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ORIGINAL PAPERS

Some Remarks Regarding the Hyerarchy of Living Systems

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Abstract. *The hyerarchy of living systems comprises three categories of systems with distinct structures and functions: the individual, the multiindividual and the multicoenotic ones. Individual systems are: the prokaryotic unicellular organism, the eukaryotic unicelllar system and the pluricellular one. Multiindividual systems are the species and the biocenosis. Species, being differentiated regarding their ecological adapations, can exist only associated in biocenoses (through their populations), never independently; this is why the biocenosis is the only natural multiindividual, ecological system, consisting of other multiindividual systems – species. Multicenotic systems are: the biolandscape, the bioregion, the biozone (biome) and the biosphere. These systems comprise ensembles of different types of biocenoses and look like living covers of various sizes.*

Key words: hyerarchy of living systems, organisms, biocenoses, species, living covers.

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1. Introduction

Since they started thinking and comparing, human beings became more and more aware of the diversity of the surrounding living world, of plants and animals (some similar, others different), of the communities they formed – on land or in the water – as well as of the way these communities were changing over time.

Data regarding these ascertainments are found in ancient writings, but they became the object of scientific research mainly during the last three centuries, when organisms, species, biocenoses and Earth's living covers were defined and thoroughly studied.

Some opinions regarding living world as a whole also emerged [43, 15] but the way this whole is actually made up became clear only after the theory of systems was postulated by Bertalanffy [2, 3, 4, 5] who developed this theory starting precisely from biological data.

A considerable amount of literature on the way systems theory was understood and applied has been writen. Many hyerarchies of these systems have also been advanced – quite different from one another (see tab. 1 and 2).

In romanian scientific literature, these problems were dilligently deald with by professor Nicolae Botnariuc [6, 7, 8, 9, 10, 11, 12], who put emphasis on aspects which are essential for correctly understanding of the way the theory of systems should be applied in the living world; he also submitted some hyerarchies of the living systems. A more detailed analysis of these topics can be found in his works „Evolutionism – at an

impasse?" (chapters 6, 7 and 8 [11]) and „The evolution of multindividual biological systems" (chapters 1 and 2 [12]).

Botnariuc [6, 11] was considering that living systems have several general characteristics, namely: the historical character; the informational character; nonlinearity; wholeness; selfregulation; the autoepoietic character (i.e., the capacity of selfreproduction); the antientropic behaviour; the fractal character; dynamic equilibrium, and integration [11].

The present work contains some remarks concerning the hyerarchical integration of living systems.

2. Present conceptions regarding the hyerarchy of living systems

A simple definition of hyerarchy would be that it refers to a series of phenomena involving a relation of subordination.

The hyerarchy of living systems is more than that. It signifies a series of integrated living entities – from the most simple one – the cell – to the most complicated one – the biosphere. This hyerarchy demonstrates the way living world is organized, the way its different components interact to ensure the existence and the perpetuation of life.

Knowledge about the hyerarchy is necessary to all, considering it makes possible a correct orientation of scientific study concerning each integration level of the hyerarchy.

Reffering to the hyerarchy of living systems, Bertallanffy (he founder of the theory of systems) wrote: „We find in nature a tremendous architecture, in which subordinate systems are united, at subsequent levels, in more and more high and large systems" [5].

Many hyerarchies have been published so far. A first series was presented in a table and in the text of the work Botnariuc [11] (table 1) and Ceapoiu [14].

Table 1 – Hyerarchies of living systems table 2 and mentions in the text [11]

