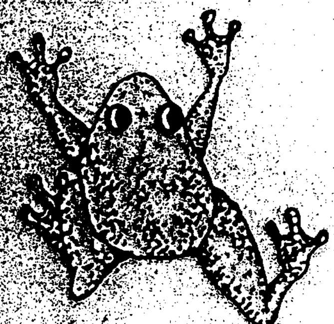

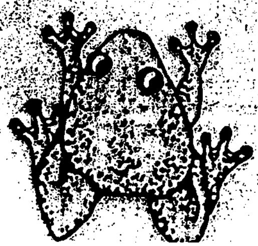

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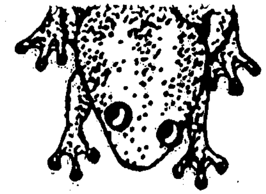
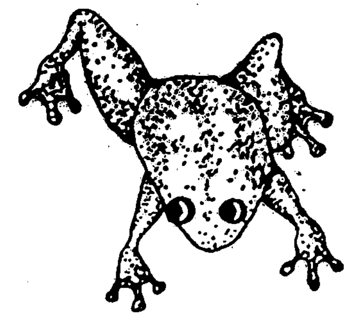
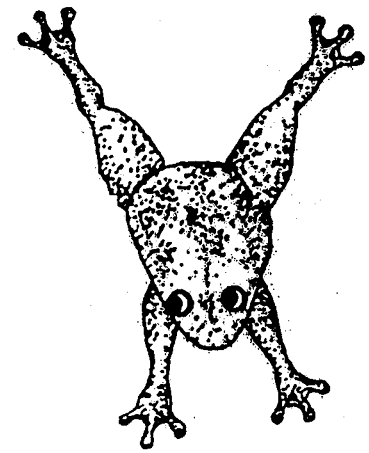
DUS VITALIS / vol. III / núm. 5 / 1995







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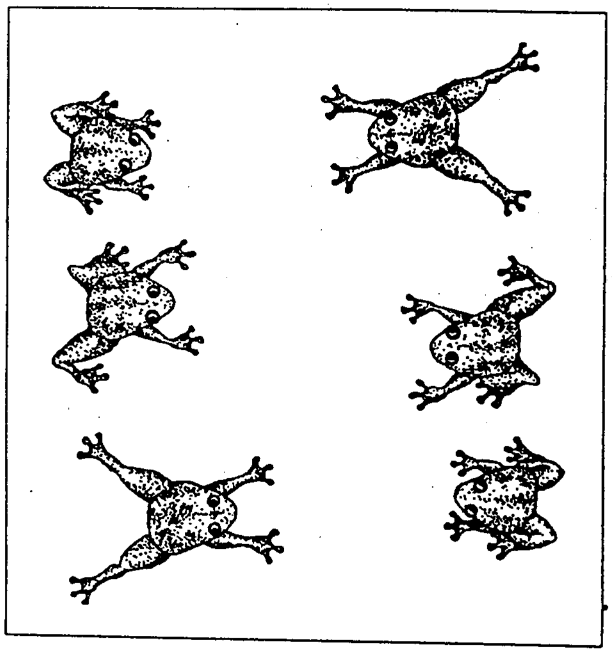

LUDUS VITALIS / vol. III / num. 5/ 1995 / ISSN 1133-5165

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-

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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 Feibleman (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 mentioned. Odum does not make it clear whether he considers these properties to be "collective" or "emergent". It is, however, an essential difference, and one which Odum does not perceive: by definition, the emergent properties of a given integrative level cannot be deduced from the study of its components, while collective properties, even when they are not the characteristics of individuals with statistical functions, can be inferred (deduced) from the combined characteristics of all the individuals of a population or community. One of Salt's analyses (1979, p. 145) helps clarify this fundamental point:

> (The) age-class structure of a population is a result of the combined ages of all the individuals which make up the population. Similar remarks could be made about such other properties as the birth rate and death rate of a population. For communities, the species diversity index represents a summation of the proportional contribution of each of the individual species populations. In all these cases, the property is determined through an examination of the characteristics of the components of the ecological unit. Such properties are therefore not emergent, but collective [13].

Definitions of collective and emergent properties, which are formally similar, cease to be so on a methodological level. The explanation of a characteristic requires different methods depending on whether it is collective or emergent. Collective properties can be understood by the classic research strategy of additional analysis (that is, breaking up a complex object into its component parts and extrapolating, from the sum of these, the characteristics of the object as a whole), while the study of emergent properties requires very different methods.

