not faithfully reproduce a phenomenon, but, on the contrary, simplifies it sufficiently to be able to analyze and explain it (at least partially), to be able to foresee its repetition. The model is a simple tool in the service of understanding, without ontological claim: it is replaced, if a better one is found ». The part called logical modeling considers the statements, as well as the mathematical relations specific to the model, in a first stage, as formal ones. The model tries to describe, within certain limits, a certain structure, verifying, in this way, the respective relationships, assigning them a meaning. Reference works in mathematics, such as "Fundamentals of Geometry" (David Hilbert) or "The Erlangen Program" (Felix Klein), generate the view that "geometry is a model of a formal language rather than a formalization of idealized properties, starting from the observation of the sensitive space ». By formal language, in this case, is meant that belonging to arithmetic and algebra, and by the formulation "idealized properties" references are made to the situation of Euclidean geometry, two-dimensional/three-dimensional, through the use of which, exclusively, intuitive imaging representations take place. A correspondence is made between the set of statements and their models, they have many formal aspects. Based on these considerations, any mathematical theory becomes a formal language, involving a certain number of models. What has been described constitutes the so-called "logic" part of modeling. Through this, the model is created starting from the elements of a structure, sometimes theorizing them, but not experimenting, trying to get meaning, by grouping them into a specific whole. However, there is also the reverse way, by which an organization and a symbolic description can be associated with an empirical process, it being close to the current procedures. These generate some confirmed theories, the model being integrated. In applied mathematics, the "organization and symbolic description" of a process involves finding equations (linear/non-linear) with differential, time-varying, explicit/implicit forms, boundary conditions, state parameters. In these situations, the model being, in fact, a "reduction" of "reality", its simulation and comparison with it, generate indications on its degree of approximation for the analyzed phenomenon. Depending on the results obtained, the model implies a realization "in steps". Through optimization and adaptation to "reality", integration generated by these stages, it tends to get closer to accuracy and precision, failing, however, most of the time, to fully access them. The introduction of scientific paradigms and through artificial intelligence, the theory of fractals, chaos (deterministic) and catastrophes, systemic biodynamics - existing against the background of stochasticity and determinism, generated the development of models. They have some predictive, decisional, heuristic and cognitive characteristics. Example in biology: regarding biosystems, most living processes take place in non-linear conditions, most of the time having stochastic forms. Under these conditions, their models, which are made within the biocomplexity, must (sometimes) be built by assigning these characteristics, also called stochastic models. There are homogeneous/inhomogeneous models in which the processes taking place are Markovian (the inhomogeneous model better approximates the biological reality, being preferable in modeling evolutionary systems). Also, the category of optimized statistical models includes the vector-optimized ones, which can be used to establish the density of some biological processes (eg: visual accommodation). There is biosequential modeling, another category called "relaxation" (eg: neural processes), approximate Markovian models, some composite, others. Within the biodynamics of open systems, having random elements, considered biological automata, certain energetic models are made, using variational principles, optimization criteria, establishing the biological value. In this context, various mathematical formalisms are used, as well as various other biodynamic principles describing the evolution of biological systems. In the context, there are invariance criteria, quantum principles, using Schrödinger equations, others, generating possibilities for evolution analysis. There are some models of the growth of microorganism populations, of probabilistic image perception, specific models of the functioning of neuronal structures, the erythrocyte, hemodynamic models, including, for the most part, systems of differential equations having partial derivatives of various orders, non-linear forms, boundary conditions, different equations of mathematical physics. These represent the initial approaches in the theory of models, some of them representing methodology. Currently, some models are made containing elements of fractality, deterministic chaos and dissipation, catastrophes and artificial intelligence, cellular automata, topological deformations... In the approach to "reality" thanks to the built model, it is important to choose the scale of representation of the observed phenomenon. The mathematical model can be inferred on a microscopic scale, when it is possible to describe the evolution of each of its individual elements. The extension can be made to the macroscopic scale, when the built model refers to the evolution of the quantities, whose local behavior was obtained for the microscopic state. It is possible to schematically show the description of the analyzed behavior by means of analytical solutions and simulations based on the existence of biosystemic models. A timeline is added.

Numerical or analytical solution

Differential equation → f : R → R

↓

simulation

Structural description (comportamental) → Behavioural description

------------------------▶

TIME

Fig. 9 The description of the behavior of a biosystem studied by means of the analytical solution of the simulation, made on the basis of the existence of some biosystemic models by means of the analytical solution of the simulation,

In conditions where the algorithm has priority in relation to the model (sometimes it is not executed if the algorithm is unsatisfactory), a modeling takes place having a procedural form. In such situations, the algorithm used is important, it can have exact, or approximate, heuristic forms (the search for solutions, obtained through experience and intuition).

Heuristic processes are used to simulate learning and self-training. After the mathematical modelling processes, the differential equations belonging to the model are converted into algebraic equations, which can be solved by numerical methods, by applying discretization procedures. The boundary conditions attached to the model, as well as certain initial parameters, are generally invariant quantities for these transformations, they generally do not involve differential equations. The procedure is necessary to implement the initial model on the computer, to transform it from analytical to numerical form, to generate the simulation. It is necessary that by applying the discretization procedures the meaning of the phenomenon is not changed, even under the conditions of applying an approximate numerical method and some truncation errors. An example can be shown for a (biological) cell, in the case of considering the conservation equation applied to the cellular transport of a substance «Φ», the control volume being denoted by «V». The first form, reproduced below, is attached to the initial, non-discretized model, containing circular (existing in thermodynamics and electrotechnics...) and volume integrals, while the second is attached to the discretized form, containing finite algebraic sums.

$$\oint \rho\phi \vec{v} \cdot d\vec{A} = \oint \Gamma_\phi \nabla\phi \cdot d\vec{A} + \int_V S_\phi \, dV$$

where: ρ – the density of the substance; $\vec{v}$ – velocity vector, attached to the transport of the substance in the cell, A - the vector attached to the cell surface area; Γ_ϕ– diffusion coefficient of the substance in the cell, Φ - the diffusion gradient of the substance (two dimentionally considered), S_Φ - he size of the substance source corresponding to a volumetric unit.

$$\sum_{f}^{N_{faces}} \rho_f \vec{v}_f \phi_f \cdot \vec{A}_f = \sum_{f}^{N_{faces}} \Gamma_\phi (\nabla\phi)_n \cdot \vec{A}_f + S_\phi V$$

where: N_{faces} – the number of compartments belonging to the "f" faces in which the cell decomposes; ρ_f – the density of the substance that is inside a compartment;

$\vec{v}_f$ – velocity vector, attached to the transport of the substance in the cell (two dimensionally considered); Φ_f – the amount of substance that passes through a compartment;

$\vec{A}_f$ – the vector attached to the surface area of a cell face belonging to a compartment;

$\rho_f \vec{v}_f \vec{A}_f$ - the mass flow belonging to the diffused substance, corresponding to a compartment;

$\vec{A}_f$ – the vector attached to the surface area of a cell face belonging to a compartment;

Γ_ϕ– diffusion coefficient of the substance in the cell;

$(v\ \Phi)_n$ – the size of the normal projection of a cell face located inside a compartment;

S_Φ – the size of the substance source corresponding to a volumetric unit;

V – cellular volume

Discretization methods are also used in biostatistics. The next step, which follows the mathematical discretization, through which the numerical form of the model is obtained, is generally represented by the process of simulating the phenomenon. Usually, a stabilization of the model takes place after several "steps" of modeling, these imply obtaining intermediate mathematical models, which are to be discretized, located closer and closer to the real form, belonging to the phenomenon (physical, biological...), until the existence of a minimal deviation between the final model and reality, when the modeling process stops. Within these stages, there are some processes of convergence and approximation, also considering a model code. There are computer programs that model complex biological phenomena (eg: the activity of proteins related to a series of organisms, the evolution of some tumor processes), such as the brain study project, started in 2002, containing interdisciplinary methods, entitled "BLUE BRAIN". This is still ongoing at the University of Lausanne in Switzerland (École Polytechnique Fédérale de Lausanne, Brain & Mind Institute), where only a single neocortical column has been modeled comprising 10,000 neurons connected in a network, the respective column having a height of 2 mm and a width of 0.5 mm. 8192 processors of an IBM Blue Gene computer are used, used in solving physical-mathematical expressions that describe the electrical activity of simulated neurons.[20]

At the addresses http://en.wikipedia.org/wiki/Discretization, http://en.wikipedia.org/wiki/Osmosis there are images of discretized models originating from models containing differential equations with[21] partial derivatives, non-discretized (3D), respectively computational simulations of osmosis processes (biomembrane diffusion of a substance, which takes place with a certain gradient, from low concentrations to high concentrations). Some computer programs suitable for simulation processes can be highlighted, such as STELLA, EXTEND, SIMULA. Within them, the "accuracy" of the stages through which the input data are acquired, the realization of the control, the application of the coding system is important. They take place within some hierarchical levels belonging to the biosystem or even the simulated process. There is a grouping [22]of "misleading" aspects that can appear in the simulation of a process belonging to a biosystem.

This includes the following:

a) the possibility that the state of knowledge of the biosystem is not adequate to the analyzed phenomenon, although it has its origin within the respective biosystem;

b) biosystem identification techniques to be limited;

c) the acquired data be, in fact, "noise";

d) the possibility that a hypercomplex biosystem "transcends" its investigative abilities;

e) the possible existence of some incompleteness, generated by the difficulty of acquiring some data representing criterion functions;

f) the existence of some differences between the incorrectly estimated time scales, as well as the observational scales, uncorrelated with the hierarchical levels of the biosystem;

g) lack of dimensional compatibility of the state variables;

h) decomposition of complex biosystems into smaller, more controllable fractions, which may be insignificant for observation; the possibility that input-output models, describing cause-effect processes, can roughly lead to some erroneous directions;

i) the absence of relevant data for the existence and functioning of the biosystem, necessary for the purpose of building an appropriate model for it, they being sometimes impossible to acquire.

