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ECOLOGICAL EMERGENCES WITHIN THE MULTI-INDIVIDUAL LEVEL OF SYSTEMIC ORGANISATION

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Abstract: The ecological emergences arise owing to the integration of organisms into hierarchically ranked systemic units into the multi-individual level of organisation i.e., population, species and biocoenosis and ecosystem (the latter including in addition the abiotic environment). The ecological emergences of the multi-individual level encompass both general and systemic unit-specific forms in terms of structures, relationships, processes, information and variability. The most important effect of the different ecological emergences is the initiation of the process of production, consumption and decomposition of biomass and necromass, which ensures the amount of energy and matter needed for the negentropic functioning of all living systems. For each form of general ecological emergence, an example involving plant systems is given.

Key words: biocoenosis, ecosystem, general/specific ecological emergences, hierarchy of living systems, multi-individual level of organisation, population, species, structure/information/function/relation/variability emergences.

Introduction

The emergence is the natural phenomenon through which new, unpredictable and unreducible forms and processes develop when, within an entity comprising several hierarchical levels, the transition from a lower to an upper level takes place.

The concept of emergence was dealt with since ancient times [1], but only in the XIXth century it was mentioned again in a work by G.H. Leves (according to Bizzari et al. [3]). This subject was referred to in a more detailed way at the beginning of the XXth century by C. Lloyd-Morgan (according to Kim [15]).

The concept of ecological emergence has long been contested by reductionists and individualists. Nonetheless, following the publishing of the systems theory and the debates concerning the organisation levels of the living world, emergence has become a recurrent theme [21]. Since the 1980s of the last century the debates have amplified and are still going on, resulting in a vast literature which mainly approaches the theoretical aspects of the issue, less frequently the actual manifestations of emergence.

In an analysis of the current situation, it is stated that sufficient clarification and consensus regarding the concepts of system, organisation level, hierarchy and emergence have not yet been reached. Reductionist and sceptical attitudes concerning their occurrence persist, as well as ambiguities, confusion and inconsequences [5].

Some opponents even deny the existence of organisation levels and propose another form of organisation of the living world – a scalar, uninterrupted one [19][1)]. Nevertheless, many authors put effort in clarifying several controversial aspects; some examples are edifying.

According to J. Kim [15], certain properties of the complex systems are emergent because:

1. Systems with a high degree of complexity, belonging to superior organisation levels, develop from inferior ones by acquiring new structural configurations.

2. All emerging characteristics develop besides the characteristics of inferior systems.

3. Emerging characteristics are not predictable, depending on the characteristics of the inferior systems.

4. Emerging characteristics are not reducible to the ones of inferior systems.

5. Emerging characteristics have new causal forces, which cannot be reduced to the characteristics of the inferior systems.

B.D. Fath and B. Patten [12] draw attention to the fact that, within ecosystems, a network synergism is present, which manifests itself by symmetry, indirect relations and the open character of the system. The emerging relation between the system and the non-living environment is also important.

W.C. Wimsatt [24] points out that emergence has nothing in common with the aggregation and reductionist tendencies. Emergence implies an organised interdependence of the parts within the whole, not their simple aggregation or reduction to the properties of the components.

D. Pumain [20] states that, in social structures, emergence indicates an increased number of interactions and a discernible stabilisation of the structure.

According to S.E. Jørgensen and B.D. Fath [14], the utility of a systemic approach in biology is tightly connected to the knowledge regarding the amplitude of the emergence. Any biological system and any complex system cannot be understood by the exclusive study of its composing elements. Each organisation level is a specific entity, with its own, new characteristics – based on the characteristics of its components, but not their direct consequence. The important part played by self-organisation – at every hierarchic level – is emphasized.

S.E. Jørgensen [13] asserts that systems with emerging properties cannot be described by listing their components and the properties of these components. An understanding of emergences developing in the new systems, as a result of a new organisation and new structures, is necessary as well as a description of these emergences.