Author, years	*Hyerarchies (levels)*
Dice, 1955	Organic matter, organic compounds, unicellular organisms, pluricellular organisms, social groups of organisms, biocenoses.
Odum, 1959	Protoplasm, cell, tissue, organ, systems of organs, organisms, population, biocenoses, ecosystems, biosphere.
Wright, 1959	Gene, cell, organism, deme, species, ecologic system, fauna and flora.
Rowe, 1961	Cell, organism, local ecosystem, regional terrestrial ecosystem, ecosphere, universe.
Weisz, 1961	Subatomic particles, atoms, molecules, molecular aggregates, cells, tissues, organs, systems of organs, organisms, species, biocenoses, living world.
Zavadski, 1961	Organism, population (species), biocenosis, formation, biosphere.
Stugren, 1975	Molecular level, supramolecular level, cell, tissue, organ, organism, population, biocenosis.
Koestler, 1969	Individual, population, biocenosis, ensemble of biocenoses.
Setrov, 1971	Micelle, colloid, organelle (viroid), cell, tissue, organ, (individual) organism, population, biocenosis, biosphere.
Valentine, 1973	Individual, population (deme, cline, species), community, province, total marine biota.
Salte, 1975	Molecular level, cellular level, organism, population, biocenosis.
Alexander et	Genes, chromosomes, genomes, individuals, demes, populations, species,

Borgia, 1978	biocenoses, ecosystems.
MacMahon, 1978	Subatomic particle, atom, subcellular structure, cell, tissue, organ, system of organs, organism, deme, population, biocenosis, ecosystem, biosphere.
Arnold et Fristrup, 1982	Genes, individuals, populations, species.
Odum, 1983	Genes, cells, organs, populations, biocenoses, regional biota.
Eldridge, 1985	Molecules, cells, organisms, populations, biocenoses, regional biota.
Prosser, 1986	Atoms, molecules, organelles, cells, tissues, organs, dependent organisms (colonial or parasitic ones), independent organisms, biocenoses.

The bibliography containing the works mentioned in the table can be found in Botnariuc's volume [11].

Making a critical analyzes of these hyerarchies, Botnariuc [11] deduces that there is confusion regarding nomenclature, that units are not equivalent, that hyerarchies include non living units, that certain units are missing etc. The author concludes by affirmig that „Taken as a whole, these hyerarchical series look so heterogenous that they give the impression of having been arbitrarily constructed, according to the subjective evaluation of each author – which induces a great confusion in the whole matter".

The hyerarchy of living systems, as proposed by Botnariuc [11, 12] is presented in Fig. 1.

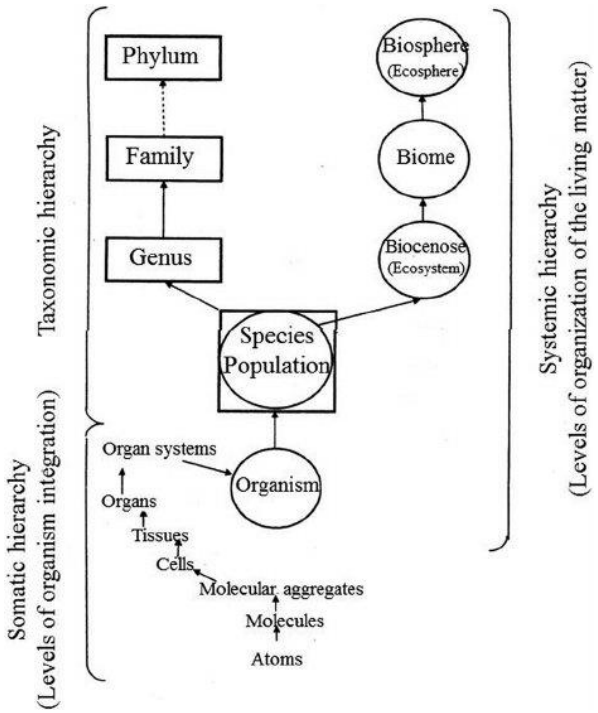

Fig. 1. The hyerarchy of living systems as proposed by N. Botnariuc [12]

Meanwhile, a quite substantial number of hyerarchies has been published. Some of them are presented in Table 2.

The above mentioned criticism is valid for these hyerarchies, too; moreover, they contain mixed (living and nonliving) systems (ecosystem, landscape, region, ecosphere). It is a good sign that the authors are aware of the existence of living systems superior to the biocenosis, even if the hyerarchies they suggest include these systems as mixed ones.

