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Eco-cybernetics: the ecology and cybernetics of missing emergences

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Abstract *Considers that in ecosystem, landscape and global ecology, an energetics reading of ecological systems is an expression of a cybernetic, systemic and holistic approach. In ecosystem ecology, the Odumian paradigm emphasizes the concept of emergence, but it has not been accompanied by the creation of a method that fully respects the complexity of the objects studied. In landscape ecology, although the emergentist, multi-level, triadic methodology of J.K. Feibleman and D.T. Campbell has gained acceptance, the importance of emergent properties is still undervalued. In global ecology, the Gaia hypothesis is an expression of an organicist metaphor, while the emergentist terminology used is incongruent with the underlying physicalist cybernetics. More generally, an analytico-additional methodology and the reduction of the properties of ecosystems to the laws of physical chemistry render purely formal any assertion about the emergentist and holistic nature of the ecological systems studied.*

> . . . to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution (Descartes, 1637).

Introduction

The aim of Descartes was to develop a logical method that could serve as a guide to reasoning, so as to arrive at "clear" and "distinct" ideas. That said, in the scientific paradigm dominant amongst the various scientific communities today, from physicians to sociologists, biologists and psychologists, this methodological maxim has gone well beyond the initial function of "enlightening" the mind. It became the clear basis of the epistemic approach which takes the reductionist *credo* of the extreme decomposability of the entities studied as its crowning height. When such an approach, however legitimate, becomes "the universal method", it nevertheless risks turning into a "metaphysical system", the success of which is due to the elimination of any phenomena that might undermine its value (Feyerabend, 1965, I chap.).

The variables considered in the scientific models are necessarily limited, because with respect to biological and psycho-sociological phenomena, unlike man-made machines, the totality of components and their relationships can never be fully known. The search to be exhaustive is an unattainable ideal.

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The reductionist paradigm holds that the organization levels of reality are characterized by different degrees of semantic value: the laws and theories of levels said to be "fundamental" (e.g. physics, chemistry, genetics) should make it possible to explain and predict the characteristics of other levels (e.g. ecology, biology, psychology). From this point of view, the latter are entirely epiphenomenological. This directly raises a classic topic in the philosophy of science, which is whether "emergent properties" are a phenomenological reality? This epistemological problem concerns all scientific disciplines. It has, of course, played a particularly important role in the cybernetics and systems models, a role that in all likelihood is destined to become even more significant. Paradoxically, the term "emergence" and the conception itself were entirely alien to cybernetics at its origins (Wiener, 1948, 1950). For a sense of how much this has changed today, it is interesting to see just how much space on *Principia Cybernetica Web*, for example, is devoted to the analysis of the multiple facets and implications of the concept of emergence in cybernetics and systems theory. At the moment, by way of a conventional introduction, we can say simply that the "emergent properties" of a given integration level cannot be explained, predicted or deduced by the study of its components.

Among cyberneticists, Ross Ashby (1956) was one of the first to focus attention on emergent properties. Ashby's epistemological presupposition is that the organization of systems "is partly in the eye of the beholder", and, more specifically, as the observer's viewpoint changes, a great variety of "arbitrary parts" can be determined (Ashby, 1968, p. 110). On the other hand, with regard to the emergent properties of complex systems, even if ideally full knowledge of the parts should allow a complete prediction of the characteristics of the whole, Ashby acknowledges that "often, however, the knowledge is not, for whatever reason, complete" (Ashby, 1956, p. 111). He concludes that it is necessary, sometimes, "(to treat) the system as an unanalyzed whole" (Ashby, 1968, p. 109). In fact, in a situation involving a broad range of parts and arrangements, "(the) complex systems cannot be treated as an interlaced set of more or less independent feedback circuits, but only as a whole" (Ashby, 1956, p. 54).

General System Theory, however, underwent a different sort of development. Even in his earliest writings, Ludwig von Bertalanffy, in reaction to the predominance of various forms of reductionism throughout the scientific disciplines (for the reductionist and emergentist categories see: Ayala and Dobzhansky, 1974; Koestler and Smythies, 1969; Ruse, 1988; Bergandi, 1998), proposed an alternative model that found a *raison d'être*, at least formally, in the phenomena of emergence. Bertalanffy (1968) considers the systems as real entities belonging to nature, and his interpretation of emergence raises a noteworthy anomaly. His definition could lead to the conclusion that emergence poses a baseless problem, because "If . . . we know the total of parts contained in a system and the relations between them, the behavior of the system may be derived from the behavior of the parts" (Bertalanffy, 1968, p. 55).

Note that the "pragmatic holism" of Simon and the "emergent materialism" of Bunge converge with Bertalanffy's definition (see Bergandi, 1998). His methodological acceptance of emergence can ultimately be superimposed on the reductionist method (Amsterdamski, 1981; Bergandi and Blandin, 1998, pp. 187-9). This is true despite Bertalanffy's repeated assertions in principle to the contrary.

