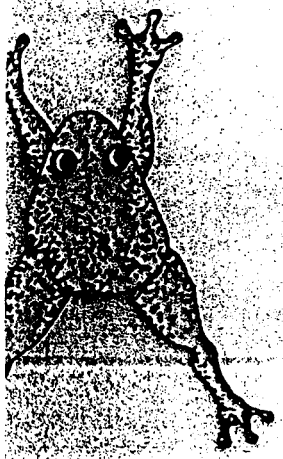



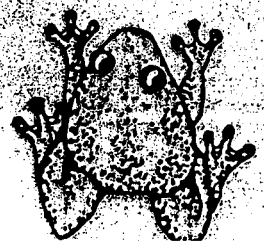


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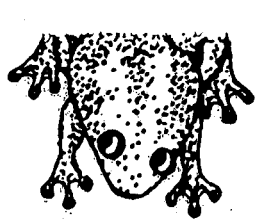
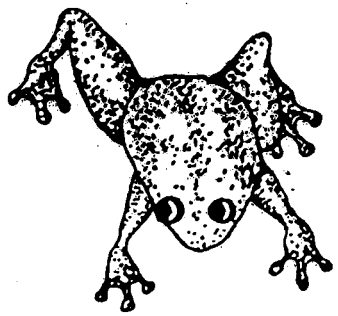
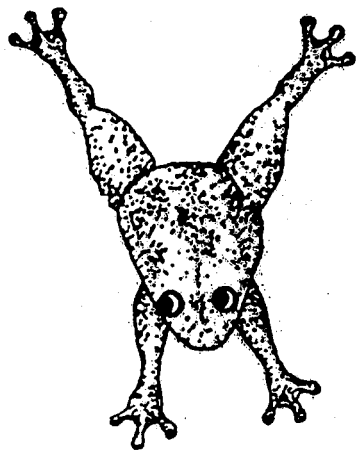







The abridged version of this paper has been reprinted in: Keller, D.R. and F.B. Golley, (eds.), *Philosophy of Ecology. From Science to Synthesis*, The University of Georgia Press, 2000.


# LUDUS VITALIS


REVISTA DE FILOSOFÍA DE LAS CIENCIAS DE LA VIDA
Journal of Philosophy of Life Sciences
Revue de Philosophie des Sciences de la Vie

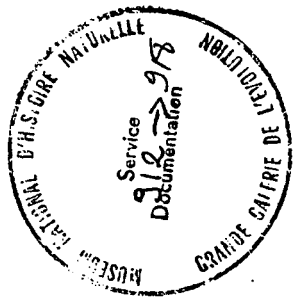
Vol. III / núm. 5 / 1995 / ISSN: 1133-5165

Revista semestral editada por el
**Centro de Estudios Filosóficos, Políticos y Sociales "Vicente Lombardo Toledano"**
Lombardo Toledano 51, México, D.F., CP 01050. Tel.: (525) 661 46 79, Fax: (525) 661 17 87
e-mail: lombardo@servidor.dgsca.unam.mx
**Secretaría de Educación Pública**
Cert. de licit. de contenido: 6097; cert. de licit. de título: 8123; num. de resv. de derechos autor: 002901/94

Distribución, suscripciones y publicidad:
EDITORIAL ANTHROPOS. Promat, S. Coop. Ltda.
Viladomat, 308, 08029 Barcelona (España). Tel.: (93) 419 13 88, Fax: (93) 419 18 58

Dep. legal: B. 30.865-1993 Impresión: Novagràfik. Puigcerdà, 127. Barcelona



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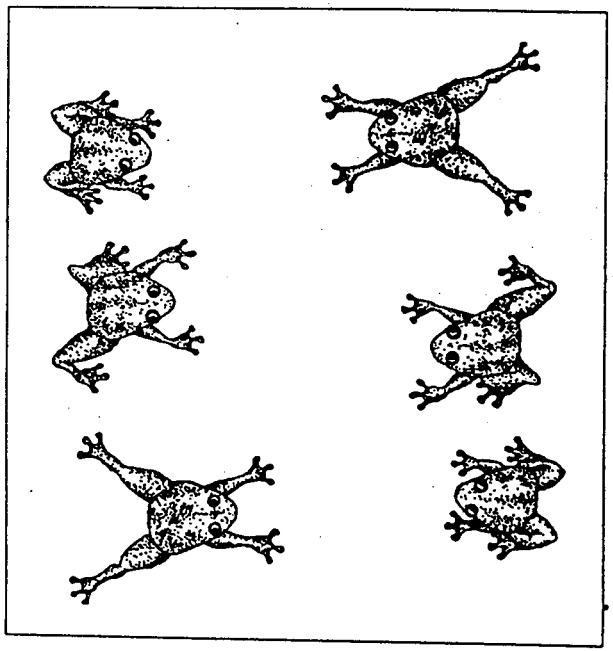