Tablel 2 – Hyerarchies of the living systems published during the last decades

Authors, years	*Hyerarchies*
André et al., 2003	Subcells, cells, cell-populations (tissues, organs), organisms, populations, communities, ecosystems, landscapes, ecoregions (bioclimatic units), biosphere.
Pavé, 2006	Subcells, cells, unicellular organisms, pluricellular organisms, populations, communities, ecosystems, ecocomplexes (landscapes), drainage areas, bio- or ecoregions, biosphere.
Lidiker, 2007	Multicellular organisms, populations, communities (biocenoses) ecoscapes (biomes), physiographic (topographic) regions, (biotic provinces, ecoregions), biosphere (ecosphere).
Miller, 2007	Individual organisms, populations, local communities (or ecosystems), regional (or provincial) ecosystem up to the biosphere.
Jørgensen, 2012 and Jordan et Jørgensen, 2012	Atoms, cells, tissues, organs, individuals, species, populations, ecosystems, landscapes, regions, ecosphere.
Jørgensen et Nielsen, 2013	Molecules, cells, tissues, individuals, species, populations, communities, ecosystems, landscapes, regions, ecosphere.
Eldredge et al., 2016	From the cell to the biosphere, through intermediate levels – organisms, populations, communities, ecosystems.
Lean et al., 2016	Organisms, populations, communities, ecosystems, landscapes, regions.
Umerez, 2016	Molecules, pre-cells, organisms, populations, community, ecosystems.
Brooks et Winsatt, 2021	Molecules, cells, tissues, organs, organisms, populations, ecosystems.

The bibliography reffering to the cited works can be found at the end of the present paper [12].

The above mentioned criticism is valid for these hyerarchies, too; moreover, they contain mixed (living and nonliving) systems (ecosystem, landscape, region, ecosphere). It is a good sign that the authors are aware of the existence of living systems superior to the biocenosis, even if the hyerarchies they suggest include these systems as mixed ones.

A remark concerning the way the hyerarchy of living systems is understood and denominated: as well in older works as (mainly) in more recent ones, the hyerarchy is not that of systems, but of the organisation levels, to which characteristics belonging in fact to the living systems: composition, order, emergent function (through integration) and control are assigned [41].

The truth is that the hyerarchy is that of living systems, which are found at several levels of organisation – i.e., the places where integration of inferior systems into a superior one occurs. The organisation level should consequently be named integration

level. This is also obvious in the way Bertalanffy, the founder of the theory, understood the hyerarchy of living systems.

There are authors who object to the existence of levels of organisation and of a hyerarchy [35, 38]. In their oppinion, living world is a continuum, with no organized in distinct, separable units, and research should be made in a „scalar" system, on areas of different sizes, according to the sizes of the objects of study, and in periods of time consistent with the processes they imply. In the case of vegetation, the continuity theory has been sustained by H.B. Gleason [25].

3. Remarks concerning the living systems included in the hyerarchy

The hyerarchy of living systems includes three categories, each of them grouping systems with the same type of organisation and the same vital functions: compact individual ones (organisms), multiindividual, associative ones (cenoses – the species, the biocenosis) and multicoenotic, agglomerative ones – the biolandscape, the bioregion, the biozone (biome) and the biosphere.

The remarks below refer to these three categories of systems.

3.1. Individual systems

In all hyerarchies, the organism is designated as the first individual system. In some of them, the components of the organism are also listed (but no mention is made whether they are systems or not).

According to Botnariuc [12], the individual level consists in pluricellular organisms (considering the components of the organism he mentions – which he does not consider systems).

It is not taken into account that there are three kinds of organisms with all the characteristics of systems, since they are ensembles of living interacting elements which ensure, through their existence and their functions, the existence and the perpetuation of life. These kinds of organisms are: the prokariotic unicellular organism (bacteria), the eukariotic unicellular organism (algae) and the pluricellular organism (plants, animals, fungi).

Single-celled organisms are, on the one hand, integrated in the pluricellular level, while on the other hand they are free beings and, as such, directly included in biocenoses, as populations.

The existence of the cell as a system is questioned [11] – but the cell exists through unicellular organisms.