In the two later editions, Odum emphasizes his epistemological development in considering the relationships which exist between the theories relating to different levels of integration: "(...) no one level is any more or less important, or any more or less deserving of scientific study than any other level" (2nd ed., p. 7; 3rd ed., p. 5). This view forms the basis of the representation usually accepted as "epistemological holism" and stands in contrast to "epistemological reductionism", according to which the theories and the laws relating to specific levels of integration can be "reduced" or "explained" in terms of theories and laws which belong to more "fundamental" fields of science (Ayala and Dobzhansky 1974, Introduction, p. IX). Odum's rejection of epistemological reductionism becomes clear in the following statement: "the findings at any one level *aid in the study of another level, but never completely explain the phenomena occurring at that level*". [Odum's italics] (2nd ed., p. 7; 3rd ed., p. 5).

Continuing his analysis in the third edition (pp. 5-6), Odum goes into his notion of the relationships between laws and theories relating to different integrative levels in even greater depth, and he clarifies his epistemological holism still further:

> In other words, not all attributes of a higher level are predictable if we know only the properties of the lower level. Just as the properties of water are not predictable if we know only the properties of hydrogen and oxygen, so the characteristics of ecosystems cannot be predicted from knowledge of isolated populations; one must study the forest (i.e., the whole) as well as the trees (i.e., the parts). Feibleman (1954) has called this important genalization the "theory of integrative levels" [14].

Implicit in these statements is the notion generally known as the "theory of emergence", which, as we have seen, forms the logical and ontological core of the "theory of integrative levels". I should emphasize that an ecologist such as Odum felt it necessary to refer to a philosopher of science such as Feibleman (1954, "Theory of Integrative Levels", *The British Journal for the Philosophy of Science* 5, 59-66). Odum, in order to give his own approach structure, takes up essentially philosophical concepts, and works them into the scientific discipline of ecology, and thus gives them official weight several decades after the last philosophical debates on the subject.

Moving on to an analysis of the methodological approach advocated by Odum, which one might expect would invite research methods on broadly holistic ontological lines, we should point out that the author, in the chapter "Systems Ecology: the systems approach and mathematical model in ecology" of the third edition, puts forward a form of analysis of systems as follows:

> As the formalized approach to holism, systems ecology is becoming a major science in its own right for two reasons: (1) extremely powerful new formal tools are now available in terms of mathematical theory, cybernetics, electronic data processing, and so forth, and (2) formal simplification of complex ecosystems provides the best hope for solutions to man's environmental problems that can no longer be trusted to trial-and-error, or one-problem-one-solution, procedures that have been chiefly relied on in its past (p. 276).

Thus Odum makes cybernetics his dominant theme. His aim is to propose a holistic model—that is, a model that takes into consideration "the ecosystem as a whole" (1st ed. p. 89; 2nd ed. p. 148). However, by using the cybernetic model, he paradoxically puts himself in a position which contradicts his own basic epistemological arguments. The following pas-

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sage, and the corresponding diagram, are of major importance in this respect:

> Ability to describe and predict behavior of ecological systems by the use of models depends largely on a principle of all systems: that of *hierarchical organization* (or principle of integrative levels). This principle, discussed in chapter I, states simply that it is not necessary to understand precisely how a component of a system is structured from simpler subcomponents in order to predict how it will behave. Thus, it is not necessary to have full comprehension of biochemistry in order to describe the physiology of cells, nor is it necessary to understand physiology completely in order to describe the dynamics of animal populations. The concept of hierarchical organization is illustrated in figure 10-1 in terms of "black boxes".

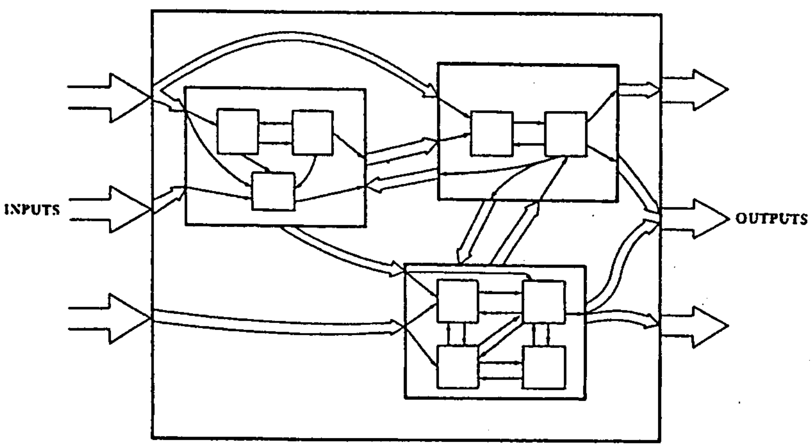

Figure 10-1. Processes and structures in ecological systems can be thought of as "black boxes" consisting of simpler black boxes, in a hierarchy of complexity. This diagram shows three levels of organization. By observing the input-output relationship for any box, one may be able to predict its behavior without understanding how it is put together from simpler components (p. 277)[15].