W. Miller [17] draws attention to the fact that some ecologists have doubts regarding the emergence of characteristics occurring in complex systems and do not analyse the properties of living, dynamic systems from an ontological point of view. The hierarchy of organisms and their communities seems to be essential for covering the maximum complexity of such structures. A development of studies concerning this complexity (still not fully understood) is necessary.

I. Tëmkin and E. Serrelli [22] emphasize that organisation levels are discrete through the characteristics of their composing entities and through the processes involving these entities. They cannot be reduced to the characteristics of the entities within their inferior levels, nor can

[1)] The father of the systems theory mentioned, in a memorable sentence, how living world must be understood: "We find in nature a tremendous architecture, within which subordinate systems are united, as subservient systems, in ever larger and wider systems" [2].

be described by these characteristics. J. Umerez [23] reveals that the organisation levels have their own characteristics: composition, integration, emergence, control, organisation. If the integration implies relations of the whole with its component parts, the emergence indicates, in addition, the particular character of the processes within the whole.

M. Bizzarri et al. [3] claim that, in a complex organisation level, emergence occurs when component parts interact. Emerging phenomena cannot be predicted on the basis of the components' characteristics. They take place through a change in symmetry. Attention is also drawn to emergences occurring in the relations between living systems and their non-living environment.

N. Botnariuc [4] mentions that the characteristics of the whole cannot be reduced to the characteristics of its components, nor to the sum of these components. The result of connections among its component parts – hence, of their organisation – is the development of new, emerging characteristics of the whole that no component possesses.

I. Dediu [6] defines the ecological emergence as a fundamental characteristic of complex systems, generator of effects that should not be reduced to the capabilities of their component parts, being a consequence of their interactions.

Each of the quoted authors contributed to the theoretical clarification of the concept of emergence, but do not come with tangible examples of emergence occurring in one or the other level of systemic organisation. A concrete description of emergence cases occurring at four levels of ecological complexity (organism, population, community and landscape), was advanced by W.Z. Lidiker Jr. [16]. The emergences he mentions are in part ecological, but he also refers to other kinds of emergences (namely, genetic). It is true that this author regards ecology as a general science of all living systems.

In this paper, we address another point of view regarding the ecological emergences, namely those occurring by the transition from the individual organisation level (organisms) to the multi-individual one (represented by populations, species, biocoenoses and ecosystems). At this level, genetical emergences occur too, but they are not discussed here.

Theoretical premises

So far, no consensus has been reached regarding the organisation levels of the living world, nor the systems included in these levels and their functions.

Several previous reviews (e.g., [9, 11]) contain theoretical specifications on this matter, on the basis of which ecological emergences within the multi-individual organisation level are presented. In an integrated approach regarding the population or the species, it has been showed that, in most cases, the definition of these terms does not mention the fact that both entities are also ecological units, responsible for the maintenance of life. The authors emphasized the double (ecological and genetical) function of populations and species. Concerning the relations between these units, they pointed out that species do not represent a separate system, but are integrated in biocoenoses through their populations [11]. A more detailed description of the population, species and biocoenosis (hence, ecosystem), from an ecological point of view, was recently published elsewhere [10].

The special role of the biocoenosis and ecosystem in the hierarchy of living systems and in the energy and matter cycling, necessary for the survival of all living systems, was pointed out [9].

A new hierarchy of living systems, including eight levels, was recently advanced [7]:

- three individual levels (unicellular prokaryotic, unicellular eukaryotic and pluricellular organisms);
- one multi-individual level, composed of four integrated systemic units (populations, species, biocenosis and ecosystem);
- four multicoenotic levels, distinguishable at large (geographical) spatial scales (biolandscape, bioregion, biozone and biosphere).

The terms multi-individual and multicoenotic have been employed to express more precisely the nature of these levels of organisation of the living systems.

Within this framework, ecology has been defined as the systemic science studying the sole units included in the multi-individual level – populations, species and biocoenoses (integrated in ecosystems) – as well as their adaptations, their connections and the processes through which they maintain the functioning of all living systems [8].

