Complete hierarchy of universal life patterns

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Life is extraordinarily complex. Multilevelness is the key characteristic of its complexity: living world is actually a hierarchically organized system of systems. An important attribute of the hierarchy is the gradual integration of systems from the bottom level to the apex. To determine particular level in biological hierarchy, it is necessary to know a corresponding universal life pattern which variability underlies the diversity of systems at this level. However, just in this respect, our knowledge is woefully incomplete. Here, I show that the investigation of living world from the information processing perspective allows recognizing the complete hierarchy of universal life patterns.

Complexity of the living world continues to be in focus of debates (Cohen IR and Harel D 2007, Coveney PV and Fowler PW 2005, Csete ME and Doyle JC 2002, Emmeche C 1997, Gilbert SF and Sarkar S 2000, Grizzi F and Chiriva-Internati M 2005, Mikulecky DC 1996, Van de Vijver G *et al* 2003, Weiss JN *et al* 2003) substantiating the need for the systems approach that would combine analysis with synthesis in scientific research. In current biology, the methodology of empirical and theoretical investigation is experiencing the Renaissance of the systems approach due to the recent progress in data processing (Andrianantoandro E *et al* 2006, Barrett CL *et al* 2006, Drubin DA *et al* 2007, Heinemann M and Panke S 2006, Ideker T *et al* 2001, Kitano H 2002, Mesarovic MD *et al* 2004, Westerhoff HV and Palsson BO 2004, Wolkenhauer O 2001).

Multilevelness is the key characteristic of life complexity: living world is actually a hierarchically organized system of systems (Andrianantoandro E *et al* 2006, Emmeche C 1997, Grizzi F and Chiriva-Internati M 2005, Mesarovic MD *et al* 2004, Valentine JW 2003, Van de Vijver G *et al* 2003, Zylstra U 1992). An important attribute of the hierarchy is the gradual integration of systems from the bottom level to the apex so that upper levels are said to emerge out of the lower levels. To determine particular level in biological hierarchy, it is necessary to know a corresponding universal life pattern which variability would underlie the diversity of systems at this level. However, just in this respect, our knowledge is woefully incomplete. The only universal life pattern recognized is the cell (Mazzarello P 1999). All other known life patterns are doubtlessly specific. Recently, the list of familiar subcellular and supercellular (supracellular) life patterns such as organelle, tissue, organ, organism, etc. has been significantly extended through various structural and functional units referred to as modules, motifs, etc. (Alm E and Arkin AP 2003, Alon U 2003, Csete ME and Doyle JC 2002, De Silva E and Stumpf MPH 2005, Huang S 2004, Oltvai ZN and Barabási AL 2002). However, no one of them can be accepted as universal life pattern. Therefore, the presentation of their hierarchy as “life’s complexity pyramid” (Oltvai ZN and Barabási AL 2002) is an overestimation of their significance.

Thus, the biological hierarchy composed completely of universal life patterns lacks. This big gap in biology foundation hampers progress within the “era of biology” significantly.

Meanwhile, the investigation of life from information processing perspective allows recognition in living world of many new life patterns (Tirjatkin N 2005a, 2005b, 2005c, 2007). Some of them seem to be universal. Here, I show their significance discussing some particular and general aspects of life complexity and life diversity. Aspects which are internal to biology are discussed first. Then, the discussion is extended to aspects which intrinsically connect biology with closely-related disciplines. Finally, concluding discussion closes the theme.

Intradisciplinary aspects of life complexity and life diversity

Subcellularly, the information processing involves two tightly coupled reactions: genome expression and genome replication. During genome expression, information is converted first from DNA into RNA (transcriptome) form by DNA transcription, then from RNA into polypeptide (proteome) form by RNA translation, and finally from polypeptide into metabolite (metabolome) form by catalysis. It is important to note that the genome is a limited set of genes and each gene is usually expressed separately to be fully converted into the corresponding element of the cell structure or function. For each gene, its own sequence of DNA transcription, RNA translation, and catalysis can be determined. This directed sequence of chemical reactions is the most basic universal life pattern which can be called a gene expression network, abbreviated GEN. Its variability is virtually unlimited. Additionally, in some GENs, the obligatory sequence of chemical reactions can be restricted or extended. So, in many GENs, end products are polypeptides functioning always as substrate molecules and never as catalysts. In many other GENs, end products are RNAs that never become translated into polypeptides, but function always at the level of RNA as substrate molecules. On the other hand, in many GENs, products of DNA transcription or RNA translation undergo post-transcriptional or post-translational processing respectively. The cell itself can be considered as a highly regular composition of interacting GENs which can be called GENome. Whereas gene and genome are notions that refer to how information is stored in the cell, GEN and GENome refer to how the gene and genome work. During information processing in particular GEN, it is just the job of other GENs to provide necessary elements for gene expression machinery. Collectively, GENs in GENome work to replicate the complete genome so that the life history of the single cell begins with one cell but ends with two. In particular cell, the GENome is suited to specific subset of sources of mass, impulse (momentum), and energy to produce their usable forms essential for the cell life. Thus, subcellularly, all chemical reactions are organized highly regular: first into GENs and then into GENome.