Odum believes that it is possible for cybernetic models to respect the complex nature of hierarchical organization, while allowing a certain economy of effort in analysis. Odum's assessment is in error, however, for his reference to Feibleman can only make sense if the proposed models are able to take into account and to explain emergent properties.

It is certainly true that cybernetic models consider the feedback loops which exist between sub-systems on the same level and the hierarchical interdependence of feedback loops which link different levels of organization, but these models do not make clear which integrative levels need to be taken into consideration in order to explain an emergent property observed on a given level. By side-stepping this issue, Odum is pushing all truly holistic concerns aside.

Furthermore, I should underline the fact that, in cybernetic models, the inputs taken into account at each level of organization are the results of an *a priori* choice which risks being arbitrary. Odum, indeed asserts that:

> Contrary to the feeling of many skeptics when it comes to modelling complex nature, information about only a relatively small number of variables is often a sufficient basis for effective models because "key factors" (...) often dominate or control a large percentage of the action (3rd ed., p. 7).

A "key-factor" is not an ontological characteristic determined once and for all, but rather a contextual characteristic. Only by halting the variable time[16] and by interrupting the network of interaction can we abstract an element from the system and a priori define it as a key factor or otherwise. In this respect, Odum's thought has undergone a subtle but absolutely fundamental shift. Indeed, by implying that a complex whole can be properly understood simply by taking into account basic components with respect to their dominance in the trophical network or to their control function, Odum would seem to be suggesting that an approach is holistic simply because it does not need to analyze all the components of a system in order to understand it in its entirety. It is therefore legitimate to suppose that Odum is likening reductionism to exhaustivity. But in reality, what he is proposing is a simplification. If there is no doubt that a model is necessarily a simplification, it follows that its value can either be reductionistic or holistic.

In the end, cybernetic models, with their potentially global significance with respect to the assessment of the variables of ecological systems, are in fact used to an end which is epistemologically reductionistic. Models of this type are used to describe the trophical networks of an ecosystem from the point of view of energy, and from the perspective of cycles of matter. The prototype of this form of analysis goes back to

Hutchinson; Lindeman formalized and extended the form, and Patten (1972) and H.T. Odum (1982) developed it to its highest level of sophistication.

This type of analysis, legitimate when we wish to consider the dimension of energy and that of the flow of matter inside ecosystems, becomes completely illegitimate, reductive and obscurantist when it is perceived as the one true form of analysis of ecosystems. In practice, this exclusivist tendency goes so far as to consider as relatively unimportant the fact that it destroys the structural and functional specificity of the levels under consideration.

One might think that this whole discussion is out of date, since the systemic approach in biology and ecology has decided on its tools. In our opinion, however, this is not so. The state of the methodologically holistic approach to the discipline of ecology has recently been very well described by Loehle (1988, pp. 100-101):

> Unfortunately, holism means at least the following four things in ecology:
> 1) The view that ecosystems are integrated, interconnected systems with their own laws and organizational principles. It is not necessarily denied that reductive explanations are possible, but merely that they are so impractical that the higher level system should be studied phenomenologically.
> 2) The practice of embedding a problem in larger context. Thus when designing a waste-treatment pond, holism might mean keeping in mind that migratory ducks might use the pond and be killed. It is this type of holism that ecologists complain is lacking in civil engineers and urban planners.
> 3) A black box approach which includes questions such as: What is the nutrient loss response of a whole watershed to acid rain? The watershed is treated as an input-output system without detailed concern for mechanisms or particular species. This is an empirical approach that does not necessarily seek laws or principles (in contrast to 1).
> 4) Detailed systems analysis such as ecosystem models that are mechanism-oriented. This approach is holistic because it includes all components and processes.

Strictly speaking, only the first definition coincides to any degree with the theory of emergence as it is proposed by Feibleman and Novikoff. The second definition can be accepted as holistic, but only in a very broad sense. Unfortunately, neither the first nor the second definition can be developed into a real systemic methodology. Indeed, the first limits itself to a warning as to the limits of epistemological reductionism, whereas the second is, methodologically speaking, completely trivial. The third definition coincides with the cybernetic models proposed by Odum and the fourth confuses holism with an approach which seeks exhaustivity (an impracticable theoretical ideal).

