LEVELS OF BIOTIC ORGANIZATION

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Summary

The level of biotic organization may be considered from different perspectives and these are briefly outlined. A merely structural level of the individuals is the most traditional approach, but it must be considered that there is a basic difference between a simple structure that is actually primitive and such highly evolved conditions as obtain in some parasitic or symbiotic organisms. Other levels of biotic organization that have to be considered concern the organization of communities and ecosystems, as well as symbioses. A brief discussion is therefore provided for each of the different aspects that biotic organization may take according the perspective from which it is considered.

1. Introduction

Living beings may be studied from different, albeit converging perspectives. They may be studied from the simplest level of organization of the individual organism, such as that of procaryotes. Then one may consider more and more complex levels of individual structure. But we may begin by considering the individual's interactions with its immediate environment, and then follow the chains and networks of such organisms, until we reach the comprehensive idea of "biosphere" or, perhaps, given the close interactions that have obtained since the origin of life, between living organisms and all other components of the ecosystem, up to the so-called Gaia system.

Moreover, as to be really meaningful biological studies must be framed within an evolutionary, that is, historical, framework, this will lead us through another system of levels, which will envisage both the changes in the morphology and biology of the different lineages and the progressive differentiation of biocenoses, both marine, freshwater and terrestrial, each one changing both in structure and complication over time.

Organisms evolved and branched into a number of taxa that may be grouped at different levels. Even if we choose not to consider formal systematics, it is obvious that quite different strategies of organization were pursued in the different kingdoms: Plants, Fungi, Metazoans, and the many and quite different phyla of protozoa, each one being characterized by its own peculiar levels of organization. Finally, what to say of parasites and symbionts? Structurally, many of them are very or even extremely simple, yet this is the result of an extreme level of specialization.

2. The Development of Organization at the Individual Level

We may begin by considering the different levels of organization that distinguish procaryotes from eucaryotes. In procaryotes (bacteria) the inner structure is fairly complex, yet it is not subdivided into compartments. The genes are usually arranged along a single double loop of a DNA, usually attached to the cell membrane. Thus all the vital functions of the cell are performed in this single compartment. It is now generally agreed that the eucaryote level of organization was the result of the development of a symbiosis between a somewhat larger bacterium with other bacteria that became the mitochondria and thus realized the basic metabolic pathways of eucaryote cells, while, at least some such cells increased their complexity by incorporating as symbionts photosynthetic bacteria, which became the plastidia of photosynthetic cells, such as those of the Protophyta, Algae, and plants. Different routes were apparently followed by such organisms that gave rise to the different fungi.

The usual subdivision of living beings into Procaryotes, Protozoans, Plants, Fungi, and Animals is apparently an oversimplification of the true relationships of living organisms, as the evolutionary relationships of organisms increasingly appear to be much more complex than previously thought. For instance the so called Fungi apparently have three independent origins: some may be close to slime-moulds, some derive from Algae that have lost photosynthetic capacity, some may actually be closer to animals than to plants, and derive from some sort of choanoflagellate. (Figure 1).