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# ÍNDICE

## RESUMEN

### LOS TRES ROSTROS DE LA ENFERMEDAD

### UNA INTEGRACIÓN DE LOS COMPONENTES FÍSICOS, RACIONALES Y EMOCIONALES EN EL DIAGNÓSTICO Y LA TERAPÉUTICA

Es necesario un nuevo modelo de la enfermedad que permita integrar los tres componentes principales de la entrevista clínica, ya que muchos pacientes y médicos están insatisfechos con el modelo biomédico actual. Toda situación clínica está compuesta por tres elementos básicos. Los tres deben tomarse en cuenta para formular un diagnóstico preciso e instituir un tratamiento adecuado. Estos tres componentes son los factores racionales, físicos y emocionales.

Los componentes *racionales* se exploran verbalmente al realizar el interrogatorio y durante el manejo subsecuente. Incorporan el conocimiento y comprensión del paciente respecto a su enfermedad, asistido por las preguntas dirigidas de médicos, e incluyen las explicaciones sobre la enfermedad que proporciona este último.

Los componentes *físicos* son aquellos que pueden obtenerse por medios físicos o tecnológicos: exploración física, análisis de laboratorio y técnicos de gabinete o imagen.

Los componentes *emocionales* se constituyen por la respuesta emocional del paciente hacia su enfermedad, percibida mediante la *empatía* en la relación médico-paciente, y la respuesta emocional del propio médico. Este último factor puede usarse como una potente herramienta que ayude en el proceso diagnóstico y mejore la eficacia terapéutica.


# "REDUCTIONIST HOLISM": AN OXYMORON OR A PHILOSOPHICAL CHIMERA OF E.P. ODUM'S SYSTEMS ECOLOGY?

DONATO BERGANDI

## INTRODUCTION

The epistemological issue "holism-reductionism" affects every level of integration: from physics to chemistry, from biology to psychology and even sociology. At each of these levels, one is faced with the same type of questions: Is it possible to understand an event or an object from any given integrative level by dissecting it in ever greater detail, or is it necessary to *respect* its structure and functions as much as possible by studying it in its proper context? Can a given integrative level be *reduced*—that is to say *explained* or *predicted*—from a basis of the laws or theories of a "lower" level of integration, or can each integrative level only be explained by means of its own laws and theories? Reductionists believe that ever more sophisticated molecular research will be able to reveal the essential struc-

Muséum National d'Histoire Naturelle, Laboratoire d'Ecologie Générale. 4, rue du Petit-Chateau, Brunoy, 91800 France.

ture of bio-physical objects. Some go on to suggest that from this basis it will be possible to understand if not all, then at least a significant proportion of psycho-sociological phenomena. Holists, on the other hand, maintain a more phenomenological world view, which is characterized by a greater respect for the objects of study and by an attempt to take into account the complexity of the spatio-temporal interconnections which give them their character (Nagel 1961, Koestler and Smythies 1969, Ayala and Dobzhansky 1974, Hoyningen-Huene and Wuketits 1989).

The reductionist paradigm, or what one might more accurately term the atomist-analytical-reductionist paradigm, is well structured and has already been proven to function at the most different levels of integration, but increasingly often, it is encountering anomalies which undermine it. Its epistemological base is derived from determinism. The holist paradigm, on the other hand, with its rich history of philosophical development, is engaged in a search for a theoretical and operational unity which it has not yet attained. The issue is rendered more complex by the fact that the proponents of the two approaches (especially in scientific fields) misunderstand their actual impact. Moreover, the epistemological evolution of whole disciplines, such as ecology—the holistic science *par excellence* (E.P. Odum 1971, H.T. Odum 1982, Ramade 1992, Patten 1993 (a), Patten 1993 (b), E.P. Odum 1993)—has been founded on misunderstanding and misinterpretation.

From time to time, in the development of a scientific discipline, some texts emerge which rapidly become and remain a fundamental work of reference. This is due to their ability to function as a "point of attraction" for the discipline, and above all, to provide a new and useful perspective.

E.P. Odum's *Fundamentals of Ecology* belongs to this small group of texts which one can define as "paradigmatic", since they provide the starting point and the material for specialists of the discipline to progress in their research. The book was first published in 1953, and then in 1959 and 1971. It seems to me that a comparative analysis of the three editions is a necessary preliminary not only to understand the text in all its subtleties but also to grasp better the importance of the systemic ecology which is presented within it.