The key to understanding this epistemological inconsistency can be found in the principle of "downward causation" proposed by Donald Campbell (1974), as well as in James Feibleman's interpretation of emergence (Feibleman, 1954). The downward causation principle asserts the hierarchical organization of biological (and sociological) systems, in the sense that higher levels limit and determine the characteristics of lower levels:

> . . . the laws of the higher-level selective system determine in part the distribution of lower-level events and substances. Description of an intermediate-level phenomenon is not completed by describing its possibility and implementation in lower-level terms. Its presence, prevalence or distribution (all needed for a complete explanation of biological phenomena) will often require reference to laws at a higher level of organization as well (Campbell, 1974, p. 180).

Methodologically, this implies the necessity of an approach considering higher levels, because "upward causation" – which involves limiting analysis to the lower levels of the hierarchy – is not sufficient to explain the laws of a given level. Reference to the higher levels of integration is therefore essential, while, according to Bertalanffy and to some extent Ashby, knowledge of the parts and relationships of a given level should be sufficient. One trailblazer in the development of a multi-level epistemological perspective was Feibleman, who in a seminal paper in 1954 asserted that any level of integration characterized by specific emergent properties entails laws congruent with the level of complexity (Feibleman, 1954, pp. 59 and 64). Like Campbell, Feibleman does not reject the necessity of analysis of the lower level of integration (Campbell, 1974, pp. 182-3), but he considers that knowledge of the lower level is insufficient, because "*for an organization at any given level, its mechanism lies at the level below and its purpose at the level above*" (Feibleman's italics) (p. 61). In other words, to analyze a given level, a study of at least three levels of integration is required. If, for example, the subject is an ecological system such as a community, it is necessary to consider simultaneously not only the population level, but also the ecosystem level. Therefore, Bertalanffy's version of emergence, limited as it is to a study of the relationships between the parts of a system, in reality eviscerates the problem of emergence. His version is, rather, a form of "complexified reductionism". While it is of course not limited to the mere analysis of a system's components, it nevertheless remains a reductionist approach in that it explains the higher levels by means of the lower levels.

Finally, a framework founded on emergent properties and a triadic multi-level approach is essential in order to understand the epistemological value of the different heuristic models of cybernetics and General System Theory, in ecosystem, landscape and global ecology.

Ecosystem ecology

In ecology, the use of cybernetics models, which could be called eco-cybernetics, reached its apex in the 1950s to 1970s. This was associated in particular with the rise of the Systems Ecology theory of E.P. and H.T. Odum. The use of cybernetics simulations and systems models in ecology continued, however, well into the 1980s and 1990s, at which point Landscape Ecology and Global Ecology, with its focus on global change, became the new frontiers of ecological research.

The paradigm proposed by the Odum brothers reflects a judicious *mélange* of cybernetics and General System Theory and played a decisive part in the development of modern ecology. The concept of emergence is repeatedly invoked as the core of the systems approach (Odum, E.P., 1971, p. 6; Odum, E.P., 1993, pp. 29-30; Odum, H.T., 1994, p. 4). In passing, it is very interesting to note that for Odum, E.P. (1971) the reference for emergence is Feibleman (1954). Following in the path of the trophic-dynamics analysis of Lindeman (1942), the Odum brothers sought the basic energy relationships between living and non-living parts of the ecosystem as a whole. This "formalized approach to holism" (Odum, E.P., 1971, p. 276) incorporated certain cybernetics models, and was characterized by a limited number of "key factors" which determined a large percentage of the action (Odum, E.P. 1971, p. 7). Although this research was undoubtedly "systemic", it should not be confused with an emergentist perspective, which stresses the "emergence" of specific characteristics at every level of the hierarchical organization of biological systems. Indeed, formally it is the concept of emergence that is the basis of the following epistemological position: ". . . the findings at any level *aid in the study of another level, but never completely explain the phenomena occurring at that level*" (Odum, E.P., 1971, p. 5; Odum, E.P., 1992, p. 542; Odum, E.P., 1993, p. 30; E.P. Odum's italics). Otherwise, a reductionist perspective would suffice.

Yet if we examine certain texts that summarize the work of the Odum brothers, such as *Fundamentals of Ecology* (1971), *Ecology* (1993) and *Ecological and General Systems* (1994), it is clear that cybernetics models based on energy flows and nutrient cycles in the ecosystem represent the core of the analysis (see Figure 1).

The energetics approach to the ecosystem in the 1971 work is certainly very important, but later it will become even more decisive, to the extent that it even gave shape to the systems models used. Later, H.T. Odum, who developed many of the systems models used in the two brothers' work, created an "energy circuit language" in order to construct energy diagrams for a wide variety of ecological systems, from the more basic trophic levels up to the biosphere (see the biosphere model in Figure 2).