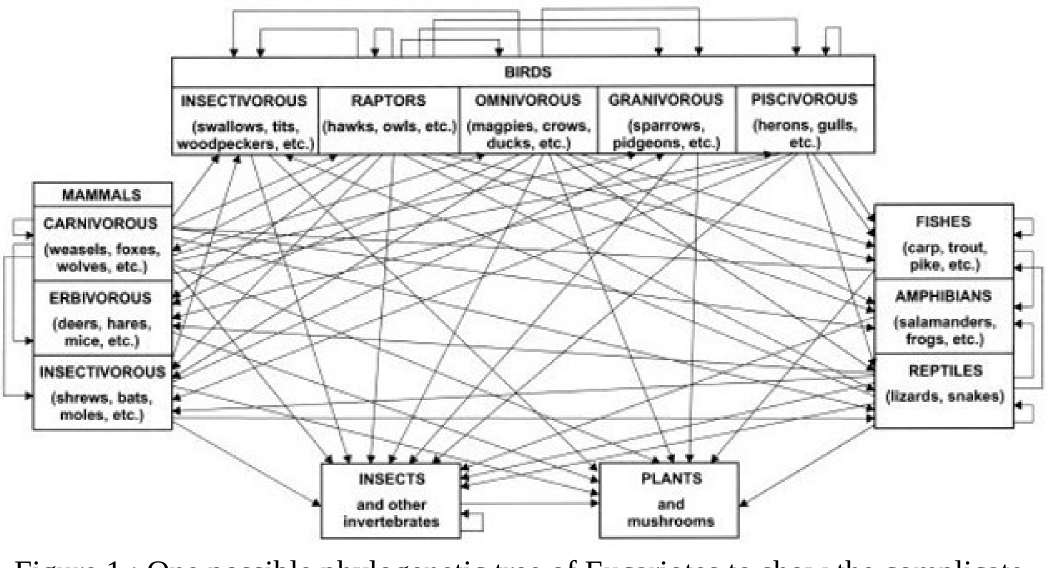

Figure 1 : One possible phylogenetic tree of Eucariotes to show the complicate branching evolution of these organisms.

Evolutionary radiation has currently produced some millions of living species (estimates vary widely, and in any case, there is no doubt that in a number of phyla we still know only a minority of their components).

When we consider cellular structures there is no doubt that the most complex are to be found among the Protists. Indeed these unicellular organisms, though sometimes capable of forming complex "colonies" made of a number of cells organized in a definite pattern and, sometimes, to some extent specialized for different functions (for instance among the Volvocales, usually not all the cells in the colony can develop into gametes) normally have to do with just one cell and thus they may develop extremely complex skeletons, their cytoplasms are differentiated into a greater number of organelles than in multicellular organisms, where the different functions are usually performed by different types of cells.

Some major strategies have been followed in the evolution of different organisms and a major problem that has been solved independently in a number of lineages is that of adapting to a terrestrial habitat.

In the different fungi, which neither developed tissues nor any suitable device for water circulation, adaptation to terrestrial life entailed for many of them a unique ability to develop networks of extremely thin iphae, which may grow through the soil for incredible extents: apparently a single individual may extend through some acres.

It is curious that fungi of entirely different groups have independently developed symbioses with algae, so as to evolve the many different species of lichens. True algae gave origin to terrestrial plants by developing a well organized tissular structure, cells being basically joined by their cellulose walls and developing vascular systems which allow the plant to pump water from the ground and distribute it through its structures (actually some extremely advanced Algae, such as Fucales, have developed by convergent evolution, a sort of tissues, of meristemes of cells functioning like sieve cells and of specialized reproductive organs). Parallel with the development of tissues went the acquisition of the different specialized reproductive structures. Plants, however, never developed anything like a nervous system.

Among animals, by contrast, with the probable exception of sponges, there is always a nervous system and the more active the animal, the more it tends to have a conspicuous amount of nervous tissue and its cells concentrated in one or a few organs (brain, ganglia), while both incoming information and outgoing operational signals travel along longer or shorter nerves. So both information and responses are elaborated in localized places where the numbers of different nervous cells are knit in a closely integrated system. However, apparently, organisms had in a sense but two options: either to have a largely stereotyped pattern of responses and behaviors, which may be extremely complex and based on extremely sensitive sense organs, and which may obtain even if the number of cells and of intercellular connections is rather limited, or, otherwise, have a highly flexible behavior, largely depending on learning, but which requires a considerable expansion of the brain, this reaching in mankind its maximum development relative to body size (while the brain of the larger Cetaceans, are absolutely much larger than human brains).

Obviously, in order to meet an immense variety of functional requirements, an endless variety of morphologies have been evolved. Again, it is necessary to consider that quite often comparatively simple organizations may go hand in hand with highly specialized kinds of tissues or of cells and vice versa. For instance jelly-fish have a simple basic structure, but they are endowed with highly specialized and unique kinds of cells, such as the stinging cells (cnidocysts), or form complex colonial organisms, composed from just a few individuals, to thousands of them, organized into specialized categories of highly different morphologies, usually arranged into well defined patterns.