Odum's contribution has been essential in determining the scientific status of modern ecology—its holistic concept of the ecosystem has enabled us to focus ecological research by giving it an original epistemological foundation. It has not, however, resolved the methodological problems which accompany the analysis of "complexity" in ecology. Neither has it enabled us to move beyond the historical debate between the followers of reductionism and those of holism.



The existence of this debate precedes Odum in the development of ecology, but it is with Odum that it reaches its full force. The discussion/confrontation between these two visions of the world has its origin in the reaction to Clements' metaphorical and methodological proposition of 1916, which put forward a conception of the vegetal community as a single organism[1]. The concept was refuted first by Gleason (1926) and then by Tansley (1935). They all but denied the importance of the concept of "organic whole" when applied to vegetal communities. Tansley's vision of the world in particular emerges as a mechanistic concept of what he considers to be the "basic unit of nature", the ecosystem [2], a concept which is developed to become a method in the works of Hutchinson (1941) and Lindeman (1942). Following the path laid down by Hutchinson, Lindeman proposes an analytical method which detects economicist strategy based on thermodynamics in the exchange of energy between living beings, a method which, by additive reconstruction, appears sufficient to explain the ecosystem fully.

In the 40's, the group of ecologists in Chicago presided over by Allee[3] revived the holistic concept by adopting it to propose interpretative frameworks for coevolutionary relationships in animal communities, concentrating on phenomena which cannot be tackled satisfactorily with an energy-based approach.

Approximately ten years after the creation of cybernetics by Wiener (1948) [4], Margalef (1957, 1968) was the first to use cybernetic models in ecology, opening up the way for a new approach based on ecological systems capable of associating the concepts of trophical transfers and regulatory interaction [5]. In the late 70's and early 80's, after this type of model had been in use in ecology for several years, a debate was opened on the cybernetic nature, or otherwise, of ecosystems (Engelberg and Boyarski 1979; Knight and Swaney 1981; Jordan 1981; Patten and Odum 1981) [6]. Even recently, Loehle (1988) has stated in an analysis of methodologies used in ecology that cybernetics could be one of the possible holistic approaches.

There is a mutual relationship between the terms "holism" and "emergent properties": we cannot mention one without referring to the other. However, when we speak of emergent properties, we inevitably come up against the problem of their existence in nature and that of their explanatory power in science (Salt 1979; Edson *et al.*, 1981).

In the introduction to the last edition of his work (1971, p. VII), Odum asserts in the course of a retrospective self-analysis that: "Practice has caught up with theory in ecology. The holistic approach and ecosystem theory, as emphasized in the first two editions of this book, are now matters of world-wide concern". In this respect, I only partially support

the view of the author, who gives the impression that the same fundamental notion underlies the three editions. If one proceeds to a comparative analysis of the three editions, one cannot fail to notice that certain analysis, certain concepts, have survived whereas others have disappeared. In particular, the approach which Odum calls "holistic"[7] undergoes major modifications in the last two editions while remaining the main line of the text. My aim is to define the holistic approach proposed by Odum and to highlight the ways in which it is modified in the development of the work. I will further attempt to establish whether the holistic vision of the world proposed by Odum is in harmony with the methodological tools he uses, i.e., whether there is a gap between his philosophical assumptions and the research methods which he advocates.

## "HOLISM": AN EMERGENT SCIENTIFIC PHILOSOPHY

A significant proportion of the key concepts which form the basis of the approaches encompassed by the terms 'holism', 'globalism', 'systemics' and 'organicism' have their origins in philosophical thought. If to nothing else, one must refer in this context to the Anaxogorian and Platonic concepts of nature as an integral whole (Anaxagoras, 6th Fragment; Plato, *Meno*), and the Aristotelian idea of the state as an ontological entity which takes precedence over the family and the individual (*Politics*)[8].

A brief historical review of the scientific disciplines which have felt the influence of holism will help us to better understand the scope and significance of the issue.

In the second half of the 19th century, holistic thought, principally by means of Hegelianism, was introduced into and spread in the developing field of cultural anthropology (Tylor 1871). Tylor's conception of culture has a symbolic significance in this respect. Culture is perceived for the first time as a "complex whole" whose various elements (laws, customs, art, economy and so on) interact. In psychology, holistic thought finds its clearest expression in the extremely well-known phrase "the whole is greater than the sum of its parts", an axiom proposed by Ehrenfels (1890), who was among the first people to concern themselves with the holistic properties of cognitive phenomena, and with the semantically similar principle of "creative synthesis" (Wundt 1912). In the 20th century, Gestalt psychology (Koehler 1929; Koffka 1935; Wertheimer 1945), a vital transitional phase in the process of "scientification" of holistic thought, came to represent the natural development of this trend.