Supercellularly, the information processing involves other two important reactions: genome multiplication and genome diversification. Mechanism of genome multiplication is always the same: the genome replication by genome expression. On the contrary, mechanisms of genome diversification differ greatly ranging from the spontaneous sequence mutation to the highly regulated sequence transfer. Progressive genome replication is usually associated with progressive cell propagation producing a sequence: one cell, two cells, four cells, eight cells, and so on. This sequence can be called cell (GENome) progression. The whole cellular world is only one cell progression which arose from one single primordial cell and has 3 or 4 billions years of uninterrupted history. It can be called general cell progression. The present-day biosphere is merely a tiny slice from it, a visible top of iceberg in ocean of time. The ancient part of this gigantic life pattern leaves very scarce traces. Although all cells of the general cell progression should be theoretically identical to each other genetically, this is not the case in the nature: genome diversification produces cell progressions each of which is specified by a particular individual genome and can be called individual cell progression. Respectively, the general cell progression can be considered as a growing composition of an increasing number of individual cell progressions. Individual cell progression is universal life pattern with virtually unlimited variability. Spatiotemporal organization of a particular individual cell progression mostly depends upon whether the cells divide symmetrically or asymmetrically, whether the asymmetric cell divisions occur occasionally or regularly, whether the asymmetric cell division is associated with symmetric or asymmetric kinetics of the cell propagation, whether the cells will be rather randomly dispersed in space to become autonomous in behaviour or remain in an association to form cell colony (primary, secondary, etc.), whether the cell association grows continuously or is a steady state system, and so on. Thus, supercellularly, chemical reactions are organized highly regular too: first into individual cell progressions and then into the general cell progression.

So, from information processing perspective, all chemical reactions in living world fall into three categories: DNA transcription, RNA translation, and catalysis. They are organized in strong hierarchy of life patterns: GENs, cells (GENomes), individual cell progressions, and the general cell progression (Table 1).

Table 1. Complete hierarchy of universal life patterns

Level	Spatiotemporal pattern
4	general cell progression
3	individual cell progression
2	GENome
1	GEN

The general cell progression occupies the apex of the hierarchy. Most likely, it is unique and merits its own name (for example, Zoe). Other three life patterns in this hierarchy are doubtlessly universal. Their innumerable variations underlie the life diversity.

Management of life diversity is of crucial importance for many purposes in biology and beyond (Mayr E and Bock WJ 2002). On the one hand, individual living things are to be differentiated from each other: they must be specified and compared. As a result, types, sorts, kinds, etc. of individual living things can be recognized. On the other hand, individual living things are to be integrated with each other: they must be classified and systematized. As a result, abstract groups, sets, collections, etc. of individual living things can be recognized. Processes of specification, comparison, classification, and systematisation are so intimately interwoven that they are hard to discern clearly.

To manage life diversity, Carl Linnaeus arranged abstract groups of individual living things (taxa) within taxonomic hierarchy where each level is indicated by taxonomic category (rank). It is important to note that the Linnaean taxonomic hierarchy is not only an abstract system of systems but also formal system of systems. It is abstract since taxa are abstract groups by definition whereas taxonomic categories are not concrete patterns but mere abstract indicators of levels. It is formal since formal rules prescribe even how names of taxa have to be formed while the number of levels in hierarchy is arbitrary. There is great deal of convenience by arrangement of taxa within the Linnaean taxonomic hierarchy. In the past 250 years since publishing of the tenth editions of *Systema Naturae* by Linnaeus, his taxonomic hierarchy has been considerably elaborated and some new categories and an extensive variety of supercategories, subcategories, infracategories, etc. have been proposed. Table 2 shows most familiar categories prevailing in modern interpretations of the Linnaean taxonomic hierarchy.

Table 2. Linnaean taxonomic hierarchy

Level	Category
7	kingdom
6	phylum
5	class
4	order
3	family
2	genus
1	species

In his theory of descent with modification, Charles Darwin provided an explanation of the origin of species. Suggesting their common descent, this theory substantiates the possibility and necessity for conversion of the Linnaean taxonomic hierarchy into genealogy. The term "phylogeny" coined by Ernst Haeckel corresponds quite strictly to the theory of common descent: phylogeny is equivalent to the taxonomic genealogy. Phylogeny may be presented in form of a tree-like drawing (dendrogram) usually referred to as the Tree of Life. The Tree of Life is often assumed to be better suited to manage life diversity than the Linnaean taxonomic hierarchy. Therefore, there are tremendous attempts to reconstruct phylogeny as precisely as possible. Recent progress in data processing contributes significantly to this endeavour. Diverse schools compete in this field of research delivering stuff for hot debates at all epistemological levels (Hull DL 2001a, Mayr E and Bock WJ 2002). Unfortunately, results obtained are rather contradictory than compatible and the success is not yet in sight (Brummitt RK 2002, Doolittle WF and Bapteste E 2007, Simonson AB *et al* 2005). Ironically, the Linnaean taxonomic hierarchy becomes rather supplemented than replaced and continues to be in use (Brummitt RK 2002, Dayrat B 2005, Schuh RT 2003). How ever that may be, it must be noted that even if the conversion of the Linnaean taxonomic hierarchy into genealogy would succeed successfully, resulting taxonomic genealogy would remain formal abstract system of systems.