We suggest that the three kinds of organisms should be included in the hierarchy as distinct systems.

3.2. Multiindividual living systems

Present hyerarchies mention several such systems, namely the population, the community (sometimes called biocenosis) and (less frequently) the species.

3.2.1. The population

In all hyerarchies, the population is placed next to the community or the species, its systemic role being unclear.

In the hyerarchy suggested by Botnariuc [12], the population is linked to the species in a single system, placed between the organism and the biocenosis.

Population has been much studied and has been defined as a spatial, a genetic or an ecological (complex) unit. In a recent work [20, 29] we discuss these definitions and suggest a new, more extensive one.

The systemic nature of the population and its place in the hyerarchy are well expressed in a short, but clear definition: „a group of organisms belonging to a species and inhabiting a biocenosis" [21]. This definition illustrates the fact that the population is a component of both: species and biocenosis, that it actually exists within a biocenosis, as part of a species and, as such, concurs in building the biocenosis, that the population is not autonomous.

As a group of inferior systems forming two superior sytems – the species and the biocenosis – the population is a subsystem in the hyerarchy of living systems.

The role the population plays in the two systems is not solely a structural one, but also a double-functional one: the genetic role within the species and the ecological one within the biocenosis. Both functions take place in the biocenosis and in its non-living environment – hence, in the ecosystem [17, 18, 19].

3.2.2. The species

In the present hyerarchies, the species is not often mentioned, which means there are doubts regarding its systemic position.

Botnariuc [12] states that the species and the population are at the same organisation level, namely between the organism and the biocenosis.

The species is mainly a genetic system, in which similar individuals (which it consists of) are reproducing, adapting to the environment and evolving [39]. But the species has ecological adaptations, too (in response to to the living and nonliving environment) which allow the component individuals to exist in this environment and to use it [43, 26, 29].

Over the evolution of life, species functionally and ecologically differentiated in three basic groups: biomass producers, biomass consumers and necromass decomposers. The result was a more efficient consumption of energy and matter – an almost complete matter cycle, virtually devoid of residues. Consequently, species cannot exist separately, as whole units, but only associated in biocenoses (as populations with different ecological functions) and in the corresponding non-living environments (in ecosystems) [16].

Species became structural elements in particular types of biocenoses, as dispersed systems, and were included in biocenoses as a result of their ecological adaptations. Their genetic processes (within species) [24] take place in the biocenoses, too, and the related non-living environment.

Considering its particular position in the hyerarchy of living systems, the species must be placed in a distinct system, together with the biocenosis (Fig. 2).

Biocenoses belonging to a given type are made up of the same populations, and all similar populations included in biocenoses of a same type are forming a species. The population is a component of both the biocenosis and the species.

This is only natural, considering that populations are structural and functional parts of both the species and the biocenoses, uniting the two in a whole.

Type of biocenoses formed by populations of some species						Species
Biocoenosis 1		Biocoenosis 2		Biocoenosis 3		Species
Population 1	+	Population 1	+	Population 1	→	Species 1
Population 2	+	Population 2	+	Population 2	→	Species 2
Population 3	+	Population 3	+	Population 3	→	Species 3
Population 4	+	Population 4	+	Population 4	→	Species 4
•	+	•	+	•	→	•
•	+	•	+	•	→	•
•	+	•	+	•	→	•

Fig. 2 – Relations between the biocenoses and the species (Doniță et al., 2019)

3.2.3. The biocenosis (the community)

As a rule, the present hyerarchies mention the community (sometimes, the term „biocenosis" is used).

In Botnariuc's opinion [12], the biocenosis is an organisation level placed between the mixed level species/population and the biome (see also fig. 1).

The biocenosis has all the features of an ecological system, but it has a special character, being formed by another system (a genetic one), the species.

The biocenosis is the first living system having a non-living environment of its own. This environment is the non-living component of the ecosystem and is utilized by all the individual systems which are integrated, through populations, in the biocenosis [18, 27, 29].

The important thing is that, as a result of the interrelations between the biocenosis and its nonliving environment, this one is locally altered; in the superior living systems, the fact is amplified, and all the non-living covers of the Earth are modified.