In biology, an initial organicist wave with radical tendencies (Montgomery 1882; Haldane 1884; Russell 1924; Smuts 1926) was succeeded by a second, more moderate one (Woodger 1932; Needham 1936, 1937; Bertalanffy 1952, 1969; Goldstein 1963; Weiss 1967). If one excepts the very definition of ecology as a scientific discipline—i.e., a global science of the relationships between organisms and their environment (Haeckel 1866)—holism first makes its appearance in ecology with the works of Clements (1916) and, providing the necessary refinements, Allee (1949), E.P. Odum (1953, 1959, 1971), H.T. Odum and E.P. Odum (1955).



Let us now consider contemporary authors who have had a direct influence on the development of holistic concepts in biology and ecology.

Morgan (author of *Emergent Evolution* [1923], a book which has contributed a great deal to the spread of the concept of "emergence") traces the origin of the word "emergence" and the corresponding concept to Lewes's *Problems of Life and Mind* (1875).

From the same period, a very clear statement of the general character of emergence is proposed in Engels's *Dialectics of Nature* (1875-1876; English transl. 1940, pp. 28-29):

> If we imagine any non-living body cut up into smaller and smaller portions, at first no qualitative change occurs. But this has a limit: if we succeed, as by evaporation, in obtaining the separate molecules in the free state, then it is true that we can usually divide these still further, yet only with a complete change of quality. The molecule is decomposed into its separate atoms, which have quite different properties from those of the molecule. In the case of molecules composed of various chemical elements, atoms or molecules of these elements themselves make their appearance in place of the compound molecule; in the case of molecules of elements, the free atoms appear, which exert quite distinct qualitative effects: the free atoms of nascent oxygen are easily able to effect what the atoms of atmospheric oxygen, bound together in the molecule, can never achieve.
>
> But the molecule is also qualitatively different from the mass of the body to which it belongs. It can carry out movements independently of this mass and while the latter remains apparently at rest, e.g., heat oscillations; by means of a change of position and of connection with neighboring molecules it can change the body into an allotrope or a different state of aggregation.
>
> Thus we see that the purely quantitative operation of division has a limit at which it becomes transformed into a qualitative difference: the mass consists solely of molecules, but it is something essentially different from the molecule, just as the latter is different from the atom. It is this difference that is the basis for the separation of mechanics, as the science of heavenly and terrestrial masses, from physics, as the mechanics of the molecule, and from chemistry, as the physics of the atom[9].

Dialectical materialism, according to which the combination of entities from a lower order creates new properties which are not deducible from

the study of individual components, has often been perceived as one of the main waves of the emergentist thought.

Morgan (1927, p. 146), who was undoubtedly influenced more directly by the organicistic philosophy proposed by Whitehead in *The Concept of Nature* (1919) than by dialectical materialism, made his own a concept of "organism" whose primary characteristic is to be, in a very broad sense, a social entity:

> (...) the organism—any organism in the unrestricted sense—is, I make bold to say, a community of members in fellowship each of which is in sympathy with, and of service to, the others, and each of which plays its part in relation to the parts played by other members in the organic whole which is the organism, whatsoever may be its modal status.

From this starting point, Morgan (1927, p. 145) distinguishes between systems mechanically interpretable as "resultant" where "with full knowledge of some given phase of the state of affairs [in the system] any subsequent phase could be confidently predicted", and systems whose qualities "are claimed to be emergent because they are not reducible to, or deducible from, the qualities of organisms of lower status in the hierarchy".

Later, Woodger (1932, p. 118) made an extremely significant contribution to the analysis of the holistic problem in the field of biology by clarifying up conclusively the relationships between "whole" and "parts". According to him, there would be:

> (...) two possible types of parts, yielding the possibility of three types of system. Roughly speaking, parts of type 1 would be complexes which do not change when they enter as parts into complexes of higher order than themselves; parts of type 2 would be complexes which, while remaining of the same order, do change when they enter into the composition of complexes of higher order than themselves. We could then have systems whose parts were all of type 1, systems whose parts were all of type 2, and systems with parts some of which were of one type and some of the other. Now some of those who have written about "wholes" seem to have intended to apply the term only to systems whose parts are of type 2; and this is clearly a much narrower use of "whole".