It is true that taxonomic genealogy reflects real process of common descent. But, this in no way justifies treating taxa of taxonomic genealogy as concrete groups of individual living things. Taxa are actually formal abstract groups and must be treated as such in both the taxonomic hierarchy and taxonomic genealogy. It is also true that individual living things may integrate into concrete groups, sets, collections, etc. such as population, community, society, etc., but taxa do not belong to them. Unfortunately, abstract and concrete groups of individual living things are often mixed producing rather distorting picture of the living world.

Originally, the principal objects of research in biology were individual living things for which the concept of an organism has been introduced. When the multicellular nature of known organisms has been revealed by a microscope and numerous unicellular organisms have been discovered (Mazzarello P 1999), the organism concept became very heterogeneous while ranging from the single cell to multicellular composition. Multicellular organism in turn is very heterogeneous concept while ranging from loose cell associations to tight cell associations which differ vastly in form and display great variability in degree of organization (Tirjatkin N 2005c). As a result, an organism is treated very differently in distinct biological disciplines. For example, in developmental biology, morphology, and physiology, an organism is a multicellular composition which is viewed as a system while cells are viewed as subsystems. In microbiology, on the contrary, an organism is a cell which is viewed as a system while the multicellular composition is viewed as supersystem. In general biology, evolutionary biology, and ecology, an organism is both the cell and multicellular composition. Dealing with life complexity, systemics tends to discern the cell and organism concepts restricting the later to the multicellular composition. Dealing with life diversity, systematics adopts heterogeneous concept of organism. The role of the organism concept in the conceptual and theoretical framework of biology continues to be in focus of debates (El-Hani CN and Emmeche C 2000, Greene HW 2005, Gutmann M and Neumann-Held E 2000, Perlman RL 2000, Ruiz-Mirazo K *et al* 2000, Van Speybroeck L 2000, Wagner GP and Laubichler MD 2000).

On the one side, there is an intuition of organism as an individual in the living world. However, individuality in the living world is always relative changing from level to level in the hierarchy of life patterns. On the other side, there is an intuition of individual in the living world as an organised entity. However, degree of organization in the living world is always relative changing not only from level to level in the hierarchy of life patterns but also at each level from poorly organized to highly organized entities. There is no clear criterion to decide to what level in the hierarchy of life patterns or to what degree of organization the concept of organism can be applied. Criteria such as self-organization, self-maintenance, self-regulation, etc. belong to the most unclear ones.

Under these considerations, in systemics, an organism can not be saved not only as universal life pattern but even as specific life pattern. Subsequently, in systematics, it can not be saved as an individual living thing. According to complete hierarchy of universal life patterns (Table 1), individual living things are GENs, cells (GENomes), individual cell progressions, and the general cell progression. While the general cell progression is most likely unique, three other types of individual living things are enormously variable. Therefore, it is reasonable to have at least three taxonomic hierarchies (or genealogies): first for GENs, second for cells (GENomes), and third for individual cell progressions. It is important to note that, in addition to abstract taxonomic genealogies, such individual living things as GENs, cells (GENomes), and individual cell progressions also arrange in concrete genealogy and that this concrete genealogy is just the general cell progression. According to the nature of universal life patterns in hierarchy (Table 1), this concrete genealogy is one single genealogy of individual cell progressions at lower resolution, one single genealogy of cells (GENomes) at middle resolution, but a multiple N_1-fold genealogy of GENs at higher resolution where N_1 is a number of genes in genome (or GENs in GENome) of the primordial cell from which the general cell progression arose. Both abstract and concrete genealogies may be presented in form of a tree-like drawing (dendrogram). Some individual cell progressions may produce cell associations in form of true trees.

Particular and general aspects of life complexity and life diversity discussed above are internal to biology. However, the living world is a part of the whole world and in turn itself involves human world as a part. Therefore it is reasonable to examine here some interdisciplinary aspects of life complexity and life diversity.

Interdisciplinary aspects of life complexity and life diversity

The living world is mere a tiny part of the entire world. An explicit knowledge of how does hierarchical organization of the living world correspond to the hierarchical organization of the entire world would be advantageous.

The entire world (Universe) is considered to be material in the sense that it comprises only one single thing: a matter. The matter is simply defined as that which exists. To exist is the general feature of the matter. The entire world is also considered to be complex in the sense that it comprises a multitude of different material objects being in specific relations to each other. To be material is a feature which makes all the material objects similar and therefore undistinguishable. On the contrary, specific relations of material objects to each other can be used to recognize differences between them. Relations are however of various degree of specificity. Some of them are of principal significance and must be shortly introduced here.