Mathematical and physical modeling, which takes place within the systems belonging to biocomplexity, involves the step-by-step obtaining of some approximations located, however, closer and closer to the biological reality belonging to living structures, including those of humans. Within the deterministic models, modeling identifies the main differential equations of state of biodynamic systems, considered linear for the simplicity of mathematical calculations,

[20]Amuzescu Bogdan, (2013), Mathematical Modelling of Complex Biological Systems, in “The Issue Mind-Brain in cognition neuroscience”, (2013), Editors : Gabriel Vacariu and Gheorghe Ştefanov, Ed.Universităţii Bucureşti, p.69.
[21]Jay W. Forrester, (1991), System Dynamics and the Lessons of 35 Years, edited by Kenyon B. De Greene, pp.25-49.

these, for the most part, being, in fact, non-linear, as well as the output biosystemic equations, accepting and the existence of constant quantities (parameters). Biological systems (biosystems) that have time-varying parameters can also be described by differential equations, being reduced, by calculations, as a rule, to linear systems, but not always (e.g.: the neuron membrane, in the modeling of which the excitation variables intervene and return). Biological reality is non-linear. The so-called multiple biosystems, having a large number of inputs and outputs, have associated, for each output size, a state variable, the latter being able to be different from each other. Obviously, in the calculations, certain inputs and outputs, selectively chosen, are considered. We are referring, in a deterministic context, to the blood circulatory system, in which arterial pressure is also considered, dependent on the processes that take place at the heart level, on the elasticity of the walls of the arteries and arterial trunks through which the blood circulates, on resistances, frequencies and many automatisms. This category includes the cardio-respiratory system, which has a dynamic behavior, sometimes non-linear (pathological), due to some cumulative phenomena, its mathematical model being, in fact, linearized. In the context of biosystemic nonlinearities, the differential equations of evolution, the models obtained by differential equations within the framework of functional analysis, the particularities of operational research (evolution trajectories, optimality...), the vector of nonlinearity as well as the index, asymmetry, optimization and the limit model, etc., also intervene.The second form of mathematical model is represented by the probabilistic model, typical of random forms, where random variables appear as determining quantities. Depending on the discontinuous forms and biological processes, these models are called stochastic. Stochastic optimal models refer to neural mechanisms (populations of neurons), associative memories, probability densities, moment vector, constraints, optimalities and others. The third form of model, built within biocomplexity, is the one also called "unknown model". In this framework, (approximately) unknown biosystems are included as forms of modeling equations, having less common, unknown behaviors, outside some limits considered to be normal. The unknown parameters, specific to the analyzed biosystem, in this case, are like operators from the Hilbert space (as are those from quantum physics). It is, in fact, a mathematically difficult field, involving the need to identify the biosystemic output linearities/nonlinearities, without actually knowing the causes (input quantities). The problem of determining the mathematical model attached to an unknown biosystem, having a known finality, is even more difficult. However, there are prospects (AI, Big Data and others). We recall, according to a reference work ("Cybernetics and Biology", Emil Bittman, Scientific Publishing House, 1974), the series of themes that still exist today in the mathematized research belonging to some biosystems (biological servomechanisms, the reception and codified transmission of information, homeostasis water/blood, the automatic regulation of the cardiovascular system, the existing servomechanisms in the regulation of pulmonary breathing, the existing regulatory mechanisms in nutritional processes, the regulation of body temperature, the neuro¬endocrine interrelationships...). We remind you that currently, instead of the term "biocybernetics", the expression "biodynamic systems with feedback operated by energy flows" is used.

We think it is necessary to still use the term "feedbefore", as well as the expression "internal energy of a living organism, considered to be a biosystem". In the current period, in the world there are numerous concerns of biological mathematics belonging to biological systems included in biocomplexity, even psychocomplexity, most of them having, in fact, an interdisciplinary level. We recall the remarkable achievements of mathematical and computer modelling, mathematical profile theories, existing also in the field of genetics and epigenetics, epidemics, physiology and medicine, behavioral analysis, in which there is also formality (e.g. of works and current research concerns): a) "*The role of diffusion in mathematical population biology*", D.G. Aronson, School of Mathematics, University of Minnesota, Minneapolis, USA; b) "*Model for endemic diseases*", K.P. Hadeler, Tübingen; c) "*Stochastic epidemics as point processes*", Grace L. Yang, Department of Mathematics, University of Maryland, USA: d) "*Stochastic differential equation* *models of fisheries in a uncertain worlds extinction probabilities, optimal effort and parameter estimation*", Carlos Braumann, Universidade de Evora, Portugal; e) "*A mathematical model for cardiac electric sources and related potential fields*", P. Colli Franzone, Institute di Matematica, Informatica e Sistemistica dell Universita di Udine, UDINE and Instituto di Analizi Numerica del CNB, PAVIA, Italy; f) "*Mathematical analysis of immobilized enzyme systems*", E,J. Doedel, Computer Science Department, Concordia University, Montreal and J.P. Kernevez, Université de Teghnologie de Compiègne, France; g) "*Modeling controls and variability at the cell cycle*", Lilia Alberghina, Luigi Mariani and Enzo Martegani, Faculta di Scienze, Università de Milano, Italy; h) "*A staging process with applications in biology and medicine*", L. Chiang, University of California, Berkeley, USA; i) "*Stability of delay differential equations with applications in biology and medicine*", Kenneth L. Cooke, Pomona College, Claremont, California, USA.

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Glossary of scientific terms

A.<u>Quantum physics and chemistry (terms also used in the essays of epistemology and philosophy of science)</u>

- a construct (by selection) made after the following works: *"Quantum – Einstein, Bohr and the Great Debate About the Nature of Reality",* [2008], 2009, 2014, UK, Icon Books Ltd., pp.373-386, author: Dr. Manjit Kumar; *"Chimie Quantique"*, [1967], Ed. Dunod Paris, author: Dr. A. Julg; *"Quantum Chemistry",* John Wiley & Sons Ltd, USA, [1983], authors: Dr. Raymond Daudel, Dr. Georges Leroy, Dr. Daniel Peeters, Dr. Michel Sana -

Affinity to the electron – energy necessary for a molecule in order to "fix" an electron, the result being a negative ion.

Bell's inequality – A mathematical condition derived by John Bell in 1964 concerning the degree of correlation of the quantum spins of entangled pairs of particles that has to be satisfied by any local hidden variables theory.

Bell's theorem – A mathematical proof discovered by John Bell in 1964 that any hidden variables theory whose predictions agree with those of quantum mechanics must be non-local.

Collapse of the wave function – According to the Copenhagen interpretation, until it is observed or measured, a microphysical object like an electron does not exist anywhere. Between one measurement and the next it has noexistence outside the abstract possibilities of the wave function. It is only when an observation or measurement is made that one of the "possible" states of the electron becomes its "actual" state and the probabilities of all the other possibilities become zero. This sudden, discontinuouschange in the wave function due to an act of measurement is called the "collapse of the wave function".

Complementarity – A principle advocated by Niels Bohr that the wave and particle aspects of light and matter are complementary but exclusive. The dual nature of light and matter is like the two sides of the same coin that can display either face, but not both simultaneously. For example, an experiment can be devised to reveal either the wave properties of light or its particle nature, but not both as the same time.

Copenhagen interpretation – An interpretation of quantum mechanics whose principal architect Niels Bohr was based in Copenhagen. Over the years there were differences of opinion between Bohr and other leading advocates of the Copenhagen interpretation such as Werner Heisenberg. However, all agreed on its central tenets: Bohr's correspondence principle, Heinsenberg's uncertainty principle, Born's probability interpretation of the wave function, Bohr's principle of complementarity, and the collapse of the wave function. There is no quantum reality beyond what is revealed by an act of measurement or observation. Hence it is meaningless to say, for example, that an electron exists somewhere independent of an actual observation. Bohr and his supporters maintained that quantum mechanics was a complete theory, a claim challenged by Einstein.

Correspondence principle – A guiding principle advocated by Niels Bohr in which the laws and equations of quantum physics reduce to those of classical physics under conditions where the impact of Planck's constant is negligible.

De Broglie wavelength – The wavelength λ of a particle is related to the momentum p of the particle to the particle by the relationschip $\lambda = h/p$, where h is Planck's constant.

Electron – An elementary particle with a negative electric charge that, unlike the proton and the neutron, is not composed of more fundamental components.

Energy levels – The discrete set of allowed internal energy states of an atom corresponding to the different quantum energy statesof the atom itself.

Entanglement – A quantum phenomenon in which two or more particles remain inexorably linked no matter how far apart they are.

Hidden variables – An interpretation of quantum mechanics based on the belief that the theory is incomplete and that there is an underlying layer of reality that contains additional information about the quantum world. This extra-information is in the form of the hidden variables, unseen but real physical quantities. The identification of these hidden variables would lead to exact predictions for the outcomes of measuraments and not just probabilities of obtaining certain results. Its adherents believe that it would restore a reality that exists independently of observation, denied by the Copenhagen interpretation.

Interference – This is a characteristic phenomenon of were motion in which two waves interact. Where two wave troughs or crests meet, they coalesce to produce a new bigger trough meets a crest or viceversa, they cancel each other out, a process called destructive interference.

Izotopes – Different forms of the same element that have the same number of protons in the nucleus, i.e. that share the same atomic number, but each having a different number of neutrons. For example: there are three forms of hydrogen with thei nuclei containing zero, one and two neutrons respectively. All three have chemical properties, but different masses.

Light – The human eye can detect only a small portion of all electromagnetic waves. These visible wavelengths of the electromagnetic spectrum range between 400nm (violet) and 700nm (red). White light is made up of red, orange, yellow, green, blue, indigo, and violet light. When a beam of white light is passed through a glass prism, these different strands of light are unpicked and form a rainbow band of colours called a continuum or continous spectrum.

Locality – The requirement that a cause and its effect occur at the same place, that there is no action at a distance. If an event A is the cause of another at B, there must be enough time between the two to allow a signal travelling at the speed of light from A to reach B. Any theory which has locality is called local.

Matrix mechanics – A version of quantum mechanics discovered by Heisenberg in 1925 and then developed in conjunction with Max Born and Pascal Jordan.**Matter wave** – When a particle behaves as though it has a wave character, the were representing it is called a matter wave or a de Brogle wave.

Maxwell's equations – A set of four equations derived by James Clerk Maxwwel in 1864 that unified and described the disparate phenomena of electricity and magnetism as a single entity.

Neutron – An uncharged particle that is similar in mass to a proton.

Non-locality – An influence is allowed to pass between two systems or particles instantaneously, exceeding the limit set by the speed of light, so that a cause at one place can produce an immediate effect at some distant location. Any theory that allows non-locality is called non-local.

Nucleus – The positively-charged mass at the heart of an atom. Initially believed to be made up only of protons, but later found to include neutrons. It contains virtually the entire mass of an atom but occupies a tiny fraction of its volume. Discovered in 1911 by Ernest Rutherford and his co-workers at Manchester University.

Observable – Any dynamical variable of a system or object that can, in principle, be measured. For example, the position, momentum and kinetic energy of an electron are all observables.