Ecological emergences at the multi-individual organisation level

Within the hierarchy of living systems, the populations, species, biocoenoses and ecosystems emerge as systemic units at the superior, multi-individual organisation level, as a result of the organised association of organisms in a spatially limited non-living environment. In these new ecological units, the process of production, consumption and decay of biomass emerge through new structures, new information and relations by providing more efficiently the energy and matter necessary to the antientropic existence of all living systems. But in the same new systemic units, other mass processes emergently develop, too: genetic ones, reproduction, adaptation to non-living and biotic environments, as well as processes of similar or evolutive perpetuation of living systems.

At the multi-individual organisation level, ecological and genetical emergences occur in response to vital necessities of organisms as open systems:

- to ensure their existence, by occupying and utilising as many environments as possible, in order to obtain the energy and matter they vitally need;
- to ensure an incessant perpetuation under the pressure of negative biotic interactions (e.g., herbivores, pathogens) and abiotic disturbance (e.g., drought, windthrow).

In order to be able to exploit different environments, the development of adequate ecological adaptations is necessary. A continuous perpetuation is ensured by the occurrence of a sufficiently large number of descendants through reproduction.

The ecological emergences have both a general and specific character – for all systemic units included in the multi-individual systemic level – and respectively, for every single unit.

General ecological emergences

Structure emergences. The emergence of organised assembly of organisms as new mass but not compact forms of life, dispersed in spatially limited environments, together with which mixed living/non-living structures (ecosystems) are also emergently generated. An example of such type of emergence is the forest canopy made up of overlapping tree crowns.

Information emergences. The emerging occurrence in these mass assemblages of new, external ecological information concerning the state and movement of the composing organisms and of their non-living environment. An example of such type of emergence is the information regarding the colour, shape and/or smell of certain flowers, that is transmitted to pollinators.

Relation emergences. Based on these pieces of information, new types of mass ecological relations emerge between organisms and between organisms and their environment; the result is the self-regulation and structural stability of the different systemic units, as well as the emerging development of ecological processes responsible for the maintenance of life. An example of such type of emergence is the facilitation of annual plants by overlying nurse shrubs in arid environments.

Function emergences. The emerging generation, through special mass relations of the process of production, consumption and decay of biomass and necromass i.e., the process sustaining the life of all systems. The mass biosynthesis of organic matter by plants is an example of such type of emergence.

Variability emergences. The emergence of phenotypic variability in organisms, through the dissimilar development of organisms due to their relation with the living and non-living environment. An example of such type of emergence is the variability in tree size in even-aged, pure stands due to habitat heterogeneity and/or intraspecific interactions.

Specific ecological emergences

At population level

Structure emergences. The emerging formation of the population as a multitude of genetically similar but phenotypically differing organisms, characterised by specific quantitative populational indices (e.g., number, dispersion, size, age and sex structures, biomass) having their own dynamics; the formation, in connection with the environment, of a living/non-living structure - the ecological niche.

Information emergences. The emerging generation, as a mass phenomenon, of specific information of a new kind, concerning the state and the mobility of similar organisms forming the population and with regard to the non-living environment within the ecological niche.

Relation emergences. The emerging development, based on this information, of mass, external relations between the organisms of a population; these relations may be negative (competition), positive (facilitation) or social (e.g., families including functionally modified organisms); many relations involving energy and matter exchanges with the non-living environment within the ecological niche are also generated; all contribute to the self-regulation and stability of the population.

Function emergences. The mass participation of the population in the process of producing or consuming or decomposing the biomass and necromass and in other processes within biocenoses (ecosystems).

Variability emergences. Within population, as an assemblage of phenotypically dissimilar organisms, the emerging phenomenon of phenotypic variability.

At species level

Structure emergences. The emerging formation of species from one – but usually, from several populations of genetically similar but phenotypically different organisms, dispersed in biocoenoses of same or several types; unlike the population and the biocoenosis, the species is a system which is dispersed in biocoenoses through its populations.

Information emergences. The emergence of high amount of ecological information generated in each population of the species, as well as of information spread between populations by migrating organisms.