There is a specific relation between two material objects which is called a distance. If defined to each other by distances only, material objects constitute that which is referred to as a space. If any distance is chosen to be a standard quantity of space, other distances can be measured by it provided any appropriate instrument can be constructed for this task. The space is of course abstraction while ignoring all the relations of material objects to each other except distances. Nevertheless, it remains material while referring to at least one type of relations of material objects to each other. In addition to distance with its length, the space concept contains a large number of notions derived from distance notion. Whereas some of them such as a field with its area or a room with its volume remain material, others such as point, line, or surface do not. While natural space is too cumbersome to establish a spatial reference frame for scientific purposes, various artificial spaces are invented. Most familiar is the so called Euclidean space which is imagined as a homogenous and isotropic continuum of points. The homogeneity means the equivalence between all the points in space or invariability in spatial translocation. The isotropy means the equivalence between all the directions in space or invariability in spatial rotation. Thus, the Euclidean space is multidimensional and multidirectional. In Euclidean space, various spatial reference frames can be established. Most popular is the so called Cartesian reference frame consisting of three plane surfaces perpendicular to each other. In Cartesian reference frame, the specification of the position of a particular point is reduced to the measure of the lengths of the three perpendiculars dropped from this point to those surfaces. A particular material object can be thus defined by position of all the points involved in the space amount which is occupied by this object. These points can be used to determine all the spatial characteristics such as size, shape, volume etc. One specific point can be chosen to represent position of the object in the space. In chosen spatial reference frame, each given material object can be described by unique set of spatial characteristics.

There is also another specific relation between two material objects which is called an event. In contrast to distance, event is a complex relation. However, events are recognized to build sequences of events and all sequences are recognized to build a bundle of sequences which are all oriented in the same direction. Some sequences of events can be used as the so called temporal reference frames. In this respect, most useful are sequences of cyclic events in which moments correspond to periods with their duration just in similar way as points correspond to distances with their length in spatial reference frame. Therefore, the period is usually considered as amount of what is called a time. If any period is chosen to be a standard quantity of time, other periods can be measured by it provided any appropriate instrument can be constructed for this purpose. A particular material object can be thus defined by "position" of all the moments involved in time amount which is "occupied" by this object. These moments can be then used to determine all the temporal characteristics. In temporal reference frame, each given material object can be described by unique set of temporal characteristics.

Further, events are recognized to hide a subordinate relation between two material objects which is called an interaction. In turn, interaction is also a complex relation which hides a sophisticated hierarchy of successive subordinate relations. Each of these relations becomes more and more specific and can be responsible only for limited number of events in the entire world. Consequently, a bewildering hierarchy of notions is developed to describe interactions between material objects. This hierarchy is yet not completely understood. Some notions are well defined, other on the contrary are not. Moreover, some well defined notions are often used very inaccurately. Therefore, misleading sentences are very abundant in the scientific literature. For example, while the well defined notion of energy is used sometimes too freely, such senseless statements as "The Universe is composed of two things: matter and energy" can be found even in textbooks. This statement ignores that energy is merely one of the all specific notions characterizing matter and is invented solely to describe some particular aspects of interaction between material objects. In addition to spatial and temporal reference frames, other reference frames can be established to take into consideration particular aspects of interaction between material objects. Different reference frames are often unified into single one for scientific purposes. Unification is usually based on invention of space-like abstractions. For example, Euclidean space and time are often unified into the so called Minkowski space. One of the more general types of space-like abstractions is the Hilbert space in which more general reference frames can be established. Although all these space-like abstractions are hard to imagine, they are very useful scientific tools.

Generally, material objects are said to exist and interact in space and in time. Both space and time seem to be infinite, but distances and periods accessible for scientific investigation by modern instruments are limited. Using scientific methods, researchers try to recognize spatiotemporal patterns of interactions between material objects in accessible distances and periods. But, there is a great deal of convenience by introduction of spatial and temporal reference frames, by definition of boundaries of a given material object in space and in time, and so on. How material objects are distributed in space: discretely or continuously? How does the distribution of material objects in space change with time: discretely or continuously? These and many other questions remain a matter of hot debates. Respectively, numerous assumptions underlie the scientific investigation of the entire world and a large numbers of models are developed to describe it.

Table 3 summarizes current knowledge on hierarchical organization of the entire world (Ellis GFR 2002, Haubold H and Mathai AM 1998). This knowledge is rather implicit. The hierarchy is incomplete. There is no one spatiotemporal pattern which universality would be unquestionable. Therefore, the determination of levels of the hierarchy is restricted to labelling by numbers whereas labelling with plus or minus reflects common schema of investigating the entire world from the focal level (designated here as level 0) in two directions: up to the largest scale (numbers with plus) and down to the smallest scale (numbers with minus). The largest scale corresponds with the entire world. But, how large is this scale is not clear. It is also unclear how many levels must be there in hierarchy.

Table 3. Hierarchical organization of the entire world

Level	Spatiotemporal patterns
…	entire world
…	…
…	…
+2	group of galaxies, cluster of galaxies, supercluster of galaxies, …
+1	cluster of stars, galaxy
0	body (asteroid, comet, moon, planet, star), star system
-1	compound subatomic particle, atom, molecule
-2	…, “fundamental” particle
…	…

Actually, it is assumed that the entire world is an extremely complex network composed of huge numbers of “fundamental” interactions continuously creating an enormously complex matrix composed of bewildering numbers of different “fundamental” particles involved in these interactions. It is also assumed that “fundamental” particles fall into two categories: ordinary particles and virtual particles. Ordinary particles do not directly interact with each other but rather exchange virtual particles which are thus the mediators of “fundamental” interactions. Four types of “fundamental” interactions – gravitation, electromagnetism, weak interaction, and strong interaction – recognized at present are believed to be different aspects of a single “fundamental” interaction. There are numerous theories about this believe but no one with decisive confirmation. Further investigations can dramatically change our knowledge on “fundamental” interactions and corresponding “fundamental” particles.