Subsequently, Needham (1937, p. 16) would clarify Woodger's position further, by retaining three types of relationships between parts, which are known respectively as:

1) Independent
2) Functional
3) Existential



I think it is fair to summarize the views of these authors as follows: First, that a part which is characterized by relations of the first type carries on its normal activities, either when it is linked to the whole or when it is isolated [10]; a part which has relationships of the second type becomes disrupted once isolated from the whole, without affecting the rest of the whole; finally, a part which has relationships of the third type ceases to exist in that form, ensuring at the same time the total disorganisation of the system.

According to Needham (1937, p.16), to consider all systems to be characterized by relationships of an "existential" type between components of a whole is the same as to propose a dogmatic and obscurantist vision of the world, as all analysis would be doomed to failure.

Moreover, as there are no limits in nature, since closed systems are a mere theoretical ideal, once the idea that there are only existential relations between components in nature becomes axiomatic, we would have no alternative but to extend the concept of "system" to the entire universe, thus rendering it beyond the reach of knowledge.

Pepper (1926, pp. 242-243) helps us to avoid quite a number of misunderstandings by drawing attention to the existence of at least two semantical dimensions: on the one hand that of the properties of reality, the ontological dimension, and on the other, that of laws, the epistemological dimension:

> Accurately speaking, we must first observe, laws cannot emerge. Emergence is supposed to be a cosmic affair and laws are descriptions. What emerge are not laws, but what the laws describe (...) Cosmic events don't deduce or predict one another; they occur. It is only we who describe them by laws, who also make predictions concerning them by means of our laws. Cosmically speaking, nothing is deducible, and hypothetical emergent qualities or events would be no more peculiar in this respect than the qualities and events that occur on the bedrock level. It is only humanly speaking that anything is deducible. And what are strictly deducible are neither qualities nor events, but laws.

This text suggests that, if the property of emergence can be related to the qualities of reality, this could be seen in the fact that the laws of a certain level of integration could possibly be "deduced" by, or "reduced" to, other laws belonging to lower levels of integration.

As far as the possible predictability of laws relating to the phenomena of emergence is concerned, Henle (1942, pp. 491-492), Hempel and Oppenheim (1948, pp. 150-151), not accepting the ontological dimension of emergence, reduce it to a mere complication, to a simple indicator of the level of our own knowledge. On this point, Hempel and Oppenheim are particularly explicit:

> (The) emergence of a characteristic is not an ontological trait inherent in some phenomena; rather it is indicative of the scope of our knowledge at a given time; thus it has no absolute, but a relative character; and what is emergent with respect to the theories available today may lose its emergent status tomorrow.

This firm rejection of the issue of emergentism is brought into focus by Novikoff (1945) and Feibleman (1954) who wrote two articles which we believe to be of crucial importance. They lay out a set of principles which should be considered by anyone wishing to analyze the heuristic potential of holism. They both agree on saying that:

— Each level of integration is characterized by the possession of one or more emergent properties which are appropriate to it (respectively p. 209 and 59).

— It is impossible to reduce a hierarchically higher level to a lower level as such a form of explanation would imply the loss of the emergent qualities of the higher level (p. 209 and 62). This does not in any way imply that knowledge of the lower level is dispensable; rather, it is necessary, but not sufficient (p. 209 and 61).

— Each level of integration requires laws appropriate to that particular level (p. 209 and 64).

The theory of levels of integration, at least as far as these two authors are concerned, does not lead to an excessive estimation of the worth of the properties of the "whole" at the expense of the properties of the "parts"; according to Novikoff (1945, p. 209), for example:

> The concept of integrative levels recognizes as equally essential for the purpose of scientific analysis both the isolation of parts of a whole and their integration into the structure of the whole. It neither reduces phenomena of higher level or those of a lower.

This balanced vision can also be found in the work of Feibleman (1954, p. 61), who underlines the multidimensional nature needed by any systemic scientific approach to a specific level of integration: "*For an organization at any given level, its mechanism lies at the level below and its purpose at the level above*. This law states that, for the analysis of any organization, three levels are required: its own, the one below and the one above" [Feibleman's italics]. In so doing, Novikoff and Feibleman not only contribute to clarify the conceptual content of holism, but also propose the basis of a methodology. Thus, they provide the tools for appreciating what is covered by Odum's holistic "choice" and the degree of consistency between his concepts and his methods.



## THE CONFRONTATION BETWEEN TWO SCIENTIFIC PHILOSOPHIES

Before moving on to the analysis of instance, which is archetypal as far as the misunderstanding and misuses of epistemological meaning in the holism-reductionism debate are concerned, we shall highlight the different positions taken by the two paradigms on the ontological, methodological (strategies of research), and epistemological (the relationships which exist between the theories and laws of different levels of integration) levels. This distinction between the various semantic fields, which was used by Ayala and Dobzhansky (1974; see also Mayr 1982, 1988) to clarify nuances of the reductionist paradigm, I shall apply to the holist paradigm. It will soon become clear that in reality there is no such thing as "reductionism" or "holism" per se, but rather that there are several forms of both reductionism and holism.