Salthe (1995: private correspondence) suggests that Odum confused two distinct interpretations of hierarchy theory when discussing Feibleman. According to Salthe, Odum believed that Feibleman was referring to a "scalar hierarchy", while in fact, Salthe maintains, Feibleman was concerned with the hierarchy theory of level of integration (which, according to Salthe is intrinsically linked with the "hierarchy of specification"[17]). More particularly, he claims that Odum (1971, figure 1.2) proposed a hierarchical perspective based on scalar levels, while nonetheless referring to them as integrative levels. It should be noted that, if one accepts Salthe's criticism, Odum reaffirms this logical inconsistency in a recent work (1993, chapter II). In effect, he once again proposes a hierarchical concept where the levels of analysis can be seen as scalar levels wrongly termed "levels of organization". Having said this, Salthe's logical process would in my opinion involve a "displacement" of the semantic value (integrative levels, emergence) of epistemological emergentism (which is fundamentally linked to evolutionist theories) from the point of view of development theory (epigenesis). This reading allows him to identify two types of emergence, one predictable (developmental emergence), and the other unpredictable (evolutionary emergence) (see also Lillie 1948, pp. 121-126). I believe, on the other hand, that the core of the problem concerns the position that Odum adopts with regard to the concept of emergence (which is formally accepted) and its methodological repercussions (which are completely non-existent).

CONCLUSION

In Odum's work the two spirits present in the history of ecology exist side by side, at least to a certain extent: the systemic, globalistic, holistic component prevalent in the work of Clements, Phillips, Allee, as well as in that of other authors of the Chicago group, and the reductionistic component of ecology represented by Tansley, Hutchinson, Lindeman, and Margalef. Any mediation between these two visions of the world, their methodologies and their epistemologies is very difficult, and perhaps even impossible, to effect. Odum's mistaken interpretation of the collective properties of community and population as emergent is the most obvious evidence of this theoretical aporia.

The ecosystem is mainly interpreted from the perspective of energy, as Lindeman conceived it, using a holistic ontology which has at its core the concept of emergent properties. Thus it is this "emergentist" notion that the reductionistic approach disowns, whether at an ontological, a methodological or an epistemological level.

According to reductionism in the ontological field, the ultimate essence of any given integrative level is made up of individual units from a level lower than the one under consideration. From a methodological point of view, the properties of a given integrative level can be foreseen and/or explained from its components: this is the case with the evaluation of energy of ecosystems derived from the methods of Lindeman, who uses an approach based entirely on additional analysis. From an epistemological point of view, the laws of integrative levels relating to biology should be replaced by laws belonging to more fundamental levels, that is, ultimately, laws of biophysics or even chemistry and physics. On the other hand, according to ontological holism, each level of organization has a value in itself, for it is characterized by the acquisition of one or more new emergent properties which increase the complexity of the system. From a methodological point of view, holism cannot limit itself to a form of additional analysis of the lower integrative level, but rather must consider at least three integrative levels. Lastly, from an epistemological viewpoint, there are no fields of science to which other fields should be reduced.

Odum's position can be defined as crypto-reductionist for, while his vision is holistic on ontological and epistemological levels, the author proves to be purely reductionist in his methodology. It is truly paradoxical that an author as strongly involved in epistemological holism as Odum confines himself to understanding the ecosystem essentially in terms of energy. This means that, even if the physicalist tendency is no longer explicitly stated in the second and third editions, a permanent trace of it remains throughout. In this approach, cybernetics is the tool used to over-simplify the ecosystem, by reducing it to the assessment of components providing the greatest transfer of energy and to some supposed key factors.

The "theory of integrative levels" defined by Feibleman is much more complex than the one proposed by Odum. Feibleman asserts that at least three levels must be taken into account in the analysis of a given integrative level: obviously, the level which has been chosen as the principal subject for study, and the levels immediately above and below it. This may seem obvious, but how many ecological research studies have explicitly followed this approach? Understanding the "structure" of populations, for example, involves knowledge of the growth, development, physiology, behavior, etc. of the individuals which make them up. At the same time, one has to be equally familiar with the structure of the communities which populations fit into, so that it is possible to know how they "function", if only because most populations are dependent for food upon, or are fed on by, other populations. This approach does not deny the importance of the study of lower integrative levels, but at the same time it affirms the legitimacy and the necessity of a phenomenological analysis of the chosen level as a primary subject for study, and it affirms equally the absolute necessity of taking the higher integrative level into account. In my opinion, only this methodologically integrative approach deserves to be termed "holistic".

Reductionism and holism represent two opposing approaches which are not always perceived as such. A lack of understanding of their distinctive characteristics and, at the same time, more or less conscious attempts to find a middle point between these two world views have led to profound aporia. To illustrate the existence of this epistemological obstacle we have used an example from the field of ecology as an archetypal instance. However, the epistemological clash between holism and reductionism affects every scientific discipline. Some are naturally inclined towards reductionism, while others lean towards holism. Systemic ecology has made its choice: "reductionist holism". This latter forms a kind of scientific paradox which is not recognized for what it is.