Here is no place to discuss how “fundamental” particles integrate to form all the spatiotemporal patterns at higher levels of the hierarchy. For purposes of this article, it is enough to focus attention just to the focal level and examine the diversity of corresponding spatiotemporal patterns to find such tiny celestial body as the planet named Earth. Planets are abundant but not ubiquitous. Not all star systems bear planets. The Solar System only by chance involves some of them inclusive Earth which seems to be unique in owing tiny space where its lithosphere, hydrosphere, and atmosphere come together. This space referred to as ecosphere consists of non-living (abiotic) and living (biotic) components being in tight interconnections. Living component usually referred to as biosphere represents the known living world. Whether there are other planets or other celestial bodies bearing their own living worlds is unknown. It is important to note that the non-living and living components are undistinguishable from the perspective of mass, impulse, and energy processing. The difference becomes apparent only from the perspective of information processing: life originates by coupling of genome replication to genome expression and develops by continuous genome multiplication and genome diversification.

Thus, the known living world is not more than the Earth-specific spatiotemporal pattern restricted to the biosphere. Therefore, the universality of recognized life patterns (Table 1) is relative.

Unfortunately, the terms “ecosphere” and “biosphere” have had somewhat competing histories (Huggett RJ 1999) so that they continue to be used interchangeably. It would be advantageous to cease this practice to avoid confusions. Respectively, ecological hierarchies describing complexity of the ecosphere have to be clearly separated from biological hierarchies describing complexity of the biosphere.

Strongly speaking, there are two types of ecological systems. If attention is attracted to the abiotic component, the ecosystem is treated as a geosystem-like system (geoecosystem) and the biotic component is viewed as contributing to the mass, impulse, and energy processing within the lithosphere, hydrosphere, and atmosphere. On the contrary, if attention is attracted to the biotic component, the ecosystem is treated as a biosystem-like system (bioecosystem) and the abiotic component is viewed as an environment for biotic component. Respectively, it is reasonable to distinguish between two types of ecological hierarchies: geoecological hierarchy and bioecological hierarchy. Describing hierarchical relations between geoecosystems, geoecological hierarchy is a further quantification of the ecosphere into a series of Earth-specific spatiotemporal patterns involving corresponding fragments of the biosphere. On the contrary, describing hierarchical relations between bioecosystems, bioecological hierarchy involves life patterns extended through corresponding fragments of the ecosphere. Unfortunately, just mixed ecological hierarchies are currently in use. They rather hinder than help to understand complexity of the ecosphere.

Quantification of the ecosphere into a series of Earth-specific spatiotemporal patterns is not easy. The ecosphere seems to bear an extremely heterogeneous collection of patterns with an enormous variety of interconnections. Really good idea on how to fit all these patterns into one single geoecological hierarchy lacks. Actually, spatial thinking prevails (Gustafson EJ 1998, Olson DM *et al* 2001, Platt T and Sathyendranath S 1999, Urban DL *et al* 1987, Wu J and David JL 2002) and the ecosphere is simply quantified by gradual fragmentation of its area from global to local (Table 4). However, even such oversimplified version of the geoecological hierarchy is far from to be elaborated completely: there is even no agreement on how to name spatial categories determining its levels.

Table 4. Geoecological hierarchy

Level	Area (km^2)	Spatial category
8		ecosphere
7	$>10^5$	ecozone
6	10^4-10^5	ecoprovince
5	10^3-10^4	ecosection
4	10^2-10^3	ecodistrict
3	10^1-10^2	-
2	10^0-10^1	-
1	$<10^0$	ecosite

Extension of life patterns through corresponding fragments of the ecosphere is not easy too. The ecosphere seems to bear an extremely heterogeneous collection of interactions between individual living things and their environments. Furthermore, environment of an individual living thing may contain not only abiotic but also biotic components. Therefore, bioecological hierarchy always contains somewhat ambiguous patterns. Under such circumstances, dealing for the most part with specific life patterns does not contribute to clarity. On the contrary, an explicit recognition of the complete hierarchy of universal life patterns (Table 1) may eliminate some ambiguities from bioecological hierarchy (Table 5).

Table 5. Bioecological hierarchy

Level	Spatiotemporal pattern
4	general cell progression + its environment = ecosphere
3	individual cell progression + its environment
2	GENome + its environment
1	GEN + its environment

Thus, there is a great deal of convenience both by the quantification of the ecosphere into a series of Earth-specific spatiotemporal patterns and by the extending of life patterns through corresponding fragments of the ecosphere.