Photon – The quantum of light characterised by the energy $E = h\nu$ and momentum $p = h/\lambda$, where ν and λ are the frequency and wavelength of the radiation. The name was introduced in 1926 by the American chemist Gilbert Lewis.

Plank's constant (h) – A fundamental constant of Nature with a value of 6.626×10^{-34} joule-seconds that lies at the heart of quantum physics. Because Planck's constant is not zero, it is responsible for chopping up, quantizing, energy and either physical quantities in the atomic realm.

Probability interpretation – The interpretation suggested by Max Born that the wave function allowed only the propability of finding a particle at a particular location to be calculated. It is part and parcel of the idea that quantum mechanics can generate only the relative probabilities of obtaining certain results from the measurement of an observable and cannot predict which specific result will be obtained on a given occasion.

Proton – A particle contained in the nucleus of an atom that carries a positive charge equal and opposite to that on an electron and that has a mass some 2.000 times that of the electron's.

Quantum – A term introduced by Max Planck in 1900 to describe the indivisible packets of energy that an oscillator could emit or absorb in his model as he tried to derive an equation that reproduced the distribution of blackbody radiation. A quantum of energy (E) comes in various sizes determined by $E = h\nu$, where h is Planck's constant and ν is the frequency of radiation. 'Quantum' more properly 'quantised", can be applied to any physical property of a microphysical system or object that is discontinuous that can change only by discret units.

Quantum spin – A fundamental property of particles with no direct counter-part in classical physics. Any picturesque comparison of a 'spinning' electron to a spinning top is merely a poor aid that fails to capture the essence of this quantum concept. The quantum spin of a particle cannot be explained in terms of classical rotation since it can only have certain values that are equal to either a whole number or half a whole number multiplied by Planck's constant h divided by 2π ($\hbar$, a quantity called h-barr). Quantum spin is said to be either up (clockwise) or down (anti-clockwise) with respect to the direction of measurement.

Schrodinger's equation – The fundamental equation of the wave mechanics version of quantum mechanics that governs the behaviour of a particle or the evolution of a physical system by encoding how its wave function varies with time. Schrodinger's equation has as components, the following: m – the mass of the particle, "nabla" operator – mathematical entity also named "the del-operator' which is responsible for tracking how the wave fubction ψ changes from place to place, V captures the forces acting on the particle, i is the square root of -1, $\nu\psi/\nu t$ describes how the wave function ψ changes in time, and $\hbar$ is Planck's constant divided by 2π and is pronounced "$\hbar$-bar". There is another form of the equation that geves a snapshot in time and is called the time-independent Schrodinger's equation.

Spectroscopy – The area concerned with analysing and studying absorption and emission spectra.

Superposition – A quantum state composed of two or more other states. Such a state has certain probabilities for exhibiting the properties of the states out of which it is composed.

Uncertainty principle – The principle discovered by Werner Heisenberg in 1927 that it is not possible to measure simultaneously certain pairs of observables – such an position and momentum, energy and time – with a degree of accuracy that exceeds a limit expressed in terms of Planck's constant h.

Wave function (ψ) – A mathematical function associated with the wave properties of a system or particles. The wave function represents everything that can be known about the state of a physical system or particle in quantum mechanics. For example, using the wave function of the hydrogen atom it is possible to calculate the probability interpretation and Schrodinger's equation.

Wavelength (λ) – The distance between two successive peaks or troughs of a wave. The wavelength of electromagnetic radiation determines which part of the electromagnetic spectrum it belongs to.

B. Medicine (biology) and physiology

- a construct (by selection), taken after the essays named: *"The Oxford Dictionary of Biology"*, [1985], 1990, 1996, Oxford University Press, UK; "*Molecular Biology – present and perspectives",* Anca-Michaela Israil, Ed. Humanitas, București, România, 2000 -.

Deoxyrhibonucleic acid (DNA) – genetic material of most living organisms, being the main constituent of cromozoms in the cell nucleous. It has an essential role in determining hereditary characters, controlling the synthesis of proteins in the cells. It is also present outside the nucleous, as in the case of mitochondria (DNA – mitocondrial). DNA is a nucleic acid, composed of two molecular chains, where the ssacharide is deosyribosis, and the nitrogen bases are named 'adenină', 'citozină', 'guaninâ', 'timină'. The two chains are woven one around the other and are connected by hydrogen bridges established between the complementary nitrogen bases, forming a spiral molecule (double helix). When the cell divides itself, its DNA replicates itself, resulting two daughter-molecules, identical to the mother-molecule.

Rhibonucleic acid (RNA) – is a complex organic compound (nucleic acid), present in the living cells, implied in the sysnthesis of proteins. With some viruses, the RNA represents also hereditary material. The most part of the RNA is synthetized in the nucleous, and then is distributed towards different parties of the citoplasma. The RNA molecle is a long chain of nucleotides, where the glucide is ribosis, and the nitrogen bases are adenine, cytosine, guanine and uracil. The messenger RNA (m**RNA**) copies the genetic information from the DNA and carries it towards the specialized sites within the interior of the cell (named ribozoms), where the information is translated in the composition of the protein. The ribozomal RNA is monocatenary, but presents some helicoidal regions formed by pairing complementary bases. The transfer RNA (t**RNA**) is implied in assembling aminoacids within the polipeptidic chains which is synthetized in ribozoms. Each RNA is specific for a certain aminoacid and carries a three group of bases, complementary with a three group of mRNA.

Self-immunity – disorder of the defence mechanisms of the organism, which is the triggering of an immune answer against its own tissues. For example: rheumatoid artrithis is, in essence, in fact, a self disease.

Immunity – status of relative lack of sensibility of an organism against infections produced by pathogene organisms of the negative effects of toxines produced by the former. Immunity is conditioned by the presence in the blood of antibodies and some white globules (limphocites), which trigger the immune answer. Hereditary immunity (natural-born with) exists from the birth. Obtained immunity is of two types, active and passive. Active immunity occurs when the organism produces antibodies against a stranger substance (antigen) which has entered the body either by contagion or by immunization; it may be umoral, when the B limphocites produce antibodies which freely circulate in the blood or cellulary mediated, when it is due to the action of T limphocites. Passive immunity is induced by inoculating a serum taken from an already immune organism to a certain antigen; or it may be obtained also by transferring antibodies from the mother to the unborn baby. Active immunity is long lasting, passive immunity is temporary.

Immunization – obtaining immunity by artificial means. Active immunization (vaccination) implies introducing in the body, orally or by means of injections (inoculation) some living bacteria or viruses, specially treated to that end or their toxins, with a view to stimulating the production of antibodies (+ vaccine). Passive immunization is achieved by injecting already formed antibodies.

Ribozoms – spherical particles of small sizes, present in the living cells, at the level of which takes place the synthesis of proteins. Ribozoms are formed of a certain type of RNA (ribozomal) and proteins. Normally, in a cell there are several ribozoms, either attached to the endoplasmatic reticle or free, in the citoplasma. While the proteic synthesis is taking place, it associates with mRNA (messenger), forming the poliribozoms, in the translation process.

Proteins – a vast group of organic substances present in all living organisms. They are formed of carbon, hydrogen, oxigen and azote; most proteins also contain sulfur, and their molecular weight is between 6000 and several millions. Protein molecules are composed of one or more long chains (polopeptids) of aminoacids, connected one another by a characteristic succession. The sequence of aminoacids is named 'the primary structure of the protein'. There are globular proteins and fibrous proteins. The former are soluble in water, those of the second type, unlike the former, are insoluble.

Vaccine – a liquid preparated out of treated pathogen microorganisms or products of the former, used in order to stimulate an immune answer in the organism, which may confer resistence against the disease provoked by the former. Vaccines are administrated orally or by injecting (innoculation). In order to prepare different vaccines, dead viruses or bacteria are used, which act as antigenes, attenuated living microorganisms, specially treated toxins or antigenic microorganism extracts.

Virus – a particle too small to be observed by means of an optical microscope or be stopped by a filter, but with a metabolism of its own and which is capable to reproduce itself within a living cell. When it is not within a host cell, the virus is completely inert. Mature viruses (virions) have sizes between 20 and 400 nm diameter. They are composed of a central region which contains nucleic acid (DNA or RNA) surrounded by a proteic cover (capsid). Some viruses (envelopped viruses) have an exterior envelope formed of proteins and lipids, while those without an envelope are called "nude". Within the host cell, the virus initiates the synthesis of viral proteins and replicates. The new virions are eliberated by desintegration of the host cell. Viruses are parasytes for animals, plants and some bacteria. Among the human viral diseases are: the flu, the cold, the herpes, the hepatitis, the poliomyelitis, rabis. Some viruses are also implied in the apparition of cancer. With plants, among the viral diseases are some forms of yellowing and vesiculating leaves and stems. Antibiotics have no effect in the case of viral diseases, but vaccines assure a sufficient protection (when they exist and have been verified scientifically).

Annexes

4 August 1972, Volume 177, Number 4047

SCIENCE

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted without question. The workings of our minds and bodies, and of all the animate or inanimate matter of which we have any detailed knowledge, are assumed to be controlled by the same set of fundamental laws, which except under certain extreme conditions we feel we know pretty well.

It seems inevitable to go on uncritically to what appears at first sight to be an obvious corollary of reductionism: that if everything obeys the same fundamental laws, then the only scientists who are studying anything really fundamental are those who are working on those laws. In practice, that amounts to some astrophysicists, some elementary particle physicists, some logicians and other mathematicians, and few others. This point of view, which it is the main purpose of this article to oppose, is expressed in a rather well-known passage by Weisskopf (*1*):

> Looking at the development of science in the Twentieth Century one can distinguish two trends, which I will call "intensive" and "extensive" research, lacking a better terminology. In short: intensive research goes for the fundamental laws, extensive research goes for the explanation of phenomena in terms of known fundamental laws. As always, distinctions of this kind are not unambiguous, but they are clear in most cases. Solid state physics, plasma physics, and perhaps also biology are extensive. High energy physics and a good part of nuclear physics are intensive. There is always much less intensive research going on than extensive. Once new fundamental laws are discovered, a large and ever increasing activity begins in order to apply the discoveries to hitherto unexplained phenomena. Thus, there are two dimensions to basic research. The frontier of science extends all along a long line from the newest and most modern intensive research, over the extensive research recently spawned by the intensive research of yesterday, to the broad and well developed web of extensive research activities based on intensive research of past decades.

The effectiveness of this message may be indicated by the fact that I heard it quoted recently by a leader in the field of materials science, who urged the participants at a meeting dedicated to "fundamental problems in condensed matter physics" to accept that there were few or no such problems and that nothing was left but extensive science, which he seemed to equate with device engineering.