The total contrast between the two paradigms applies in every semantic field. On the ontological level, reductionism and holism share a materialist world view, but differ in their suppositions concerning those entities which make up reality. A current of philosophical atomism generally underlies reductionist suppositions, whereas holism has a relational and continuist view of reality. According to holism, the basis of reality does not consist of discrete entities, but is rather formed by a "network" of events and relationships which cannot be broken down. This network is the primary reason for the existence of emergent properties which characterize each individual level of integration: properties which symbolize all that is new in each integrative level, and which signal the increase in its complexity.

As far as methodological reductionism is concerned, it may take either a radical or a moderate form. The radical form maintains that it is possible to *predict* the properties of a level of integration by studying its constituent parts. The moderate form, on the other hand, limits itself to stating that it is possible to *explain* those properties on the basis of a study of the level below. In any case, they are both structured around additional analysis —which holds that the whole is equivalent to the sum of its parts (Amsterdamski 1981). A typical example of methodological reductionism may be found in Simon (1969), at the point where he puts forward the method which he paradoxically calls "pragmatic holism". Bertalanffy (1952) and Bunge's (1983) positions are similar. Curiously, all these methods are presented as being part not of a reductionist, but of an emergentist approach. Only Somenzi (1987), who proposes a radical reductionist approach to atomic physics, gives it its proper name.

Methodological emergentism, on the other hand, maintains that it is necessary to consider several levels of integration: according to Feible-

man (1954), this means at least three. It stands in contrast to the belief that only levels of integration lower than the one being studied can supply explanations. The radical form of methodological emergentism does not accept additional analysis (Russell 1924), whereas the moderate form, although still rejecting this particular technique, is more open to the analytical method. It is acceptable to study lower levels of integration as long as one does not claim to be able to predict the properties of higher levels solely on the basis of these studies (Koehler, 1929).

As far as epistemological reductionism is concerned, we are referring to the classic model of reduction, i.e., heterogeneous or inter-level reduction, as was proposed by Nagel (1961) and commented on and developed by Schaffner (1967, 1986, 1993) and Wimsatt (1986). In the realm of science, some fields are, they maintain, more "fundamental" than others. Biological levels of integration may be "reduced" or explained by reference to the laws and theories of chemistry and physics.

Epistemological holism, in contrast, gives precedence to the idea that the general tendency of science is towards synthesis (Bertalanffy 1952) and not reduction. According to Quine (1961), no one field is any more significant than another. The importance of science is as a global system, and therefore a change in any given area of science reverberates upon the entire system. Piaget (1970), for his part, refutes the idea of "one-way" reduction, and leans towards a reciprocal assimilation of disciplines. If a higher level of integration may be derived from a lower level, this lower level will become enriched to the extent that its structure will be radically altered.

## *FUNDAMENTALS OF ECOLOGY* FROM 1953 TO 1971: THE EVOLUTION OF ODUM'S "HOLISTIC" THOUGHT

The key work in the oeuvre of E.P. and H.T. Odum is the text *Fundamentals of Ecology*. The "epistemological manifesto" of this work will form the object of our analysis, an illustration which will help us to better understand the sharp contrast between the holist and reductionist paradigms.

Because it is so much younger a science than more established disciplines such as physics, for example, ecology is in a position where it is reliant on the basis of the dominant scientific paradigm (i.e., reductionism), while all the time proclaiming the opposite: ecology is referred to as the "holistic" science *par excellence* (Odum 1971, Ramade, 1992, Patten 1993, Patten 1993, Odum 1993). The world of ecological discourse does not always coincide with the world of experience or methodological practice.



There is a "radical difference" between holism and reductionism which is not always perceived as such. A typical example of this misinterpretation is to be found in the protracted scientific labours of the Odum brothers (E.P. Odum 1969, 1971; H.T. Odum 1957; H.T. and E.P. Odum 1957), which helped to structure the IBP (International Biological Program). The cornerstone of what we might in future call the "Odumian paradigm" is the concept of the ecosystem.

Traditionally, the authorship of the term "ecosystem" is attributed to Tansley (1935). He defines the ecosystem as follows:

> But the more fundamental conception is, as it seems to me, the whole *system* (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense. (...) It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth (p. 299).