After origin of the Life on the Earth, history of the Earth is inseparable from the history of the living world: it is obvious that the geosystems and biosystems coevolve and the geoecosystems and bioecosystems emerge at the interface of this coevolution. To explain origin of species, Charles Darwin proposed an elaborated theory which he interchangeably called either the theory of descent with modification or the theory of Natural Selection. Whereas the first name referred to the correct explanandum, the second name referred to the correct explanans. Thus, from the beginning, this theory was more than a theory of evolution of living things. Indeed, in the past 150 years since publishing of the first editions of *On the 0rigin of Species* by Darwin, his theory has been considerably extended and tends to become a theory of coevolution of geosystems and biosystems and of emergence of geoecosystems and bioecosystems at the interface of this coevolution. Respectively, the most important aspect of ecological hierarchies is that, if combined with taxonomic hierarchies embracing diversity of corresponding spatiotemporal patterns, they would reflect evolutionary relations between history of the Earth and history of the living world.

On the one side, the origin of the Life on the Earth so fundamentally altered the mass, impulse, and energy processing within the lithosphere, hydrosphere, and atmosphere that corresponding geosystems acquired a variety of additional structural and functional features that could only exist due to biotic influences (Dietrich LEP *et al* 2006, Dietrich W and Perron JT 2006, Kasting JF and Siefert JL 2002). For example, the presence of life converts some rock-forming processes into soil-forming processes so that the term "pedosphere" is usually applied to affected part of the lithosphere. Large biogenic fluxes of gases maintain atmosphere of the Erath in an extreme state of disequilibrium in which highly reactive gases such as methane and oxygen coexist many order of magnitude from photochemical steady state. Respectively, whilst geosystems and biosystems coevolved, geoecosystems emerged at the interface of this coevolution as the result of processes caused by biosystems. Taking into account profound contribution of geoecosystems to the evolution of geosystems (Lieberman BS 2005, Naylor LA 2005), it would be advantageous to restore four-dimensionality of Earth-specific patterns in geoecological hierarchy (Table 4).

On the other side, limited sources of mass, impulse, and energy within the lithosphere, hydrosphere, and atmosphere of the Earth make the living world so sensitive to changes in environment that the information processing in corresponding biosystems acquired a variety of additional structural and functional features that only exist owing to environmental influences (Kampfner RR 1998, Marijuán PC 2002). These range from simple signalling pathways to complex communication networks and from primitive responses to sophisticated conscious behaviours. Respectively, whilst biosystems and geosystems coevolve, bioecosystems emerge at the interface of this coevolution as the result of processes caused by geosystems. Taking into account profound contribution of bioecosystems to the evolution of biosystems (Bock WJ 2003, Johnson MTJ and Stinchcombe JR 2007, Ricklefs RE 2007), it would be advantageous to preserve four-dimensionality of universal life patterns by converting biological hierarchy (Table 1) into bioecological hierarchy (Table 5).

Similar to the living world (biosphere), the ecosphere is not more than Earth-specific spatiotemporal pattern. Therefore, neither the levels of biological hierarchy nor the levels of ecological hierarchies could be used to multiply the number of levels above and below of focal level in Table 3. Unfortunately, such misuse comes about very often producing rather distorted picture of the entire world.

The human world is mere a tiny part of the living world. Strongly speaking, it is specific life pattern with the highest degree of organization. However, there is strong intuition of the human world as being more than the specific life pattern.

Actually, it is assumed that the human world is an extremely complex network composed of huge numbers of “fundamental” interactions continuously creating an enormously complex matrix composed of large numbers of different individuals involved in these interactions. However, there is no agreement on what “fundamental” interactions would underlie hierarchical organization of the human world. There is also no agreement on how the hierarchical organization of the human world would look. Instead, there are large numbers of hierarchies describing different specific fragments of the human world. The most famous is the control hierarchy from which the notion of the hierarchy originates.

Maybe, investigation of the living world neither from mass, impulse, and energy processing perspective nor from information processing perspective is enough for understanding of its complexity. There is however no idea from what perspective this can be done.

Human world is the most prominent part of the biosphere usually designated as anthroposphere. In human world, communication networks are the most complex and conscious behaviours are the most sophisticated. As human activities become more evolved, corresponding part of the ecosphere (sometimes referred to as technosphere) becomes more prominent too. The technosphere is that part of the ecosphere which is not only used but also modified or even made by humans. An intangible but the most influential part of the technosphere is the noosphere – the sphere of collective human thought increasingly dominated by science.

All scientific activities fall into two categories: research and development. Research activities aim to obtain that knowledge on all the material objects in the entire world which makes able to discern between the useless objects and useful ones and between the harmful objects and harmless ones. Development activities aim to obtain that knowledge on all the material objects in the entire world which makes able to convert the useless objects into useful ones and the harmful objects into harmless ones. On the one side, science evolves by continuous exchange of facts and ideas between research and development. On the other side, it also evolves by interaction with other parts of the noosphere and technosphere. This evolution is accompanied by simultaneous differentiation of science in growing number of disciplines and their integration.