The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. In fact, the more the elementary particle physicists tell us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science, much less to those of society.

The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. That is, it seems to me that one may array the sciences roughly linearly in a hierarchy, according to the idea: The elementary entities of science X obey the laws of science Y.

X	Y
solid state or many-body physics	elementary particle physics
chemistry	many-body physics
molecular biology	chemistry
cell biology	molecular biology
•	•
•	•
•	•
psychology	physiology
social sciences	psychology

But this hierarchy does not imply that science X is "just applied Y." At each stage entirely new laws, concepts, and generalizations are necessary, requiring inspiration and creativity to just as great a degree as in the previous one. Psychology is not applied biology, nor is biology applied chemistry.

In my own field of many-body physics, we are, perhaps, closer to our fundamental, intensive underpinnings than in any other science in which nontrivial complexities occur, and as a result we have begun to formulate a general theory of just how this shift from quantitative to qualitative differentiation takes place. This formulation, called the theory of "broken symmetry," may be of help in making more generally clear the breakdown of the constructionist converse of reductionism. I will give an elementary and incomplete explanation of these ideas, and then go on to some more general speculative comments about analogies at

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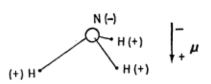
other levels and about similar phenomena.

Before beginning this I wish to sort out two possible sources of misunderstanding. First, when I speak of scale change causing fundamental change I do not mean the rather well-understood idea that phenomena at a new scale may obey actually different fundamental laws—as, for example, general relativity is required on the cosmological scale and quantum mechanics on the atomic. I think it will be accepted that all ordinary matter obeys simple electrodynamics and quantum theory, and that really covers most of what I shall discuss. (As I said, we must all start with reductionism, which I fully accept.) A second source of confusion may be the fact that the concept of broken symmetry has been borrowed by the elementary particle physicists, but their use of the term is strictly an analogy, whether a deep or a specious one remaining to be understood.

Let me then start my discussion with an example on the simplest possible level, a natural one for me because I worked with it when I was a graduate student: the ammonia molecule. At that time everyone knew about ammonia and used it to calibrate his theory or his apparatus, and I was no exception. The chemists will tell you that ammonia "is" a triangular pyramid



with the nitrogen negatively charged and the hydrogens positively charged, so that it has an electric dipole moment (μ), negative toward the apex of the pyramid. Now this seemed very strange to me, because I was just being taught that nothing has an electric dipole moment. The professor was really proving that no nucleus has a dipole moment, because he was teaching nuclear physics, but as his arguments were based on the symmetry of space and time they should have been correct in general.

I soon learned that, in fact, they were correct (or perhaps it would be more accurate to say not incorrect) because he had been careful to say that no stationary state of a system (that is, one which does not change in time) has an electric dipole moment. If ammonia starts out from the above unsymmetrical state, it will not stay in it very long. By means of quantum mechanical tunneling, the nitrogen can leak through the triangle of hydrogens to the other side, turning the pyramid inside out, and, in fact, it can do so very rapidly. This is the so-called "inversion," which occurs at a frequency of about 3×10^{10} per second. A truly stationary state can only be an equal superposition of the unsymmetrical pyramid and its inverse. That mixture does not have a dipole moment. (I warn the reader again that I am greatly oversimplifying and refer him to the textbooks for details.)

I will not go through the proof, but the result is that the state of the system, if it is to be stationary, must always have the same symmetry as the laws of motion which govern it. A reason may be put very simply: In quantum mechanics there is always a way, unless symmetry forbids, to get from one state to another. Thus, if we start from any one unsymmetrical state, the system will make transitions to others, so only by adding up all the possible unsymmetrical states in a symmetrical way can we get a stationary state. The symmetry involved in the case of ammonia is parity, the equivalence of left- and right-handed ways of looking at things. (The elementary particle experimentalists' discovery of certain violations of parity is not relevant to this question; those effects are too weak to affect ordinary matter.)

Having seen how the ammonia molecule satisfies our theorem that there is no dipole moment, we may look into other cases and, in particular, study progressively bigger systems to see whether the state and the symmetry are always related. There are other similar pyramidal molecules, made of heavier atoms. Hydrogen phosphide, PH_3, which is twice as heavy as ammonia, inverts, but at one-tenth the ammonia frequency. Phosphorus trifluoride, PF_3, in which the much heavier fluorine is substituted for hydrogen, is not observed to invert at a measurable rate, although theoretically one can be sure that a state prepared in one orientation would invert in a reasonable time.

We may then go on to more complicated molecules, such as sugar, with about 40 atoms. For these it no longer makes any sense to expect the molecule to invert itself. Every sugar molecule made by a living organism is spiral in the same sense, and they never invert, either by quantum mechanical tunneling or even under thermal agitation at normal temperatures. At this point we must forget about the possibility of inversion and ignore the parity symmetry: the symmetry laws have been, not repealed, but broken.

If, on the other hand, we synthesize our sugar molecules by a chemical reaction more or less in thermal equilibrium, we will find that there are not, on the average, more left- than right-handed ones or vice versa. In the absence of anything more complicated than a collection of free molecules, the symmetry laws are never broken, on the average. We needed living matter to produce an actual unsymmetry in the populations.

In really large, but still inanimate, aggregates of atoms, quite a different kind of broken symmetry can occur, again leading to a net dipole moment or to a net optical rotating power, or both. Many crystals have a net dipole moment in each elementary unit cell (pyroelectricity), and in some this moment can be reversed by an electric field (ferroelectricity). This asymmetry is a spontaneous effect of the crystal's seeking its lowest energy state. Of course, the state with the opposite moment also exists and has, by symmetry, just the same energy, but the system is so large that no thermal or quantum mechanical force can cause a conversion of one to the other in a finite time compared to, say, the age of the universe.

There are at least three inferences to be drawn from this. One is that symmetry is of great importance in physics. By symmetry we mean the existence of different viewpoints from which the system appears the same. It is only slightly overstating the case to say that physics is the study of symmetry. The first demonstration of the power of this idea may have been by Newton, who may have asked himself the question: What if the matter here in my hand obeys the same laws as that up in the sky—that is, what if space and matter are homogeneous and isotropic?

The second inference is that the internal structure of a piece of matter need not be symmetrical even if the total state of it is. I would challenge you to start from the fundamental laws of quantum mechanics and predict the ammonia inversion and its easily observable properties without going through the stage of using the unsymmetrical pyramidal structure, even though no "state" ever has that structure. It is fascinating that it was not until a couple of decades ago (*2*) that nuclear physicists stopped thinking of the nucleus as a featureless, symmetrical little ball and realized that while it really never has a dipole moment, it can become footballshaped or plate-shaped. This has observable consequences in the reactions and excitation spectra that are studied in nuclear physics, even though it is much more difficult to demonstrate directly than the ammonia inversion. In my opinion, whether or not one calls this intensive research, it is as fundamental in nature as many things one might so label. But it needed no new knowledge of fundamental laws and would have been extremely difficult to derive synthetically from those laws; it was simply an inspiration, based, to be sure, on everyday intuition, which suddenly fitted everything together.

The basic reason why this result would have been difficult to derive is an important one for our further thinking. If the nucleus is sufficiently small there is no real way to define its shape rigorously: Three or four or ten particles whirling about each other do not define a rotating "plate" or "football." It is only as the nucleus is considered to be a many-body system—in what is often called the $N \rightarrow \infty$ limit—that such behavior is rigorously definable. We say to ourselves: A macroscopic body of that shape would have such-and-such a spectrum of rotational and vibrational excitations, completely different in nature from those which would characterize a featureless system. When we see such a spectrum, even not so separated, and somewhat imperfect, we recognize that the nucleus is, after all, not macroscopic; it is merely approaching macroscopic behavior. Starting with the fundamental laws and a computer, we would have to do two impossible things—solve a problem with infinitely many bodies, and then apply the result to a finite system—before we synthesized this behavior.

A third insight is that the state of a really big system does not at all have to have the symmetry of the laws which govern it; in fact, it usually has less symmetry. The outstanding example of this is the crystal: Built from a substrate of atoms and space according to laws which express the perfect homogeneity of space, the crystal suddenly and unpredictably displays an entirely new and very beautiful symmetry. The general rule, however, even in the case of the crystal, is that the large system is less symmetrical than the underlying structure would suggest: Symmetrical as it is, a crystal is less symmetrical than perfect homogeneity.

Perhaps in the case of crystals this appears to be merely an exercise in confusion. The regularity of crystals could be deduced semiempirically in the mid-19th century without any complicated reasoning at all. But sometimes, as in the case of superconductivity, the new symmetry—now called broken symmetry because the original symmetry is no longer evident—may be of an entirely unexpected kind and extremely difficult to visualize. In the case of superconductivity, 30 years elapsed between the time when physicists were in possession of every fundamental law necessary for explaining it and the time when it was actually done.

The phenomenon of superconductivity is the most spectacular example of the broken symmetries which ordinary macroscopic bodies undergo, but it is of course not the only one. Antiferromagnets, ferroelectrics, liquid crystals, and matter in many other states obey a certain rather general scheme of rules and ideas, which some many-body theorists refer to under the general heading of broken symmetry. I shall not further discuss the history, but give a bibliography at the end of this article (*3*).

The essential idea is that in the so-called $N \rightarrow \infty$ limit of large systems (on our own, macroscopic scale) it is not only convenient but essential to realize that matter will undergo mathematically sharp, singular "phase transitions" to states in which the microscopic symmetries, and even the microscopic equations of motion, are in a sense violated. The symmetry leaves behind as its expression only certain characteristic behaviors, for instance, long-wavelength vibrations, of which the familiar example is sound waves; or the unusual macroscopic conduction phenomena of the superconductor; or, in a very deep analogy, the very rigidity of crystal lattices, and thus of most solid matter. There is, of course, no question of the system's really violating, as opposed to breaking, the symmetry of space and time, but because its parts find it energetically more favorable to maintain certain fixed relationships with each other, the symmetry allows only the body as a whole to respond to external forces.

This leads to a "rigidity," which is also an apt description of superconductivity and superfluidity in spite of their apparent "fluid" behavior. [In the former case, London noted this aspect very early (*4*).] Actually, for a hypothetical gaseous but intelligent citizen of Jupiter or of a hydrogen cloud somewhere in the galactic center, the properties of ordinary crystals might well be a more baffling and intriguing puzzle than those of superfluid helium.

I do not mean to give the impression that all is settled. For instance, I think there are still fascinating questions of principle about glasses and other amorphous phases, which may reveal even more complex types of behavior. Nevertheless, the role of this type of broken symmetry in the properties of inert but macroscopic material bodies is now understood, at least in principle. In this case we can see how the whole becomes not only more than but very different from the sum of its parts.