One should not conclude, however, that this is an isolated instance, and that at others levels of integration "holism" may be presented as a truly "emergentist" approach. It might appear that to speak of "emergentist holism" would be tautological and semantically redundant, but is by no means the case.

At any given integrative level, a reductionist approach is completely coherent. Its ontology, methodology and epistemology are linked in a way which is almost "organic" (an irony of science...). An emergentist approach, however, runs the risk on methodological and epistemological levels of forgetting its ontological presuppositions and metamorphosing into a hybrid form: "reductionist holism". The crux of the concept of emergence disappears and becomes secondary to attempts to explain a given level of integration by means of laws and theories from lower levels.

In conclusion, one might ask the question: is this hybrid approach a kind of oxymoron—a fine nuance of thought rendered explicit in the form of an apparent contradiction—which may soon become a philosophical and scientific truism, or is it simply a chimera (χιμαιρα) of philosophy?

Our answer would be as follows: "Reductionist holism" must be recognized as a sort of "epistemological monstrosity"—not one to be slain by a new epistemologist Bellerophon, naturally, but one which must nonetheless be unmasked. If this is not done, proponents of this kind of approach, with their problematic similarities with an emergentist world view, will continue to fail to appreciate that they are unwitting reductionists (Séméria 1993). The failure to recognize a confusion on this scale makes the possibility of constructing a genuinely emergentist approach ever more remote.

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NOTES

1 Working from this idea, Clements (1916) formulated the concept of "climax" which he understood to be a vegetal formation which has reached maturity. Phillips (1931; 1934; 1935) was one of those most active in the defense of Clements' organicism. Phillips' excesses provoked a spirited response from Tansley (1935) and his invention of this concept of the ecosystem.

2 Tansley, A.: 1935, "The use and abuse of vegetational concepts and termes", *Ecology*, 16, 284-307. See also: Egerton, (1977,1983,1985), Worster (1977), Acot (1988), Deleage (1991), Drouin (1991).

3 Allee, Emerson, O. Park, T. Park, and Schmidt (1949). This work, also know by the acronym AEPPS from the authors' names, unfortunately had its success limited by the success of Odum's book.

4 The term "cybernetics", that appeared for the first time in Wiener (1948), was coined from the Greek word *kubernetes*, meaning "steersman", to refer to the action of governing or directing.

5 It should be stressed that the subject of Margalef's study was not so much ecosystems in themselves as the individuals which make them up (1968, p. 4).

6 Engelberg and Boyarsky (1979, pp. 317-324) define a cybernetic system as one where "the action of one element of the system ultimately exerts an influence upon every other element of system. We may say, therefore, that there exist links between all the elements of the system"(p. 317). They refute the idea that the ecosystem (or the biosphere) could be cybernetic in nature, since "that a system contains one or more feedback loops does not in itself mean that it is a cybernetic system (...). It is only when such loops systematically and integratively invest all parts of a system via an information network that a system becomes 'cybernetic'" (p. 320). They reject the analogy between organisms and ecosystems since latter lack a permanent information network (pp. 321, 322).

Knight and Swaney (1981, pp. 991-992) oppose this analysis, as they perceive trophical network and cycles of matter to be an archetypal information network within the ecosystem.

Jordan (1981, pp. 284-287) considers that the symbiotic relationships in a tropical forest represent an information network which allows its survival and thus makes it a real system.

Patten and Odum (1981, pp. 886-895), along with Engelberg and Boyarsky, refute the identification of the concepts of organism and ecosystems, but reaffirm the cybernetic nature of ecosystem by considering the information network which is composed of all the factors, processes and interactions (gravity, conservation, dissipation, limiting factors, pheromones, etc.) which govern the transformations in the flow of matter and energy.

7 The word "holism" derives from the Greek term *olos*, meaning "whole". The invention of the term "holism" is generally attributed to Smuts (1926). The sole dissenting voice is that of Cassirer (1946), who proposes J.B.S. Haldane as the inventor, suggesting that the term was coined in a presidential address to the physiological section of the British Association in Dublin in 1908.

8 The extent to which the many ideas which are understood by holistic thought are present throughout the history of philosophy cannot be fully explored in this article, but will form the subject of a future work. For the present, we shall content ourselves with recalling that, throughout its long history,

holism has considered that wholes, such as organisms, individuals, societies, nations and even reality itself, are made up of parts which are dynamically linked: an interrelation which engenders qualities or characteristics which are not necessarily present in the parts themselves. In the works of ancient writers, whatever the object of analysis happens to be, it is the "whole" which tends to shape and determine the "parts", whereas in more modern authors, the relationship between the whole and the parts is reciprocal, as is clearly demonstrated by the propositions of Novikoff (1945) and Feibleman (1954), among others.