The biocenosis should be placed (in the hyerarchy of living systems) at the same integration level as the species, which is in fact included in the biocenosis (Fig. 2).

Biocenoses belonging to a given type are made up of the same populations, and all similar populations included in biocenoses of a same type are forming a species. The population is a component of both the biocenosis and the species.

3.3. Multicenotic living systems

The oldest proposals of hyerarchies very seldom refer to the multicenotic organisation levels (the biosphere, the ecosphere, terrestrial regional ecosystems). All recently published works make mention of such levels, but not as living entities, but as mixed – living and nonliving – units; they are called landscape, region, ecosphere. The existence of organisation levels larger than the biocenoses has finally been acknowledged. These units were already established and, for a long time, were regularly used by phytocoenologues and zoogeographers.

Botnariuc [12] mentions only two units higher than the biocenosis: the biome and the biosphere (Fig. 1).

Multicenotic living systems consist of complexes of different types of biocenoses inhabiting areas/volumes of different sizes, on land, in water or underground; they deal with different kinds of nonliving environmental conditions: atmospheric, geological,

pedological and hydric ones. Biocenoses within these ensembles consist of species ecologicaly adapted to the environmental conditions specific to each level. Multicenotic systems are: the biolandscape, the bioregion, the biozone (biome) and the biosphere. They look like living covers of the Earth; they occupy the non-living covers and interact with them. The local changings caused by biocenoses – in specific conditions, according to each environment – are amplified in multicenotic systems; the result is a more balanced environment – one more propitious to the existence of life.[1)]

3.3.1. The biolandscape

The biolandscape is the living cover occupying an area of thousands/tens of thousands km^2 – on land or in waters – consisting in an ensemble of different types of biocenoses which alternate according to variations in the nonliving covers. Distinct local changes generate different habitats, in which different biocenoses emerge. Examples of biolandscapes in Romania (in relation to its specific environmental conditions): Podișul Târnavelor (the Târnave Tableland), Țara Bârsei (the Bârsa Country), Podișul Moldovei (the Moldavian Tableland) etc.

A biolandscape does not contain a large variety of biocenosis, considering that the number of species within each biolandscape is rather low.

In terrestrial biolandscapes, the living element of recognition is the phytocenosis, while in the aquatic ones this element is represented by the ensembles of fixed phytocenoses and by the permanent, mobile ones, tiered in relation to light intensity.

Biolandscapes integrated in groups of different landscapes, according to the complexes of biocenoses they consist of.

Changes of organisms – even of populations – occur in a landscape; the result is the emergence of metapopulations which can influence ecological and genetic processes within biocenoses [27].

3.3.2. The bioregion

The bioregion is the living cover occupying a large area – thousands/millions of km^2 – on land or in water. It includes the living covers of all the biolandscapes it is made of.

Bioregions emerge as a result of changes occurring in zonal climates, from oceans shores towards the continental interior, since in the proximity of oceans the humidity is higher and more temperate in regard to temperatures, while on the continent humidity decreases and thermal extremes increase.

Climatic changes are conditioning the emergence of floras and faunas consisting of species adapted to the respective meteorological status – hence, of regional biocenoses which form the regional living cover.

Bioregions are integrated in biozones through groups of regions found in the same zonal climate.

[1)] An environment greatly degraded at present by inconsiderate human interference in the normal state of the planetary covers, mainly the living one.

Migrations of populations (in small proportion) may take place between bioregions; this temporarily influence the aspect and the functions of the biocenoses within the regional ensemble. The continental temperate climate biozone occupying the european subcontinent comprises three distinct regions: the atlantic, the central-european and the steppe one.

3.3.3. The biozone

The biozone is the living cover occupying areas of tens/hundreds of millions km^2 on land or in waters, which develops at the Earth surface as a very long, but less wide stretch.

Biozones occur in zonal climates differing in thermal and hydric regimes, consequently to the annual movement of the planet which induce a seasonal variation in the incident solar radiation.