The next order of business logically is to ask whether an even more complete destruction of the fundamental symmetries of space and time is possible and whether new phenomena then arise, intrinsically different from the "simple" phase transition representing a condensation into a less symmetric state.

We have already excluded the apparently unsymmetric cases of liquids, gases, and glasses. (In any real sense they are more symmetric.) It seems to me that the next stage is to consider the system which is regular but contains information. That is, it is regular in space in some sense so that it can be "read out," but it contains elements which can be varied from one "cell" to the next. An obvious example is DNA; in everyday life, a line of type or a movie film have the same structure. This type of "information-bearing crystallinity" seems to be essential to life. Whether the development of life requires any further breaking of symmetry is by no means clear.

Keeping on with the attempt to characterize types of broken symmetry which occur in living things, I find that at least one further phenomenon seems to be identifiable and either universal or remarkably common, namely, ordering (regularity or periodicity) in the time dimension. A number of theories of life processes have appeared in which regular pulsing in time plays an important role: theories of development, of growth and growth limitation, and of the memory. Temporal regularity is very commonly observed in living objects. It plays at least two kinds of roles. First, most methods of extracting energy from the environment in order to set up a continuing, quasi-stable process involve time-periodic machines, such as oscillators and generators, and the processes of life work in the same way. Second, temporal regularity is a means of handling information, similar to information-bearing spatial regularity. Human spoken language is an example, and it is noteworthy that all computing machines use temporal pulsing. A possible third role is suggested in some of the theories mentioned above: the use of phase relationships of temporal pulses to handle information and control the growth and development of cells and organisms (*5*).

In some sense, structure—functional structure in a teleological sense, as opposed to mere crystalline shape—must also be considered a stage, possibly intermediate between crystallinity and information strings, in the hierarchy of broken symmetries.

To pile speculation on speculation, I would say that the next stage could be hierarchy or specialization of function, or both. At some point we have to stop talking about decreasing symmetry and start calling it increasing complication. Thus, with increasing complication at each stage, we go on up the hierarchy of the sciences. We expect to encounter fascinating and, I believe, very fundamental questions at each stage in fitting together less complicated pieces into the more complicated system and understanding the basically new types of behavior which can result.

There may well be no useful parallel to be drawn between the way in which complexity appears in the simplest cases of many-body theory and chemistry and the way it appears in the truly complex cultural and biological ones, except perhaps to say that, in general, the relationship between the system and its parts is intellectually a one-way street. Synthesis is expected to be all but impossible; analysis, on the other hand, may be not only possible but fruitful in all kinds of ways: Without an understanding of the broken symmetry in superconductivity, for instance, Josephson would probably not have discovered his effect. [Another name for the Josephson effect is "macroscopic quantum-interference phenomena": interference effects observed between macroscopic wave functions of electrons in superconductors, or of helium atoms in superfluid liquid helium. These phenomena have already enormously extended the accuracy of electromagnetic measurements, and can be expected to play a great role in future computers, among other possibilities, so that in the long run they may lead to some of the major technological achievements of this decade (*6*).] For another example, biology has certainly taken on a whole new aspect from the reduction of genetics to biochemistry and biophysics, which will have untold consequences. So it is not true, as a recent article would have it (*7*), that we each should "cultivate our own valley, and not attempt to build roads over the mountain ranges . . . between the sciences." Rather, we should recognize that such roads, while often the quickest shortcut to another part of our own science, are not visible from the viewpoint of one science alone.

The arrogance of the particle physicist and his intensive research may be behind us (the discoverer of the positron said "the rest is chemistry"), but we have yet to recover from that of some molecular biologists, who seem determined to try to reduce everything about the human organism to "only" chemistry, from the common cold and all mental disease to the religious instinct. Surely there are more levels of organization between human ethology and DNA than there are between DNA and quantum electrodynamics, and each level can require a whole new conceptual structure.

In closing, I offer two examples from economics of what I hope to have said. Marx said that quantitative differences become qualitative ones, but a dialogue in Paris in the 1920's sums it up even more clearly:

FITZGERALD: The rich are different from us.

HEMINGWAY: Yes, they have more money.

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Natural Areas

While harboring valuable species, natural areas also serve as bench marks in evaluating landscape change.

William H. Moir

"The sheep destroy young trees and when the old ones die no forest will be left"; thus H. C. Cowles described the situation after his epochal study in 1899 of plant succession on the dunes of Lake Michigan (*1*). Cowles knew well how the heavy hand of man could accelerate changes in vegetation, often in undesirable directions. He and his colleague V. E. Shelford had seen the expanding city of Gary threaten ever more of the "quiet but varied beauty" of the dunes and wooded hills (*2*). Man's destruction of the natural landscape appeared so widespread and pervasive that in 1917 the newly organized Ecological Society of America appointed Shelford the chairman of a committee to find out what remained of wild, natural America and to promote the idea of a system of natural preserves (*3*).

Some 50 years later, President Nixon repeated the need—which had become urgent—of preserving the natural environment (*4*):

> I am submitting to Congress several bills that will be part of a comprehensive effort to preserve our natural environment and to provide more open spaces and parks in urban areas where today they are often so scarce.

Those 50 years had seen Gary fuse with Calumet City, Hammond, Whiting, and East Chicago to become an environmental nightmare. To be sure, a vestige of the extensive dunes still

Proc. Natl. Acad. Sci. USA
Vol. 92, pp. 6653–6654, July 1995
Colloquium Paper

This paper serves as an introduction to the following papers, which were presented at a colloquium entitled "Physics: The Opening to Complexity," organized by Philip W. Anderson, held June 26 and 27, 1994, at the National Academy of Sciences, in Irvine, CA.

Physics: The opening to complexity

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In the minds of the lay public, or even of scientists from unrelated fields, physics is mainly associated with extremes: big bangs and big bucks; the cosmic and the subnucleonic scales; matter in its most rarified form such as single trapped atoms; or measurements of extraordinary precision to detect phenomena—dark matter, proton decay, neutrino masses—which may well not be there at all.

The intellectual basis for this kind of science has been expounded by Victor Weisskopf, Leon Lederman, Stephen Hawking, and particularly Steven Weinberg, in his book *Dreams of a Final Theory.* The buzzword is "reductionism," the idea that the goal of physics is solely or mostly to discover the "fundamental" laws which all phenomena involving matter and energy must obey and that ignorance about these laws persists only on the extreme scales of the very small, the very cosmic, or the very weak and subtle.

The glamorous image of physics that this preoccupation projects is not necessarily all good: with the end of the Cold War and of expansionist public spending, physics is seen by all too many policymakers as too expensive for its practical return or simply too big for its boots. Some pundits have called the past half-century "The Age of Physics" and suggested that this age is coming to an end.

This pessimistic view may or may not be true even of Big Science physics. It seems to me that cosmic physics, at least, is in the midst of a very fertile period, not near collapse. But what it ignores is the fact that most physics and most physicists are not involved in this type of work at all. Eighty percent or so of research physicists do not classify themselves as cosmic or elementary particle physicists and are not much concerned with testing the fundamental laws. Admittedly, some portion of this 80% are concerned with applications of physics to various practical problems, as for example prospecting geophysicists or electronic device designers. But another large fraction are engaged in an entirely different type of fundamental research: research into phenomena that are too complex to be analyzed straightforwardly by simple application of the fundamental laws. These physicists are working at another frontier between the mysterious and the understood: the frontier of complexity.

At this frontier, the watchword is not reductionism but emergence. Emergent complex phenomena are by no means in violation of the microscopic laws, but they do not appear as logically consequent on these laws. That this is the case can be illustrated by two examples which show that a complex phenomenon can follow laws independently of the detailed substrate in which it is expressed.

(*i*) The "Bardeen–Cooper–Schrieffer (BCS)" phenomenon of broken gauge symmetry in dense Fermion liquids has at least three expressions: electrons in metals, of course, where it is called "superconductivity"; ^{3}He atoms, which become a pair superfluid when liquid ^{3}He is cooled below 1–3 $\times 10^{-3}$ K; and nucleons both in ordinary nuclei (the pairing phenomenon explained by Bohr, Mottelson, and Pines) and in neutron stars, on a giant scale, where superfluidity is responsible for the "glitch" phenomenon. All of these different physical embodiments obey the general laws of broken symmetry that are the canonical example of emergence in physics.

(*ii*) One may make a digital computer using electrical relays, vacuum tubes, transistors, or neurons; the latter are capable of behaviors more complex than simple computation but are certainly capable of that; we do not know whether the other examples are capable of "mental" phenomena or not. But the rules governing computation do not vary depending on the physical substrate in which they are expressed; hence, they are logically independent of the physical laws governing that substrate.

This principle of emergence is as pervasive a philosophical foundation of the viewpoint of modern science as is reductionism. It underlies, for example, all of biology, as emphasized especially by Ernst Mayr, and much of geology. It represents an open frontier for the physicist, a frontier which has no practical barriers in terms of expense or feasibility, merely intellectual ones. It is this frontier that this colloquium was destined to showcase. A typical (but incomplete) selection of the papers given at the colloquium are reproduced here.

The subfields of complexity which we chose to represent are only a fraction of the available material. This frontier of complexity is by far the most active growth point of physics. Physicists are also finding themselves, more and more, working side by side with other scientists in interdisciplinary collaborations at this frontier. The flavor of many of the talks was interdisciplinary.

We chose four areas under which to group the talks. These highlighted four kinds of physics. A brief description of each follows.

(*i*) Conventional solid state physics is really the quantum physics of materials, and as such deals mainly with electronic properties. There has been a resurgence of interest in this area because of several new and startling discoveries of new types of materials: We called this "The New Physics of Crystalline Materials."

(*ii*) Noncrystalline materials such as glasses and polymers have become increasingly subjects of interest in physics, so we included a section on "The New Physics of Noncrystalline Materials." Some of the deepest problems in theoretical physics still surround the dynamics of glasses. It is slightly unsuitable to include biophysical materials under this heading since biophysics is an important and growing frontier in itself but in order not to subdivide the sessions infinitely this was done.

(*iii*) Physicists are increasingly moving into realms very far from equilibrium, studying processes which form many of the natural objects we encounter as well as describing the highly nonequilibrium behavior we see all around us in turbulent convective flow (weather) and the non-

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equilibrium states we see in our geological surroundings. The phenomenology of this sort of phenomenon ("fractals," chaos, pattern formation) far outstrips our theoretical apparatus for dealing with it. The emphasis is on the "search for generalizations."