9 Engels (1875-1876), *Dialectics of Nature*, International Publisher, New York, 1940. [Translated and edited by Clemens Dutt with a preface and notes by J.B.S Haldane, F.R.S.] In fact, the first edition was published in Russian in 1925, but the preliminary writings date back to 1875-1876.

It has not been sufficiently noted that dialectical materialism encompasses two senses of emergence: the classical sense, relating to the properties which result from relationships between different types of component (in chemistry, for example, $H_2 + 1/2\ O_2 \longrightarrow H_2O$); and a second sense, relating to the combination of a greater or smaller number of components of the same type (in chemistry, for example, $O_2 + 1/2\ O_2 \longrightarrow O_3$).

10 Strictly speaking, one should not use either of the terms "system" or "organic whole" in this context.

11 According to the author, levels of integration are so useful a methodological abstraction that one may consider them on an epistemological level as real entities.

12 In the third edition, the reference to the theory of emergence is explicit: after defining the community, Odum adds " ... (see principle of integrative levels p. 6)".

13 The confusion between collective and emergent properties is long established. Odum, following Allee (1949, p. 264), takes up the definition given by Pearl (1937). Moreover, the same confusion can be found in more recent texts. Romme (1982), following Odum's (1971) example, identifies the sum of the characteristics of populations and communities as emergent properties. Damuth and Heisler (1988) propose a natural selection which occur simultaneously on many levels, i.e., one which involves both organisms and the groups to which they belong. Those authors who are aware of the difference between collective and emergent properties nonetheless define population density as an attribute with two values, depending on the aims of the analysis. That is to say that they define it as both a collective and an emergent property, forgetting that, by definition, one cannot attain emergent characteristics for the expedient of additional analysis. Similarly, Johnson (1992) defines, among other things, specific diversity and the biomass as emergent properties of an ecosystem, where both are in reality typical statistical properties derived from the sum of all the individual characteristics.

14 Note that this passage does not appear in either the first or second edition.

15 This more specialised chapter was not written by Odum, but by C. J. Walters. At any rate, Odum's introduction to the chapter, from which we have reproduced an extract, Walters's reference to the epistemological manifesto of the work, which contains the theory of integrative levels, and the presence of cybernetic models throughout the text, demonstrate the continuity of this chapter with the rest of the work.

16 On the subject of the absence of the variable time from E.P. Odum's ecosystem model, Blandin and Lamotte (1989, p. 37) state that: "la non spatialité du concept d'écosystème s'accompagne d'une non localisation dans le temps: l'écosystème d' Odum est sans lieu et sans histoire". Similarly, Taylor and Blum (1991, p. 284), discussing H.T. Odum's diagrams of energy flows (he designed most energy models in E.P. Odum's text), maintain that: "In Odum's ecosystem diagrams, however, space and time remain virtually unrepresented. The separation of trophic compartments is not intended to connote the spatial location of the plants, herbivores, and so on. The flow occurs in time, but is constant. Like all equilibrial formulations they show no history or prospect for change. The only spatial reference, beside the sunlight entering at an angle from above, is to inside and outside. The whole system is inside the frame, and each trophic compartment is contained within a box".

I should like to offer a final word on the energy models of H.T. Odum. The inconsistency which exists between his declared intentions and actual research methods has recently been highlighted by Mansson and McGlade (1993[a]). These authors demonstrate that, by employing a concept of energy taken from physics, and in particular from thermodynamics, any attempt to construct a model of ecosystems by holistic analysis is doomed from the beginning. This is due to the presence of various types of energy in ecosystems (i.e., solar, chemical and caloric) which cannot be reduced to a single form of energy (pp. 589, 593). On the other hand, Patten (1993[a]) defends H.T. Odum's work, declaring him to be a representative of a truly holistic approach. He supports this view, paradoxically, by treating the main element of H.T. Odum's work, that is to say, the energy analysis of ecosystems, as completely secondary (pp. 599, 601). Rather, he identifies the application of the concept of organization of complex systems to ecosystems as the specifically holistic aspect of Odum's work. This stance achieves the opposite effect to the one intended, since it runs the risk of portraying H.T. Odum not as an ecological artist (pp. 597, 602) but as simply continuing or merely reaffirming the holistic tradition in biology. His only unique contribution in this scenario would be to have chosen ecosystems as his area of study. To deny the importance of the contribution of H.T. Odum's energy analysis would be to forget, for example, that research into emergent properties in the study of the Eniwetok Atoll led to the declaration that energy evaluation is the true emergent property of the ecosystems (E.P. Odum, 1977, p. 1290; see also: Odum, H.T. and E.P. Odum, 1955).