Dealing with the most general scientific inquiries, philosophy aims to clear relations between the subjective and objective, between the potential and actual, and between the phenomenal and essential. It also aims to clear how the essential and phenomenal relate to the actual and potential and how the actual and potential relate to the objective and subjective. However, philosophers seem to be doomed to provide only subjective criteria in order to determine the “correct” epistemology and the “correct” ontology. Therefore, philosophical discussions easily become vicious circles affecting the practice of philosophy in particular and of science in general. Indeed, although dealing with more specific scientific inquiries, other scientific disciplines are far from to be in better position than philosophy. They too are doomed to provide only subjective knowledge even if they often claim to answer “objectively” on many questions. The rightness of that “objective” answers may be every time questioned. At all, how can science be ever right when philosophy is always wrong? Philosophers are aware on the failure of philosophy in the past (Searle JR 1999) but take it of course philosophically to look optimistically on the future of philosophy in particular and of science in general. Ironically, recent developments in the technosphere and ecosphere suggest rather pessimistic scenarios for the future of the anthroposphere in particular and of biosphere in general. It is not unlikely that neither science nor noosphere have time to become competent enough to be able to preserve the Life on the Earth from destruction by human activities.

To finish discussion on interdisciplinary aspects of life complexity and life diversity, it is reasonable to clearly discern two types of relation between the entire world, living world, and human world.

It is obvious that the human world is involved in the living world which in turn is involved in the entire world. This extensional relation (Table 6) is hierarchical.

Table 6. Extensional relation between the entire world, living world, and human world

entire world			
non-living world		living world	
non-artificial world	artificial world	non-human world	human world

It is also obvious that the human world evolved from the living world which in turn evolved from the entire world. This intensional relation recognized by the number of authors (Table 7) is evolutionary (developmental, progressive) but not hierarchical. Unfortunately, since the term “level” is used to describe this relation too, it is usually interpreted as hierarchy with the human world at the apex. Such erroneous interpretation not only produces an extremely distorting picture of the entire world but also makes the term “hierarchy” controversial. Because this controversy is too often ignored or overlooked in discussions about complexity-related issues (supervenience, emergence, causation, etc.), their results unavoidably become misleading.

Table 7. Intensional relation between the entire world, living world, and human world

World	Author			
	H. Spencer	C. L. Morgan	E. Husserl	N. Hartmann
human world	superorganic	mind	society consciousness	spiritual mental
living world	organic	life	nature	organic
entire world	inorganic	matter		physical

Concluding discussion

Hierarchical view has always been fundamental to understanding complexity and diversity in biology and ecology. However, although most researchers agree that the biosphere and ecosphere are hierarchically organized systems of systems, there are disagreements in how their hierarchical organization might look.

On the one side, discussions on how to apply the hierarchy concept in biology and ecology revealed some general types of hierarchies. Marjorie Grene attracted attention to differences between control hierarchies and taxonomic hierarchies (Grene M 1969, 1987). Ernst Mayr distinguished between constitutive hierarchies and aggregative hierarchies but also between inclusive hierarchies and exclusive hierarchies (Mayr E 1982). James Valentine pointed out the difference between simple and cumulative hierarchies (Valentine JW 2003, Valentine JW and May CL 1996). Stanley Salthe proposed to distinguish between specification hierarchies and scalar hierarchies (Salthe SN 1985, 1991, 1993, 2002).

On the other side, the application of hierarchy concept in biology and ecology resulted in a variety of hierarchies differing greatly in numbers of levels and in choice of patterns to determine these levels. As a rule, biological and ecological patterns have been combined in the same hierarchy (Tables 8, 9, and 10).

Table 8. Hierarchy examples (authors are biologists)

Authors		
Wright S 1964	Bonner IT 1969	Miller JG and Miller JL 1990
world biota	Universe	supranational system
local biota	galaxy	society
species	star (system)	community
deme	planet	organization
multicellular organism	Earth’s surface	group
organ	community	organism
cell	population	organ
macromolecule	organism	cell
molecule	organ	
	tissue	
	cell	
	macromolecule	
	molecule	
	atom	
	elementary particle	

Table 9. Hierarchy examples (authors are ecologists)

Authors		
Odum EP 1959	Odum EP 1991	Odum HT and Odum EC 2000
biosphere	biosphere	cosmos
ecosystem	biogeographical region	landscape geology
community	biome	society (economics)
population	landscape	ecosystem
organism	ecosystem	microbe
organ system	living community	chemical reaction
organ	population	
tissue	organism	
cell		
protoplasm		

Table 10. Most familiar (conventional) hierarchies

In biology (Campbell NA *et al* 2003)	In ecology (Allen TFH and Hoekstra TW 1990)
ecosystem	biosphere
community	biome
population	landscape
organism	ecosystem
organ system	community
organ	population
tissue	organism
cell	cell
molecule	

Genetic studies have always been associated with distinction between genotype and phenotype. After the structure of DNA molecule has been deciphered by James Watson and Francis Crick, rapid development in molecular genetics literally obliged the distinction between genotype and phenotype to become incorporated into hierarchical view in biology and ecology. Indeed, James Valentine (Valentine JW 1969, 1973, Valentine JW and May CL 1996) soon recognized "genetic" hierarchy underlying biological and ecological hierarchies (Table 11). Within "genetic" hierarchy, genes form the basic unit, aggregated at the genomic level. The genome is associated with an organism. The subsequent pattern of aggregation depends upon the hierarchy of interest. If it is a taxonomic hierarchy, the genomes are aggregated into gene pools associated with species, these into genera, these into family, and so forth. If it is an ecological hierarchy, the genomes are aggregated into gene pools associated with populations, these into communities, these into bioprovinces, and so forth.