(*iv*) Finally, there is a field that has grown up around the new statistical physics developed for some fascinating materials problems of disordered dynamical systems, which has overlapped into problems of computational algorithms for complex problems and into the theory of neural networks. This is a development which promises to allow us to deal with true complexity with physical rigor and needed to be presented: "New Theories of Complexity."

A fifth topic was omitted because of overlap with a recent colloquium: complexity in astrophysics, and I am sure those interested in complexity will have their own candidates. But, in the end, this program is what we had room for and the attendees seemed to have enjoyed the program as presented.

Some universitary and academic disciplines and concerns where one can find aspects of scientific interdisciplinarity and transdisciplinarity of complex systems

HUMANE SCIENCES	SOCIAL SCIENCES	NATURAL SCIENCES	FORMAL SCIENCES	APPLIED SCIENCES
1. HISTORY	**1. ANTHROPOLOGY**	**1. BIOLOGICAL SCIENCES**	**1. COMPUT. SCIENCES**	**1. AGRICULTURE**
African history	Biological anthropology	Biochemistry	Theory of calculation	Agroecology
American history	*Forensic anthrop.*	Bioinformatics	*Automates (formal langauages)*	Agroeconomy
Ancient history	*Coevol."gene-culture"*	Biology	*Computability*	Science of animals
Chinese history	*Ecolog. human behavior*	*Aerobiology*	*Computational complexity*	Agrology
Diplomatic history	*Human evolution*	*Anatomy*	*Concurrent theories*	Enthomology
Etnologic history	*Paleoanthropology*	*Comparative anatomy*	Algorithms	Science of the environment
European history	*Populational genetics*	*Human anatomy*	*Probabilistic algorithms*	Agricultural economy
Hist. of science and technology	*Educational anthrop.*	*Botanics*	*Distributed algorithms*	Agricultural engineering
Military history	*Etnolinguistics*	*Etnobotanics*	*Parallel algorithms*	*Engineering of biological systems*
History of intellectuality	*Sociolinguistics*	*Ficology*	Structure of dates	*Food engineering*
Cultural history	Cultural anthropology	*Cellular biology*	Architecture on computer	*Biotechnology*
Economic history	*Anthropology of religion*	*Cronobiology*	*VLSI Project*	Acquaculture
World history	*Economic anthropology*	*Criobiology*	Operation systems	Bee keeping
Modern history	*Etnography*	*Biology of development*	Communication, comput. Network	Enologie
2. LANGUAGE / LINGUISTICS	*Etnohistory*	*Embriology*	*Theory of information*	Science of aliments
Applied linguistics	*Etnology*	*Ecology*	*Internet, www*	Horticulture
Computational linguistics/ natural language	*Etnomusicology*	*Human ecology*	*Mobile calculation*	Hydrology
Analysis of discourse	*Folklore*	*Ecology of lakes*	Comput./fiability security	Meteorology
Linguistics in history	*Mitology*	*Genetics*	*Criptography*	Science of plants
History of linguistics	*Political anthropology*	*Behavior genetics*	*Tolerance for calculation errors*	*Science of fuit growing*
Philology	*Psychological anthropology*	*Endocrinology*	Distributed calculation	Forestry
Phonetics	*Primatology*	*Evolutive biology*	*Calculation networks*	Vineculture
Phonology	Linguistic anthropology	*Human biology*	Parallel calculation	**2. ARCHIT. / "DESIGN"**
Pragmatics	*Syncronic linguistics*	*Marine biology*	*High perform.calculation*	Architecture/relat. "design"
Semantics	*Diacronic linguistics*	*Microbiology*	Quantum calculation	*Architecture*
Semiotics	Medical anthropology	*Molecular biology*	Grafica computationala	*Urban "design"*
Composition	**2. ARCHEOLOGY**	*Biology of nutrition*	*Image processing*	*Interior"design"*
Rhetoric	Classic archeology	*Neurosciences*	*Scientific visualization*	*Landscape architecture*
Languages	Egiptology	*Neuroscience behavior*	*Computational geometry*	*Historical preservation*
Classic	Experimental archeology	*Paleobiology*	Computer and society	*Industrial "design"*
Standard English	Maritime archeology	*Paleontology*	*"Hardware" history*	*Ergonomy*

Business English	Paleoanthropology	*Virusology*	*History of of computational science*	*"Design" in playing industry*
Interlinguistics	Prehistoric archeology	*Molecular virusology*	*Humanist informatics*	*"Design" for parks*
Morphology	Eastern-close archeology	*Xenobiology*	*Community informatics*	*"Design" in clothes fashion*
Sociolinguistics	**3. ZONAL STUDIES**	*Zoology*	"Software" engineering	*"Design" in textiles*
Synthax	American studies	*Animal communication*	*Formal mehods*	*Visual communication*
Universal English	Studies ref. to Appalachia	*Cryptozoology*	Software languages	*Graphic "design"*
Modern languages	African studies	*Entomology*	*Paradigms of progr.*	*Interface "design"*
3. LITERATURE	Asian studies	*Etology*	*Oriented programming*	**3. COMMERCE**
English literature	Canadian studies	*Herpetology*	*Functional programming*	*Stock market accounting in commerce*
American literature	Celtic studies	*Ihtiology*	*Concurrent programming*	*Administration in art*
African-American literature	European studies	*Oology*	*Semantic programming*	*Administration in commerce*
Jewish-American literature	Germanic studies	*Ornitology*	*"Type" theories*	*Ethics in commerce*
USA Southern literature	Indian studies	*Primatology*	*Compilationsi*	*Entrepreneurship*
Australian literature	Iranian studies	*Zootomy*	Science of information	*Finances*
British literature	Japanese studies	*Biophysics*	*Data management*	*Industrial and labor relationships*
English literature	Latin-American studies	*Limnology*	*Data search*	*Optimal common commerce*
Scottish literature	Chinese studies	*Taxonomy*	*Data bases*	*Human resources*
Welsh literature	Scandinavian studies	*Micology*	*Information recovery*	*Study of organizations*
Canadian literature	Slavic studies	*Parasitology*	*Information management*	*Labor economy*
Indian literature	**4.CULTURAL/ETHNO SCIENCES**	*Pathology*	*Knowledge management*	*Labor history*
Irish literature	Asian studies	*Physiology*	*Multimed.-hypermed.*	*Information systems*
Neo-Zeelandeese literature	Black race/African-American studies	*Human physiology*	Artificial Intelligence	*"Management"*
Nigerian literature	"Chicano" (Mexic) studies	*Experimental physiology*	*Cognitive science*	*"Marketing"*
Medieval literature	Study of childhood	*Systematics (taxonomy)*	*Automated reasoning*	*Project in "management"*
Post-colonial literature	"Latino" studies	*Teratology*	*Automated learning*	*"Managament" in risk/ensurances*
Post-modernist literature	American native study	**2. CHEMISTRY**	*Artificial neural network*	*Science of commercial systems*
World literature	Persian studies	Analytic chemistry	*Computational linguistics*	**4. RELIGIOUS SCIENCES**
Arabian literature	**5. ECONOMY**	Biochemistry	*Computational vision*	Canonical law
Classic literature	Agricultural economy	Informatics in chemistry	*Expert systems*	History of church
Comparative literature	Austrain economy	Computational chemistry	*Robotics*	Religious knowledge
Chinese literature	Economic behavior	Science of materials	Interaction human-computer	*Pastoral counseling*
French literature	Bioeconomy	Mathematic chemistry	Mat./Nat. scien./eng./med.	*Pastoral theology*
Welsh literature	Computational economy	Quantum chemistry	*Numeric analysis*	*Technics of religious education*
German literature	Economy of consumer	Anorganic chemistry	*Algebraic calcululus*	*Homiletics (art of preaching)*
Hindi literature	Economic development	Organic chemistry	*Numeric calculus*	*Liturgic*
Jewish literature	Ecologic economy	Physic chemistry	*Computational mathematics*	*Sacred music*
Japanese literature	Econometry	Theoretic chemistry	*Computational*	Study of scriptures and

			science calculus	languaes
Italian literature	Economic geography	Interface science, colloidal science	*Bioinformatics*	*Biblical Hebrew*
Latin-American literature	Economic history	**3. SCIENCES OF THE EARTH**	*Computational calculus in physics*	*Biblical studies/Scriptures*
Portugeese / Brasilian lit.	Economic sociology	Edaphology	*Computational calculus in chemistry*	*Grek language in the New Testament*
Russian literature	Economic systems	Science of environment	*Neuroscience computational calculus*	*Latin language*
Spanish literature	Evolutive economy	Chemistry of the environment	*Computational engineering*	*Old church Slavonian*
Yiddish literature	Experimental economy	Gemology	*Finite element method*	Theology
Tamil (India–Ceylon)literature	Feminist economy	Geodesy	*Fluid computational dynamics*	*Dogmatic theology*
Literary theory	Financial economy	Geography	Soc. sciences /arts/humane sciences	*Eclesiology*
Critical theory	Theory of games	Geology	*Computational economy*	*Sacramental theology*
Literary critic	"Green" economy	Geochemistry	*Computational sociology*	*Systemic theology*
Poetics	Economy of growth	Geomorphology	*Computational finances*	**5. EDUCATION**
Rhetorics	Theory of human development	Geophysics	*Computation in humane sciences*	Consummer education
Creative writing	Industrial organization	*Glaciology*	Information systems	Critical pedagogy
"Non-fiction"creation	Economic information	Hydrogeology	*Information technology*	"Curriculum" and training
"Fiction" writing	Economic institutions	Hydrology	*Management of information systems*	*Primary/intermittent education*
"Non-fiction" writing	International economy	Meteorology	*Information in health*	*Secondary education*
Literary journalism	Islamic economy	Mineralogy	**2. MATHEMATICS**	*Superior education*
Poetic composition	Macroeconomy	Oceanography	Algebra	*"Master"education*
Writings on computer monitor	Managerial economy	Pedology	*Theory of groups*	*Education in cooperation*
Playwriting	Economic mathematics	Paleontology	*Representation of groups*	*Agricultural education*
4. PERFORMING ART	Microeconomy	*Paleobiology*	*Theory of rings*	*Education in art*
Art administration	Monetary economy	Planetary science	*Field theory*	*Bilingual education*
Music	Neuroeconomy	Sedimentology	*Linear algebra*	*Education in chemistry*
Accompaniament	Economic politics	Science of the soil	*Multilinear algebra*	*Education in counseling*
Chamber music	Pulic finances	Speology	*Lie algebrae*	*Linguistic education*
Church music	Public economy	**4. PHYSICS**	*Associative algebrae*	*Education in law*
Directing	Property economy	Acoustics	*Non-associative algebrae*	*Education in mathematics*
Choir	Resource economy	Astrophyisics	Universal algebra	*Education in medicine*
Orchestra	Socialist economy	Atomic physics, molecular physics/optics	Omologic algebra	*Military education and training*
"Wind" ensemble	Social economy	Biophysics	Theory of categories	*Musical education*
Organ and keyboard	Energetic economy	Theoretical physics	Theory of lattices	*Education in medical assistance*
Piano	Antreprenorial economy	Computational physics	Differential algebra	*Education in the study of peace*
Chords, harp, guitar	Economy of the environment	Physics of condensed matter	Mathematic analysis	*Physical educaton and sport*
Voice	Labor economy	Low temperature physic	*Real* analysis	*Education in physical sciences*