A single conclusion can be drawn from these two arguments: To try to base a holistic approach on "basic reductionist science" (Patten, 1993 (a), p. 598) is, in reality, to be scarcely a holist at all, for ecology must find its own laws, which will be based on those of physics, but which will not be reducible to the laws of physics. If, on the other hand, one limits oneself to energy analysis, one may well be studying the ecosystems as a whole, but as an area of physics and not as an area of ecology.

17 Salthe (1985, 1988, 1989a, 1989b, 1991a, 1991b, 1993; see also Elderedge and Salthe 1984, Blitz 1992) proposes a logical distinction between two types of hierarchy: hierarchies of scale and of specification. The author maintains that one of the reasons why these two types of hierarchy are confused is that both are referred to as "levels of integration" (or "organization"). For his part, and in contrast to classical emergentists, Salthe restricts the use of the term 'integrative levels' to refer to the hierarchy of specification.

The term 'scalar hierarchy' is generally used by systemist scientists at widely differing levels of analysis. It denotes the relationships which exist between the "whole" and the "parts" of matter (physical particles, atoms, molecules, cells, etc.). One the one hand, higher levels restrict and constrain the lower levels, and the other, these lower levels "represent the base conditions" for the behavior of the higher levels (Salthe 1985, chapter IV; 1991a, 1991b). The hierarchy of specification, in contrast, refers to classes and subclasses interlocking within one another (e.g., inorganic, organic, spiritual; see Salthe 1991a, p. 253): classes which represent emergent orders. According to Salthe, it is necessary to take into account three levels of analysis in order to assess a given level of a scalar hierarchy (see also Feibleman 1954), while only two are needed for a given level of a hierarchy of specification.

Even if one accepts the logical dichotomy between two completely different types of hierarchy, one is faced with problems with no simple solution. First, in the case which Salthe calls a hierarchy of scale, it is easy to maintan that it is extremely rare to find two authors from the same scientific discipline who employ the same series of levels of analysis. Second, it is quite clear that levels of scale do not necessarily have an ontological reference. They are "epistemological constructions" whose purpose is to aid scientific research. How can one judge the scalar levels of "population" and "community", for example, or even "ecosystem"? Are they abstract or concrete entities? Put in another way, the various levels which make up scalar hierarchies are "asymptotic abstractions" which have different reality value. There is a confusion between levels with a high reality value (e.g., cell, organism, ecosphere) and others with a lower reality value, or, if you prefer, one which is less easy to determine (e.g., population, community, ecosystem, biogeographical region). In particular, levels of analysis such as "population" and "community" should rather be considered as "classes" ("a class of (...) things is a number of (...) things that are considered as a group together because they have similar characteristics": *Collins Cobuild English Language Dictionary*), as "categories" rather than as "parts nested within a whole" (Salthe 1991a, p. 260).

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ABSTRACT

The contrast between the strategies of research employed in reductionism and holism masks a radical contradiction between two different scientific philosophies. We concentrate in particular on an analysis of the key philosophical issues which give structure to holistic thought.

A first (non-exhaustive) analysis of the philosophical tradition dwells upon:

a) the theory of emergence: each level of organization is characterized by properties whose laws cannot be deduced from the laws of the inferior levels of organization (Engels, Morgan);

b) clarification of the relations between the "whole" and the "parts" (Woodger, Needham);

c) the ontological or epistemological nature of the emergent properties: are they a phenomenological reality or solely an artifact of the state of our knowledge? (Pepper, Henle, Hempel and Oppenheim);

d) the proposition of the holistic theoretical and methodological model (Novikoff, Feibleman).

I then go on to examine the differences that exist between the reductionist and the holistic approaches at various levels of analysis: that is to say, the differences which affect their ontologies, methodologies and epistemologies respectively.

I attempt to understand the spirit of a holistic approach to ecology by analyzing the major work of E.P. Odum, *Fundamentals of ecology* (1953, 1959, 1971). I set forward what might be meant by the "holistic approach", which is implicated in all the different levels of organization at which the problem of "complexity" is debated.

Ecology presents itself as an "holistic science", and Odum's book offers a vision of the world which dates far back in the history of philosophy. By looking at the three different editions of this fundamental text on ecology, we may become aware of the evolution of Odum's thought. In fact, only in the third and last edition is there a conscious appropriation of the holistic approach (by using the theoretical models of Feibleman who, for his part, refers to Novikoff).

However, even when formally referring to the theory of emergence (that is to say, the ontological nucleus of every holistic approach), Odum's systemic analysis presents the same logical errors, which push him back into the reductionist domain.

Above all, in his examination of the main concepts of "population", "community" and "ecosystem", there is a misunderstanding of the profound difference between "collective properties" and "emergent properties".