Relation emergences. They are generated as a result of the negative or positive ecological relations occurring in every population of a species, as well as relations between populations, through migrating organisms; all these relations contribute to the self-regulation and the stability of the species as a systemic unit.

Function emergences. They occur as a mass participation of all the component populations dispersed in biocoenoses in the process of production, consumption of biomass or decomposition of necromass, as well as in other ecological processes.

Variability emergences. The emergent occurrence, within the species, of a large phenotypic variability, more substantial than the one within the comprising populations.

At biocoenosis level

Structure emergences. The genesis of complex structures, resulting from the association and establishment (both horizontally and vertically) in a confined non-living space of several populations, each one belonging to a different species, ecologically dissimilar but complementary one to another; trophic chains and networks are developing.

Information emergences. A large amount of interpopulation information appear through multiple connections between all compounding organisms and populations.

Relation emergences. The extant information within the biocoenosis determine the establishment of a vast array of relations connecting organisms and populations belonging to functionally dissimilar species (e.g., competition, amensalism, parasitism, predatorism, protocooperation and mutualism); all these relations contribute to the self-regulation and the stability of the biocoenosis [18].

Function emergences. The multitude of relations generates the important process of production, consumption and decomposition of biomass and necromass which sustains the life within all living systems by providing the energy and matter needed.

Variability emergences. A high phenotypic variability concerning the multi-individual organisation level arises in the biocoenosis as a result of the large array of relations (intra- and inter-populational and with the environment).

At ecosystem level

Structure emergences. The emerging development of a mixed (living/non-living) structure, occurring when a biocenosis, consisting of populations which belong to different species, occupies a limited abiotic environment; the result consists in the differentiation of population ecological niches and of the biotope (the ecotope transformed by the biocoenosis).

Information emergences. The development of a large mass of information between populations and between the whole biocenosis and the biotope.

Relation emergences. The genesis, based on the above-mentioned information, of multiple ecological relations between populations as well as between the whole biocenosis and the non-living environment, through the incessant energy and matter exchange.

Function emergences. The development of the process of production, consumption and decomposition of biomass and necromass, through the energy and matter exchange between the biocenosis and its habitat.

Variability emergences. The generation of between-organisms variability resulting from their different structural development, consistent with the habitat microheterogeneity and with the capacity of organisms to use complementarily the energy and matter present in their habitat. In this mixed system, which maintains life in an antientropic way, genetic processes, by which life is perpetuated and evolves, also occur, sometimes influenced by ecological processes.

Conclusions

The organised association of conspecific and heterospecific organisms in non-living environments leads to the emergence of a multitude of new systemic units (populations, species, biocoenoses and ecosystems), all belonging to the multi-individual level in the hierarchy of living systems.

As an effect of the different ecological emergences (both general or systemic unit-specific), the process of production, consumption and decomposition of biomass is initiated, ensuring the amount of energy and matter needed for the functioning of all living systems.

The ecological emergences occur as a consequence of the intrinsic force of living organisms to give birth to as many descendants as possible in the process of reproduction and to develop adaptations in accordance to the spatially and temporarily varying environment.

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EMERGENȚE ECOLOGICE ÎN NIVELUL MULTI-INDIVIDUAL DE ORGANIZARE SISTEMICĂ

(Rezumat)

Emergențele ecologice apar când organismele de la nivelele de organizare inferioare se integrează în nivelul multi-individual superior, formând prin asociere populații, specii, biocenoze care, împreună cu mediul lor abiotic, compun ecosisteme. Emergențele ecologice de la acest nivel sunt și de ordin general, dar au și forme specifice structurale, informaționale, relaționale, funcționale și variaționale pentru cele patru unități sistemice. Cel mai important efect al acestor emergențe ecologice este inițierea procesului ecologic de producție, consum și descompunere a biomasei și necromasei, care asigură cantitățile de energie și materie necesare pentru funcționarea antientropică a tuturor sistemelor vii. Pentru fiecare tip de emergență ecologică generală s-a dat câte un exemplu din lumea plantelor.

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