Table 11. "Genetic" hierarchy (Valentine JW and May CL 1996)

	Hierarchy	
taxonomic	genetic	ecological
order	collection of collected gene pool collections	realm
family	collection of gene pool collections	bioprovince
genus	collection of gene pools	community
species	gene pool	population
organism	genome(s)	organism
	gene	

After the replicator concept has been set out and the distinction between replicators and vehicles has been appointed (Dawkins R 1976, 1982), David Hull introduced distinction between replicators, interactors, and lineages (Hull DL 1980, 1988). He argued that the appropriate levels in biological hierarchy would be not genes, organisms, and species but just replicators, interactors, and lineages (Hull DL 1989, 2001b). Instead, Niles Eldredge and Stanley Salthe proposed to distinguish between "genealogical" hierarchy and "ecological" hierarchy (Eldredge N 1985, 2008, Eldredge N and Grene M 1992, Eldredge N and Salthe SN 1984, Salthe SN 1985, 1993, Vrba ES and Eldredge N 1984). Whereas "genealogical" hierarchy is viewed as hierarchy of replicators and refers to information transfer, "ecological" hierarchy is viewed as hierarchy of interactors and refers to “matter-energy” transfer. Table 12 shows patterns included in an early version of “genealogical” and “ecological” hierarchy (Eldredge N and Salthe SN 1984).

Table 12. “Genealogical” and “ecological” hierarchy (Eldredge N and Salthe SN 1984)

Hierarchy	
genealogical	ecological
(special case: all life)	entire biosphere
monophyletic taxon	biotic region
species	local ecosystem
deme	population
organism	organism
gene	cell
codon	enzyme

Of course, the literature offers much more examples of hierarchies in biology and ecology than presented in Tables 8 to 12. Known biological and ecological hierarchies can be criticized for many reasons pointing out numerous particular errors. Here, the criticism focuses not on any particular error but on one common shortcoming: all these hierarchies employ only one universal life pattern – the cell – if any. All other patterns employed are doubtlessly specific. Strongly speaking, this shortcoming degrades all these hierarchies to simple lists of levels which have to do only with some selected specific fragments of such hierarchically organized systems of systems as biosphere and ecosphere.

By contrast, proposed biological hierarchy (Table 1) employs those patterns of information processing in living world (Tirjatkin N 2005a, 2005b, 2005c) which seem to be universal. Indeed, it has been recognized that from information processing perspective, all chemical reactions in living world fall into three categories: DNA transcription, RNA translation, and catalysis. It has been also recognized that these reactions arrange in strong hierarchy of life patterns: GENs, cells (GENomes), individual cell progressions, and the general cell progression. This arrangement is undistinguishable from the perspective of mass, impulse, and energy processing. The general cell progression occupies the apex of this hierarchy representing the whole living world (biosphere). Other three life patterns in this hierarchy are doubtlessly universal. They are innumerably variable and this variability underlies the diversity of biosystems at corresponding levels.

Proposed biological hierarchy (Table 1) is complete in the sense that the life patterns employed are necessary and sufficient for understanding of hierarchical organization of the living world (biosphere) as uniform system of biosystems. Extension of life patterns through corresponding fragments of the ecosphere would convert biological hierarchy (Table 1) into bioecological hierarchy (Table 5) which would be complete in the sense that resulted patterns would be necessary and sufficient for understanding of hierarchical organization of the ecosphere as uniform system of bioecosystems. However, they would be insufficient for understanding of hierarchical organization of the ecosphere as uniform system of geoecosystems.

Explicit recognition of the complete hierarchy of universal life patterns makes the understanding of life complexity amazingly easy. Living world – an extremely complex network composed of huge numbers of different chemical reactions continuously creating an enormously complex matrix composed of bewildering numbers of different chemicals involved in these reactions – becomes at once comprehensible as soon as one becomes familiar with how such basic chemical reactions as DNA transcription, RNA translation, and catalysis arrange in strong hierarchy of such life patterns as GENs, cells (GENomes), individual cell progressions, and the general cell progression.

If combined with taxonomic hierarchies embracing diversity of corresponding life patterns, the complete hierarchy of universal life patterns provides basic reference frame for secure orientation within living world. Additionally, this basic reference frame is suited very well for ordering of innumerable specific life patterns: they either disclose specific reciprocal relations between some GENs within any cells (GENomes), between some cells within any individual cell progressions, or between some individual cell progressions within the general cell progression or disclose specific reciprocal relations between some universal life patterns and environment. In addition to conventional specific life patterns, many important specific patterns of information processing in living world have been recognized (Tirjatkin N 2005a, 2005b, 2005c, 2007).

Explicit recognition of the complete hierarchy of universal life patterns provides also an appropriate conceptual framework suited very well to give rise just to that theoretical framework for which development Sidney Brenner called at the very end of the second millennium (Brenner S 1999). If we ask, however, what we have to know about GENs, GENomes, individual cell progressions, and the general cell progression, we must state that the living world remains *terra incognita* for us and much work is needed to develop an appropriate theoretical framework which would describe life in all reasonable details.

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