Moreover, the cybernetic models of Odum's systemic analysis (introduced into ecology by Margalef) allowed him to vastly oversimplify his methodological task; in fact, neither how many levels nor which levels of organization are fundamental for the study of each individual level is clearly marked.

Finally, Odum analyses the ecosystem as composed of energetic flux and cycles of matter, referring to the trophic-dynamic vision of Lindeman. That is to say, in my opinion, he juxtaposes a reductionistic methodology and epistemology to an holistic ontology.

RESUMEN

"HOLISMO REDUCCIONISTA": ¿UN OXÍMORON O UNA QUIMERA FILOSÓFICA DE LA ECOLOGÍA DE SISTEMAS DE E.P. ODUM?

El contraste entre las estrategias de investigación empleadas por el reduccionismo y el holismo enmascara una contradicción radical entre dos distintas filosofías de la ciencia. En el presente artículo, nos concentramos en particular en analizar los puntos filosóficos clave que dan estructura al pensamiento holístico.

Un primer análisis (no exhaustivo) de la tradición filosófica se ocupa de:

a) La teoría de la emergencia: cada nivel de organización se caracteriza por propiedades cuyas leyes no pueden deducirse a partir de las leyes de niveles inferiores de organización (Engels, Morgan);

b) Aclarar las relaciones entre el "todo" y las "partes" (Woodger, Needham);

c) La naturaleza ontológica o epistemológica de las propiedades emergentes: ¿son éstas una realidad fenomenológica, o tan sólo un artefacto del estado de nuestro conocimiento? (Pepper, Henle, Hempel y Oppenheim);

A continuación, se examinan las diferencias existentes entre los enfoques reduccionista y holístico en distintos niveles de análisis, es decir, las diferencias que afectan sus respectivas ontologías, metodologías y epistemologías.

Intento entender el espíritu de un enfoque holístico de la ecología analizando la obra principal de E.P. Odum, *Fundamentals of ecology* (1953, 1959, 1971). Planteo aquello que podría definirse como el "enfoque holístico", implícito en los diferentes niveles de organización en los que se discute el problema de la "complejidad".

La ecología se presenta a sí misma como una "ciencia holística", y el libro de Odum ofrece una visión del mundo que se remonta muy atrás en la historia de la filosofía. Al observar las tres diferentes ediciones de este texto fundamental sobre ecología, podemos darnos cuenta de la evolución en el pensamiento de Odum. De hecho, sólo en la tercera y última edición se apropia de modo consciente del enfoque holístico (usando los modelos teóricos de Feibleman quien, a su vez, se apoya en Novikoff).

Sin embargo, aun cuando se refiere formalmente a la teoría de la emergencia (es decir, el núcleo ontológico de todo enfoque holístico), el análisis sistémico de Odum presenta los mismos errores lógicos que la vuelven al terreno reduccionista.

Ante todo, en su examen de los conceptos principales de "población", "comunidad" y "ecosistema", hay una comprensión deficiente de la profunda diferencia entre "propiedades colectivas" y "propiedades emergentes".

Más aún, los modelos cibernéticos de análisis de sistemas de Odum (introducidos en la ecología por Margalef) le permiten sobresimplificar mucho su tarea metodológica. De hecho, no se señala claramente cuántos niveles ni qué niveles de organización son fundamentales para el estudio de cada nivel en particular.

Por último, Odum analiza el ecosistema como algo compuesto por flujos energéticos y ciclos de materia, refiriéndose a la visión trófica-dinámica de Lindeman. Así, en mi opinión, yuxtapone una metodología y una epistemología reduccionistas a una ontología holística.

LOCALIZATION OF FUNCTION IN THE CEREBRAL CORTEX AND THE UNITY AND SELF-ORGANIZATION OF THE BRAIN

BRUNO ESTAÑOL
EDUARDO CÉSARMAN

All attempts should be made to understand the brain in terms of a system that works as a whole and interacts in non-linear ways with the environment. This attempt should include certain concepts of second-order cybernetics, the concept of information as stated by Shannon, particularly the concept of noise and redundancy, the concept of entropy as applied to the physical thermodynamic systems, and also entropy as an important concept in the information theory. Emphasis should also be put on the concept of system and, particularly, on the concept of a complex adaptive system and a self-organized system.

Ludwig von Bertalanffy demonstrated that biological organisms are open systems that exchange matter, energy and information with the environment. Prigogine showed that living systems take up energy and matter from the environment and, using this free energy, are able to self-organize internally, increase their negentropy and thereby avoid the thermodynamic equilibrium with their environment. Prigogine has called living structures "dissipative structures in non-equilibrium". How-

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