We should not forget, however, that concepts belonging to the same semantic family both preceded and followed this definition. Terms such as "microcosm" (Forbes 1887), "holocoen" (Friedrichs 1930) and "biosystem" (Thienemann 1939) share a conceptual core with the term "ecosystem": that is, they all represent the definition of a unity of reference, of an object of study where it is possible to link biotic and abiotic factors formally. This unity is identifiable by its relative autonomy, by the structures which are typical of its levels—spatial (repetitive and homogeneous surfaces), specific and trophic—and by its characteristic functions (the flow of matter and energy).

Tansley's aim was to bring into relief the organicist concept of Clements "complex organism" (1916), which had been championed several times by Phillips (1931, 1934, 1935). Tansley's concept is fundamentally anti-holistic in so far as, for him, the problem of emergentism is a non-issue, and in that he uses physics as his explanatory field of reference. And here, suddenly, is an epistemological paradox. Tansley's concept of the ecosystem was employed by E.P. Odum in his explicit proposal of a genre of ecology which, in its intentions at least, is holistic (1953, 1959, 1971).

The first chapter of *Fundamentals of Ecology*, in all three editions, represents the exposition of the core of major concepts which enable one to extract phenomenological reality from a given point of view, to choose certain methodologies and to develop specific scientific theories.

For the third edition, Odum deliberately modified the grouping of the chapters, which probably reveals an evolution in his way of thinking. Each edition begins with an analysis of the ecosystem; while analysis of

the organization in terms of "population" precedes that of "community" in the first and second editions, the opposite approach has been chosen for the third edition. It would appear that following the publication of the first two editions, the importance given by Odum to the principle of wholeness was such that it logically became necessary to deal with the "community/whole" before the "population/part". The pre-eminence of the whole is such that, even in the way the arguments are presented, the author chooses systematically a "downward" itinerary in preference to an "upward" one. It is easy to affirm that the epistemological basis of the first edition is much less thoroughly detailed and developed in contrast to the second and third editions, which appear much more structured. It is simply necessary to compare certain key passages of the three editions for this to become abundantly clear. In the first edition, Odum asserts that:

> Because ecology is concerned as much with the biology of *groups* of organisms (that is populations and communities) as with individual organisms, if not more, it would perhaps be better, and more in keeping with the modern emphasis, to define ecology as the study of the structure and temporal processes of populations, communities, and other ecological systems, and of the interrelations of individuals composing these units [Odum's italics] (1st ed., p. 4).

In the second and third editions, the individual organisms disappear and are replaced by "functional process". We will cite the whole of the corresponding passage in order to better convey the profound significance of the transformation:

> Because ecology is concerned especially with the biology of *groups* of organisms and with *functional* processes on the lands, in the oceans and in fresh waters, it is more in keeping with the modern emphasis, to define ecology as the study of the structure and function of nature (it being understood that mankind is a part of nature) [Odum's italics] (2nd ed., p. 4; 3rd ed., p. 3).

Odum's approach, at least at the level of its intentions, is not limited to an analysis which would separate out successive levels of integration, but on the contrary, brings out the links between the parts and the whole system, considering that the organisms "are intimately linked functionally in ecological systems, according to well defined laws" (pref. 2nd ed., p. 9). By extending Lindeman's trophic-dynamic vision, Odum is seeking "clarification of the basic energy relationships of the ecosystem as a whole (...)" (1st ed., p. 89 ; 2nd ed., pp. 147-148), emphasizing the laws which govern the flow of energy between the different compartments of an ecosystem.



In the first edition the "epistemological manifesto" concentrates on the links which may exist between ecology and other scientific disciplines, biological or not. The complementary nature of ecology and genetics is underlined: since "the organism [is the] result of interaction of heredity and environment", the research should try to define the various influences of "heredity mechanisms" and "ecological factors" (p. 5) in studied phenomena. Odum also underlines the main affinities between ecology and physiology as "both deal with functions", while pointing out the essential methodological differences between the two disciplines:

> As an illustration of the difference in approach, let us consider the heart. The physiologist is primarily concerned with the mechanism of its contractions and with the nervous, endocrine, and other factors controlling its beat and rate. The ecologist, on the other hand, would be primarily interested in the heart as a possible "physiology-of-the-whole" indicator. That is, the ecologist might wish to use the heart rate as an index of the way in which the organism as a whole responds to some environmental factor, for example, temperature (p. 6).

Finally, he indicates a strong and declared propensity towards physics and chemistry:

> In common with all of biology, ecology leans heavily on the physical sciences. Developments in chemistry and physics continually provide new techniques and influence ecological theory. (Ibid.)