3. The Development of Organization: Embryology and Cycles

Another approach to the problem of the development of different levels of biotic organization is to consider, in the case of multicellular and colonial organisms, the different ways by which either from a zygote resulting from the fusion of two gametes, or from parthenogenetic eggs, or from single non-gametic cells, such as spores, or, finally from small groups of unspecialized cells there develop more or less complex organisms, ranging in size from much less than a millimeter to giants such as a Blue Whale or a giant Sequoia. Again several different pathways have been followed in the evolution of organisms and it must be admitted that our knowledge of these mechanisms is still very incomplete.

Apparently, the simplest way to increase size would be to increase the bulk of the organism by developing a plasmodial structure, that is, by multiplying the nuclei without dividing the cell. And this is, indeed a possibility as we have different groups of protozoas (Foraminifers, slime moulds, etc.) which right in this way attain considerable sizes: some living foraminiferans are technically cells some centimeters across and a few fossil ones exceeded ten centimeters, other protozoas, the Xenophyophorea, may exceed some twenty centimeters and finally some slime moulds at some times in their cycle may form a slowly moving slimy mass over one meter in length! Also hexactinellid sponges may well be of considerable size and their siliceous skeleton may be an elegant structure, such as in *Euplectella*, and yet they have no true tissues but only syncytia.

In a number of animals, including ourselves, a more or less considerable part of the body, such as striated muscles, may be made of syncytia, though their structure is extremely complex. In animals tissues generally develop by multiplying cells, which develop more or less permanent joints among themselves, often of quite complex structure. Moreover, during embryonic development the complexity of structures increases not only by the multiplication of cells, but also by their reciprocal movements.

Cell and tissue specialization develop, usually, all along the development of the individual structures, but, especially in parasites, either the adults or some developmental stages or some phases that alternate in a complex life cycle, may be extremely simplified in comparison with other stages or phases. Such structural simplifications have, indeed a completely different significance from that of really primitively simple structures. Thus, for instance, in spite of some claims, the existence of nervous cells in sponges has not been proved and in simple cnidarians like the freshwater--polyp*Hydra*theseformadiffuseandscarcely subepithelial network, while in some parasitic crustaceans and mollusks they are certainly entirely lacking in the adults, yet, as arthropods and mollusks include also animals that have the most advanced nervous system among the invertebrates, in such cases the absence of a nervous system must be considered as an extreme instance of specialization.

Although the mechanisms that control the development and the functions of the various organisms are quite different, actually one can make a good case for arguing that it is just the comparative degree and complexity of such control systems that may tell us which level of biological sophistication an organism has attained in comparison with others.

It is also interesting, considering the above, that recent advances in genetics appear to show that evolutionary processes have privileged the development of control genes, rather than the simple accretion of new genes coding each one for new structures.

The evolution of biological cycles also shows a variety of evolutionary levels and specializations: the alternation of gamic and agamic generations, which may well be similar, but may be entirely different, such as in most Tracheophytes, where the agamic generation, the sporophyte, may range from a tiny grass to a giant tree, but where the gametophyts is always a microscopic structure of but a few cells living as parasytes on the sporophyte. In a number of instances the successive generation of the cycle are not only morphologically and physiologically quite different, but live in entirely different environments: some may, for instance, live as parasites their larval stages and as free animals as adults, while others do the contrary (Figure 2).

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Biographical Sketch

Alberto M. Simonetta, born 1930, is full professor of zoology at the University of Florence (Italy). He has studied in Florence, where he had his first appointments as assistant and was appointed as full professor of Comparative Anatomy at the University of Camerino in 1969. His major research interests are the comparative anatomy and evolution of Vertebrates and of Arthropods, including fossils, theoretic aspects of evolutionary taxonomy and history of biology.