Wooden, brass, percution instruments	Law and economy	Electromagnetism	*Real calculus*	*Education in reading*
Early music	Economy of transportation	Physics of elementary particles	*Complex analysis*	*Religious education*
Jazz studies	Economy of wellness	Dynamic of fluids	*Functional analysis*	*Education in science*
Musical education	**6. GENDER / SEXUALITY**	Geophysics	*Operator theory*	*Sexual education*
History of music	Feminine psychology	Mathematical physics	*Non-standard analysis*	*Sociology of education*
Theory of music	Gender studies/gender theorie	Medical physics	*Harmonic analysis*	*Education techniques*
Musicology	Heterosexuality	Science of materials	*"P-adic"analysis*	*Educational vocations*
Ethnomusicology	Human sexual becoming	Mecanics	*Ordinary differential equations*	Education of the leader
Orchestral studies	Human sexuality	Molecular physics	*Partial derivative equations*	Philosophy of education
5. PHILOSOPHY	Masculine psychology	Nuclear physics	Theory of probabilities	Psychology of education
Meta-philosophy	Study of man	Newtonian dynamics	*Theory of measure*	Technological education
Methaphysics	"Queer" study and sexuality	Optics	*Ergodic theory*	Distant education
Ontology	Sexual education	Physics of plasma	*Stochastic processes*	**6. ENGINEERING**
Teleology	Sexology	Quantum physics	Geometry and topology	Aerospatial engineering
Philosophy of mind	Study of woman	Physics of solid bodies	*General topology*	Agricultural engineering
Philosophy of artificial intelligence	**7. GEOGRAPHY**	Statistic mechanics	*Algebric topology*	Engineering of control systems
Philosophy of perception	Cartography	Dynamics of vehicles	*Geometric topology*	Mining enginnering
Space-time philosophy	Human geography	Thermodynamics	*Differential topology*	Nanoengineering
Philosophy of action	*Cultural geography*	Applied physics	*Algebric geometry*	Food engineering
Epistemology	Feminist geography	**5. SCIENCES OF SPACE**	*Differential geometry*	Architectural engineering
Logics	*Economic geography*	Astrobiology	*Projective geometry*	Bioengineering
Logic philosophy	Geographic development	Astronomy	*Affine geometry*	*Biomechanic engineering*
Logic mathematics	*Historic geography*	*Observational astronomy*	*Non-Euclidian geometry*	*Biomedical engineering*
Ehtics	Geography and time	*Astronomy of gamma rays*	*Convex geometry*	Chemical engineering
Bioethics	*Political/geopolitical geography*	*Astronomy of infrared rays*	*Discreet geometry*	Civil engineering
Normative ethics	Military geography	*Astronomy of microwaves*	Theory of numbers	*Geotechnical engineering*
Meta-ethics	Strategic geography	*Optical astronomy*	*Analytical theory of numbers*	*Seismic engineering*
Theory of value	Populational geography	*Radioastronomy*	*Algebric theory of numbers*	*Road engineering*
Moral phychology	Social geography	*Astronomy of UV rays*	*Geometric theory of numbers*	*Transportation engineering*
Applied ethics	*Behaviorial geography*	*Astronomy of X rays*	Mathematical logics and fundamentals	Engineering in computers
Political philosophy	*Geography of children*	Astrophysics	*Theory of sets*	Ecologic engineering
Philosophy of law	*Geography of health*	*Gravitational astronomy*	*Theory of demonstration*	Electrical engineering
Decision, rational, theory of games	*Geography of tourism*	*Black holes*	*Theory of models*	Electronic engineering
Esthetics and philosophy of art	*Urban geography*	Interstelar environment	*Recursive theory*	Instrumental engineering
Social and politic philosophy	Geography of the environment	Numeric simulation in:	*Modal logics*	Physical engineering

Feminist philosophy	Physical geography	*Astrophysical analysis of plasma*	*Intuitionist logics*	Environment engineering
Anarhism	*Biogeography*	*Forming/evolution of galaxies*	Applied mathematics	Industrial engineering
Marxism	*Geographic climatology*	*High energy astrophysics*	*Mathematical statistics*	Engineering of materials
Philosophic tradition and school	*Paleoclimatology*	*Hydrodinamics*	*Econometry*	Engineering of ceramics
African philosophy	*Coast geography*	*Magnetohydrodynamics*	*Mathematics in ensurances*	Metalurgical engineering
Analytical philosophy	*Geomorphology*	*Forming of stars*	*Demography*	Polymer engineering
Continental philosophy	*Geodesy*	Cosmologic physics	*Theory of approximation*	Mechanic engineering
Eastern philosophy	*Hydrology/hydrography*	Star astrophysics	*Numeric analysis*	Engineery of clothing
Feminist philosophy	*Glaciology*	*Helioseismology*	*Optimization (mathematic programming)*	Nuclear engineering
History of philosophy	Limnology	*Star evolution*	*Operational research*	Oceanographic engineering
Ancient philosophy	*Oceanography*	*Star nucleosynthesis*	*Linear programming*	*Marine engineering*
Medieval philosophy	*Ecology of lakes*	-	*System dynamics*	*Naval architecture*
Modern philosophy	*Paleogeography*	-	*Theory of chaos*	Optical engineering
Contemporary philosophy	Regional geography	-	*Fractal geometry*	Engineering of quality ensuring
Applied philosophy	**8. POLITICAL SCIENCES**	-	*Mathematical physics*	Oil engineering
Animal rights	Amercian politics	-	*Theory of quantum fields*	Engineering of security
Phil. of AI and cognitive sciences	Canadian politics	-	*Statistic mechanics*	Engineering for “software”
Philosophy of education	Civic politics	-	*Theory of calculus*	Structural engineering
Philosophy of historic sciences	Comparative politics	-	*Theory of complex calculus*	System engineering
Philosophy of religion	Geopolitics	-	*Theory of information*	Engineering of distant communications
Philosophy of language	International relationships	-	*Criptographics*	Engineering of vehicles
Philosophy of mathematics	International organizations	-	*Combinatorics*	*Car engineering*
Philosophy of music	Study of peace and conflicts	-	*Theory of codes*	**7. ENVIRONMENT AND FORESTS**
Philosophy of science	Politic studies	-	*Theory of graphs*	Conservative biology
Philosophy of social sciences	Political behavior	-	*Theory of games*	*Administration of wild flora/fauna*
Philosophy of physical sciences	Cultural politics	-	**3. SCIENCES OF SYSTEMS**	Coast management
Philosophy of biological sciences	Economic politics	-	Theory of chaos	Politics of environment
Philosophy of chemical sciences	Historic politics	-	Complex systems	Fish management
Philosophy of economic sciences	Political philosophy	-	Theory of complexity	Administration of the soil
Philosophy of psychological sciences	Psephology	-	Cybernetics	Management of natural resources
Philosophy of engineering	Public administration	-	*Biocybernetics*	Recreative ecologies
Ethtics of the environment	*Non-profit administration*	-	*Cybernetic engineering*	Sustainable development
Philosophy of systems	*Administration of*	-	*Managerial*	Toxicology

	non-governmental organizations		*cybernetics*	
6. RELIGION	Public politics	-	*Medical cybernetics*	**8. FAMILY/CONSUMMIN G**
Abraham's religion	**9. PSYCHOLOGY**	-	*"New" cibernetics*	Education of consuming
Christianity	Applied psychology ta	-	*Cybernetics of level II*	Family households
Christian theology	Science of behavior	-	Theory of control	Interior design
Bibliology	Biological psychology	-	*Theory of affectation and control*	Nutrition
Hermeneutics	Clinic psychology	-	*Control in engineering*	Management in food services
Participant theology	Psychological evaluation	-	*System control*	Textile materials
Christology	Psychotherapy	-	*Dynamic systems*	**9. SCIENCES OF HEALTH**
Pneumatology	*Rapid psychotherapy*	-	*Theory of perception control.*	Alternative medicine
Anthropological theology	*Cognitive behavioral therapy*	-	Operational research	*Acupuncture*
Soteriology	*Family therapy*	-	Biological systems	Science in laboratory clinic
Nomology	*"Gestalt"therapy*	-	*Biologic calculation systems*	*Clinical biochemistry*
Eclesiology	*Group therapy*	-	*Synthetic biology*	Citogenetics
Eschatology	*Therapy by playing*	-	*Immunologic systems*	Citohematology
Gnosticism	*Psychodrama*	-	Dynamic systems	Citology
Islamism	Cognitive psychology	-	*Social systems*	Hemostasiology
Judaism	Cognitive science	-	Ecological systems	Histology
Indian religion	Psychology of community	-	*Ecology of ecosystems*	Immunology
Budhdism	Differential psychology	-	System engineering	Microbiology
Hinduism	Psychology of development	-	*Engineering of biological systems*	Molecular genetics
Jainism	Educational pshychology	-	*Management /engineering of big systems*	*Parasitology*
Sikhism	Psychology of emotion	-	*Institutional engineering systems*	Dental sciences
Tao religion (Mandarin)	Evolutive psychology	-	*Analysis of systems*	*Dental hygiene*
Chinese popular religion	*Development of evolutive psycholoy*	-	Psychological systems	Emergency medicine
Confucianism	*Evolutionist educational psychology*	-	*Ergonomy*	*Toxicology*
Shinto	Experimental psychology	-	*System of family*	Endocrinology
Taoism	Psychology in justice	-	*Systemic therapy*	*Diabetology*
Connected religions	Psychology in health	-	Theory of systems	Epidemiology
African religion	Psychology of intrapersonal comunication	-	*Theory of biochemical systems*	Legal medicine
Ancient Egyptian religion	Legal psychology	-	*Theory of ecologic systems*	Geriatry
Native American religion	Medical psychology	-	*Theory of development systems*	Ginecology
Movement of new religions	Neuropsychology	-	*General theory of systems*	Hematology
Summerian religion	Organizational psychology	-	*Theory of living systems*	Internal medicine