Faunas and floras which emerge in each of these different climates include very diverse species (both structurally and functionally) and biocenoses specific to the respective zone.

The main climates and biozones are: the equatorial zone (permanently wet), the tropical, subtropical, temperate, boreal and subarctic ones.

Large migrations of animal populations take place between different zones, temporarily altering the aspect and the processes of the concerned biocenoses.

3.3.4. The biosphere

The biosphere is the planetary living system comprising all the other integrated lising covers; it occupies almost the entire Earth (the exception being the polar zones).

Within the biosphere, the diversity of species and biocenoses is at its maximum. The modifying influence of the planetary living cover strongly change the surface nonliving shells. One can speak clearly of the influence of the living environment upon the non-living one. The general, planetary clime is generated, the geomorphological, geochemical and hydrological processes are modified, all of them being influenced by the living cover (while the biosphere can be itself subject to possible calamitous changes affecting other covers).

Biozones are integrated in the biosphere through groups of boreal (in the northern hemisphere) and meridional (in the southern hemisphere) zones.

Considering the above-mentioned remarks, we recommend the following hyerarchy of living systems (Fig. 3).

Conclusions

The hyerarchy of living systems comprises three categories of systems, which difer regarding their structure and functions: individual, multiindividual and and multicenotic ones (Fig. 3).

Individual systems are: the unicellular prokariotic organism, the unicellular eukariotic organism and the pluricellular organism.

Multiindividual systems are the species and the biocenosis. Species being differentiated regarding their ecological functions, cannot live separately, but only in association within biocenoses, through their populations; hence, biocenoses are *in facto*

the only multiindividual ecological systems, consisting of the other multiindividual systems – species.

Multicenotic systems are: the biolandscape, the bioregion, the biozone (biome) and the biosphere. Al these systems are varying in size and consist of ensembles of different types of biocenoses, looking like living covers.

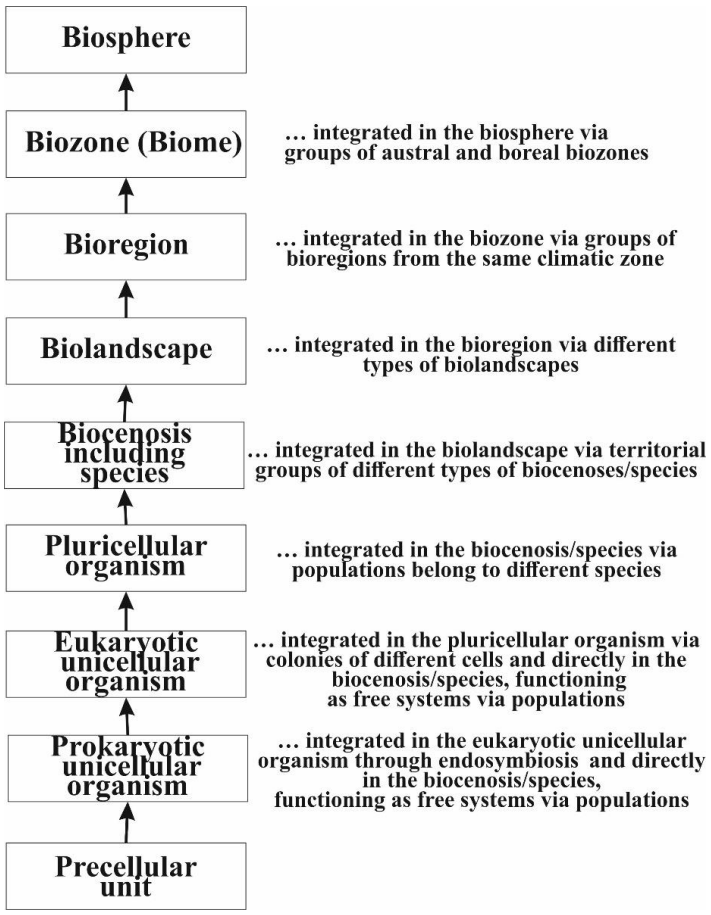

Fig. 3 – The revised hyerarchy of living systems (Doniță et al., 2019)

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