In the last two editions, the analysis of the links between ecology and other scientific fields and the declaration of the physicalist tendency completely disappear. This analysis is replaced by an explicit presentation of the theory of the levels of organization accompanied by a graphic missing from the first edition (2nd ed., pp. 6-7; 3rd ed., pp. 4-5). The theory of the levels of integration is naturally present in the first edition, but the awareness of its importance and its explicit representation emerged gradually. However, the idea of the arbitrary and instrumental nature of this theory is present even in the first edition:

> There are no sharp boundaries between any of these subdivisions which represent ways of looking at ecological problems rather than cut and dried scientific fields. It is merely convenient and profitable to approach the study of ecology from different level of complexity (p. 7).

The author expresses himself in the same way in the second and third editions on what he regards as the arbitrary character of the theory of levels of integration:

> It is important to note that no sharp lines or breaks were indicated in the above "spectrum", not even between the organism and the population. Since introductory biology courses usually stop abruptly with the organism, and since in dealing with man and higher animals we are accustomed to think of the individual as the ultimate unit, the idea of a continuous spectrum may seem strange at first. However, from the standpoint of interdependence, interrelations and survival, there can be no sharp break anywhere along the line. The individual organism, for example, cannot survive for long without its population any more than the organ would be able to survive for long without its organism. Similarly, the community cannot exist without the cycling of materials and the flow of energy in the ecosystem (2nd ed., pp. 6-7 ; 3rd ed., p. 5).

Thus, Odum's attempt to create a holistic approach (a term which will only appear in the third edition) materializes above all within his assertion that levels of integration corresponding to the concepts of ecosystem, of community and of population are functionally interlocked. The actual definition of the concept of ecosystem evolves between the first and third editions. The ecosystem is initially defined in the following way by Odum:

> Living organisms and their non living (abiotic) environment are inseparably interrelated and interact upon each other. Any entity or natural unit that includes living and non living parts interacting to produce a stable system in which the exchange of materials between the non living parts follows circular paths is an ecological system or ecosystem. The ecosystem is the largest functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. A lake is an example of an ecosystem (1st ed., p.9; 2nd ed., p. 10).

While the second edition offers virtually the same definition, if we discount the fact that the ecosystem is no longer defined as "stable system" (by no means an insignificant modification), the third edition explicitly introduces the concepts of energy flow and trophical structure. Thus the idea that the "whole" exists as a structured entity is put forward:

> Living organisms and their non living (abiotic) environment are inseparably interrelated and interact upon each other. Any unit that includes all of the organisms (i.e., the "community") in a given area interacting with physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and non living parts) within the system is an ecological system or ecosystem. (...) The ecosystem is the basic functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth (p. 8).



In this way, Odum proposes a far more highly developed definition of the ecosystem than that of Tansley. There is undoubtedly a large area of convergence in that both authors claim to define the basic units or entities of nature, but Odum views things from a clearly emergentist point of view, or at least intends to, while Tansley's concept of the ecosystem is explicitly anti-emergentist. Indeed, when Odum analyses the concepts of "population" and "community" in the chapter "Introduction to population and community ecology", by using the typically holistic metaphor of the forest, he relates it to the theory of emergence:

> (The) important point to stress is that the population and community are real entities, even though one cannot usually pick them up and put them in the collecting kit as one would collect an organism. They are real things, because these group units have *characteristics additional to the characteristics of the individuals composing them*. The forest is more than a collection of trees. The whole is not simply a sum of the parts (...) [Odum 's italics] (1st ed., p. 88; 2nd ed., p. 146; 3rd ed., partially integrated into the first chapter)[11].

However, while doing so, the author is setting up a serious logical contradiction, which will lead him to confuse the concept of "collective properties" with that of "emergent properties", as his definitions of the concept of population and community show. Odum defines population as follows:

> The population, which has been defined as a collective group of organisms of the same or closely associated species occupying a particular space, has various characteristics which, although best expressed as statistical functions, are the unique possession of the group and are not characteristic of the individuals in the group. Some of these properties are: density, natality (birth rate), mortality (death rate), age distribution, biotic potential, dispersion, and growth form (1st ed., p. 91; 2nd ed., p. 149; 3rd ed., p. 172).

The definition of community follows the same logical structure:

> A biotic community is any assemblage of populations living in a prescribed area or physical habitat; it is a loosely organized unit to the extent that it has characteristics additional to the individual and population components (1st ed., p. 181; 2nd ed., p. 245; 3rd ed., p. 140)[12].

In these two definitions, the properties which concern the group (system, wholeness, integrative higher levels) and which do not concern individuals (components, parts, integrative lower levels) which make it up, are