Zoroastrianism	Parapsychology	-	*Theory of LTI systems*	Nephrology
Atheism /Humanism	Psychology of personality	-	*Theory of sociotechnical systems*	Neurology
Compared religion	Positive psychology	-	*Theory of mathematic systems*	Pediatry
Mithology and folklore	Psychanalysis	-	*Theory of world systems*	Podiatry
Western esoterism	Psychometrics	-	-	First aid
7. VIZUAL ARTS	Psychophysics	-	-	*General practice*
History of art	Quantitative psychology	-	-	Public health
Caligraphy	Social psychology	-	-	Psychiatry
Creative art	Sports psychology	-	-	*Medicine od dependencies*
Drawing	“Media” psychology	-	-	Radiology
Beaux Arts	Psychology of deviant behavior	-	-	Therapy of relaxation
Painting	**10. SOCIOLOGY**	-	-	Medical reabilitation
Photography	Applied sociology	-	-	Respiratory medicine/ epidemiology
Studio (photographic) art	*Political sociology*	-	-	Dental surgery
Sculpture	*Public sociology*	-	-	Endodontics
Art preservation	*Social engineering*	-	-	Ortodontics
Drawing for stamps	*Study of free time*	-	-	Oral/maxillofacial surgery
-	Collective behavior	-	-	Periodontics
-	*Social movements*	-	-	Prostodontics
-	Community informatics	-	-	Implantology
-	*Analysis of social network*	-	-	Medical assistance
-	Comparative sociology	-	-	*Theory of medical assistence*
-	Theory of conflicts	-	-	*Birth assistance*
-	Cultural studies	-	-	Nutrition and diet
-	Criminology/criminal justitice	-	-	Optometry
-	Demography/populatio ns	-	-	Physiotherapy
-	Sociology of the environment	-	-	Labor medicine
-	Feminist sociology	-	-	Patholoy of speech and language
-	Study of futurology	-	-	Specializations in medicine
-	Human ecology	-	-	*Anestesiology*
-	Interactionism	-	-	*Local anestesiology*
-	*Fenomenology*	-	-	*Medicine of pain*
-	*Ethnometodology*	-	-	*Preventive medicine*
-	*Symbolic interaction*	-	-	*Cardiology*
-	*Social constructionism*	-	-	*Neurosurgery*
-	Medical sociology	-	-	*Obstretics*
-	Military sociology	-	-	*Oncology*
-	Organizational studies	-	-	*Oftalmology*
	Scientific studies/science/technics	-	-	*Orthopedic surgery*
-	Sexology	-	-	*Surgery of hand*
-	Social capital	-	-	*Surgery of foot/ankle*
-	Social control	-	-	*Sports medicine*
-	*Sociology*	-	-	*Replacing articulations*

-	Social economy	-	-	*Surgery of hip*
-	Social philosophy	-	-	*Otholaringology*
-	Social psychology	-	-	*Pathology*
-	Social politics	-	-	*Pulmonology*
-	Social research	-	-	*Medicine of sleep*
-	*Computational sociology*	-	-	*Rheumatology*
-	*Economic sociology*	-	-	*Medicine of sports*
-	*Economic development*	-	-	*Surgery*
-	*Social development*	-	-	*Bariatric surgery*
-	*Cultural development*	-	-	*Cardiothoracic surgery*
-	*Sociology of deviant behavior*	-	-	*Neuronal surgery*
-	*Sociology of education*	-	-	*Plastic surgery*
-	*Sociology of genders*	-	-	*Traumatology*
-	*Sociology of family*	-	-	*Urology*
-	*Sociology of knowledge*	-	-	*Andrology*
-	*Sociology of law*	-	-	Pharmaconomy
-	*Sociology of religion*	-	-	Pharmacy
-	*Sociology of sport*	-	-	Psychology
-	*Sociology of labor*	-	-	*Behavioral medicine*
-	Theory of society	-	-	*Clinic psychology*
-	Social stratification	-	-	*Psychology of health*
-	Sociologic theory	-	-	*Medical psychology*
-	Sociobiology	-	-	*Psychologic counseling*
-	Sociocybernetics	-	-	Veterinary medicine
-	Sociolinguistics	-	-	“Fitness”
-	Urban/rural sociology	-	-	*“Fitness”/aerobic group*
-	Visual sociology	-	-	*Personal exercise in “fitness”*
-	-	-	-	*Kinesiology/physical exercises/performance*
-	-	-	-	**10. PHYSICAL PERFORMANCES/RECREATION**
-	-	-	-	Biomechanics
-	-	-	-	Sportive exercises
-	-	-	-	Dancing
-	-	-	-	Ergonomy
-	-	-	-	“Fitness”
-	-	-	-	*“Fitness”/aerobic group*
-	-	-	-	*Personal exercise in “fitness”*
-	-	-	-	Games
-	-	-	-	Physiologic exercises
-	-	-	-	Kinesiology/physical exercises/performance
-	-	-	-	Studies of free time
-	-	-	-	Physical education/pedagogy
-	-	-	-	Sociology of sport
-	-	-	-	Sexology
-	-	-	-	Sport journalism
-	-	-	-	“Management” in sport

-	-	-	-	*"Management" in athtletism*
-	-	-	-	Sportive psychology
-	-	-	-	Sportive medicine
-	-	-	-	*Athletic exercises*
-	-	-	-	Game and entertainment
-	-	-	-	**11.JOURNALISM,MEDIA,COMMUNICATION**
-	-	-	-	Journalism
-	-	-	-	*Spreading of sport*
-	-	-	-	*Literary journalism*
-	-	-	-	*"New media" journalism*
-	-	-	-	*Edited journalism*
-	-	-	-	*Sport journalism*
-	-	-	-	"Mass media" studies
-	-	-	-	*Journalism*
-	-	-	-	*Magazines*
-	-	-	-	*Radio*
-	-	-	-	*Television*
-	-	-	-	*Television studies*
-	-	-	-	Internet
-	-	-	-	Communication
-	-	-	-	*Animal communication*
-	-	-	-	*Theory of information*
-	-	-	-	*Intercultural communication*
-	-	-	-	*Publicitary communication*
-	-	-	-	*"Design" in communication*
-	-	-	-	*"Marketing"*
-	-	-	-	*Mass communication*
-	-	-	-	*Translations*
-	-	-	-	*Propaganda*
-	-	-	-	*Public relations*
-	-	-	-	*Technical writing*
-	-	-	-	*Non-verbal communication*
-	-	-	-	*Verbal communication*
-	-	-	-	**12. LAW**
-	-	-	-	Canonic law
-	-	-	-	Compared law
-	-	-	-	Constitutional law
-	-	-	-	Civil law
-	-	-	-	*Maritime law*
-	-	-	-	*Animal rights*
-	-	-	-	*Corporations*
-	-	-	-	*Civil procedure*
-	-	-	-	*Law in contracts*
-	-	-	-	*Law of the environment*
-	-	-	-	*International law*
-	-	-	-	*Labor law*
-	-	-	-	*"Paralegal" studies*
-	-	-	-	*Property law*
-	-	-	-	*Law in fees/taxes*
-	-	-	-	*Delicts*

-	-	-	-	Law in criminalistics
-	-	-	-	*Procedures in criminalistics*
-	-	-	-	*Criminalistic law*
-	-	-	-	*Political science*
-	-	-	-	*Law science*
-	-	-	-	Islamic law
-	-	-	-	Jewish law
-	-	-	-	Philosophy in law
-	-	-	-	"Manx" philosophy
-	-	-	-	**13. LIBRARIES/MUSEUMS**
-	-	-	-	Science in archival activity
-	-	-	-	Bibliometry
-	-	-	-	*Analysis of quotes*
-	-	-	-	Informatics
-	-	-	-	Architecture of information
-	-	-	-	Museology
-	-	-	-	*Administration of museums*
-	-	-	-	**14. MILITARY SCIENCES**
-	-	-	-	Amphibious fighting vehicles
-	-	-	-	Artilery
-	-	-	-	Military campains
-	-	-	-	Combat engineering combatanta
-	-	-	-	Doctrines
-	-	-	-	Military theory of games
-	-	-	-	Science of administration
-	-	-	-	Logistics
-	-	-	-	Military history
-	-	-	-	Military intelligence
-	-	-	-	Military legislation
-	-	-	-	Military medicine
-	-	-	-	Naval sciences
-	-	-	-	*Military navy engineering*
-	-	-	-	*Navy tactics*
-	-	-	-	*Naval architecture*
-	-	-	-	*Military systems*
-	-	-	-	Strategy
-	-	-	-	Tactics
-	-	-	-	Navy t*actics*
-	-	-	-	**15. PUBLIC ISSUES**
-	-	-	-	Corrections
-	-	-	-	Biological preservation
-	-	-	-	Justice in criminalistics
-	-	-	-	Emergency "management"
-	-	-	-	Security against fire
-	-	-	-	Study of peace/conflict
-	-	-	-	Political science
-	-	-	-	Scietce of public administration
-	-	-	-	*Non-profit administration*
-	-	-	-	*Non-governmental*

				administration
-	-	-	-	Public politics
-	-	-	-	*Politics of education*
-	-	-	-	*Politics of the environment*
-	-	-	-	*Fiscal politics*
-	-	-	-	*Politics in health*
-	-	-	-	*Politics in commerce*
-	-	-		Ecology of fire
-	-	-	-	Governmental transactions
-	-	-	-	International transactions
-	-	-	-	Administration of organizations
-	-	-	-	**16. SOCIAL ACTIVITIES**
-	-	-	-	Baby care
-	-	-	-	Communitary practices
-	-	-	-	*Communitary organizations*
-	-	-	-	*Social politics*
-	-	-	-	*Corrections*
-	-	-	-	Gerontology
-	-	-	-	Social medicine
-	-	-	-	Mental health
-	-	-	-	School medicine
-	-	-	-	**17. TRANSPORTATION**
-	-	-	-	Road security
-	-	-	-	Infografics
-	-	-	-	Studies of intermediary transportation
-	-	-	-	Maritime transportation
-	-	-	-	*Port "management"*
-	-	-	-	Operational research in transportation
-	-	-	-	Transit operations
-	-	-	-	Transportation engineering
-	-	-	-	*Aerospatial transportation*
-	-	-	-	*Naval transportation*
-	-	-	-	*Railway transportation*
-	-	-	-	*Road transportation*

- after UNESCO classification -