The authors of these systems models intended that they should have universal applicability, so as to avoid a "tower of Babel" of differing models (Odum, H.T., 1994, p. 579). Nevertheless, at the heart of their cybernetic and systems models lies a concept of feedback that inevitably engenders a standardizing and ultimately reductionist analysis of energy flows. All the

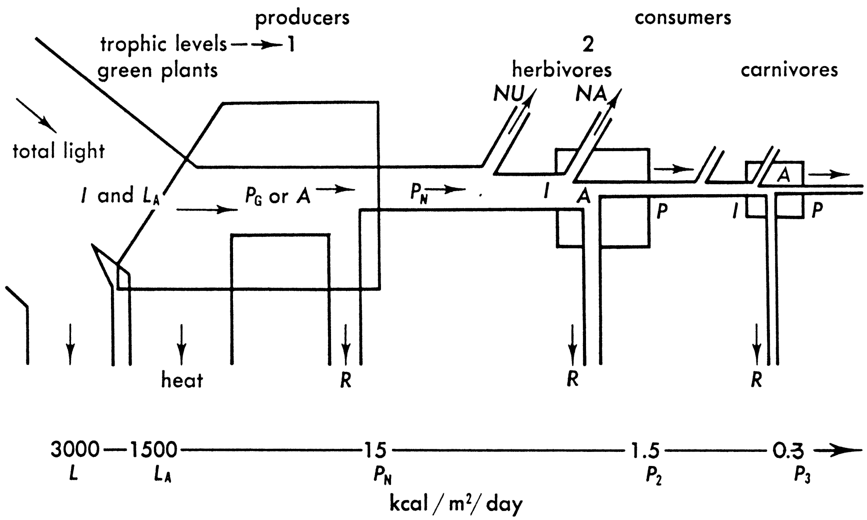

Figure 1.
A simplified energy flow diagram depicting three trophic levels in a linear food chain

Source: Odum, E.P. (1971)

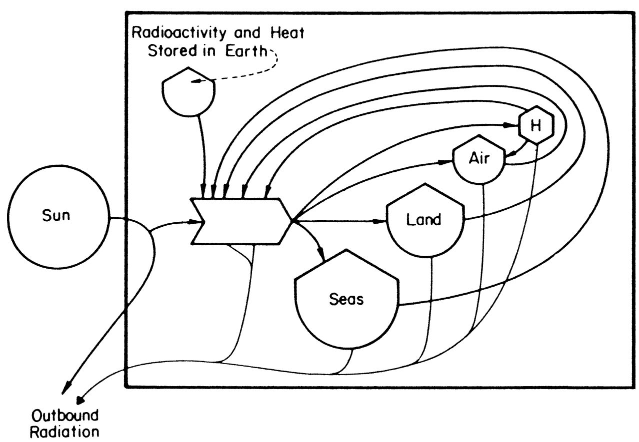

Figure 2.
Interdependent phases of the biosphere in which structures of air, sea, and earth are maintained by interactive cycles driven by solar energy

Source: Odum, H.T. (1994)

properties of ecosystems, communities and populations are translated into energetics terms. At best these models could be identified as "holological", in Hutchinson's terms (Hutchinson, 1943, p. 152), where "matter and energy changes across [an ecological system's] boundaries are studied", but not as "holistic" (see Odum, E.P., 1971, p. 276), as holism inescapably involves the notion of emergence. An emergentist approach must be more respectful of the specificities of a given level, and in particular of constraints determined by higher levels. Instead, due to its narrow focus on thermodynamics, the Odumian paradigm not only "misses the emergences" but also is "hyperreductionist" (Bergandi, 1995). All forms of energy (solar, chemical, kinetic, etc.) are reduced to a single form: heat (Mansson and McGlade, 1993, p. 593).

Finally, when E.P. Odum (1977, p. 1290) treats the flow of energy as the true "emergent property" of an ecosystem, the emergent properties are confused with the collective properties. In fact, the latter result from the statistical dynamics of the lower level (Salt, 1979, p. 145), in this case, the level of physics. Though this physicalist method is of course legitimate for certain purposes, it is the contrary of a genuinely holistic approach to ecological systems and their emergent properties.

Landscape ecology

Landscape ecology results from the unification of many sources that over different periods contributed to the foundations of this discipline. One particularly important pioneer of landscape ecology was the German biogeographer Carl Troll. For Troll, the landscape was a spatial and visual entity peculiar to mankind, a holistic entity integrating the geosphere, the biosphere and the totality of human artefacts. To explore such an entity, an ordinary analytical approach would not suffice; instead, it needed to be considered as a whole (Troll, 1939; Naveh and Lieberman, 1984). Nowadays, landscape ecology is structured around an epistemological framework proposed by a Franco-American-Canadian school that, beginning in the 1980s, created a new research field with specific features and methods. This school introduced a new vocabulary – matrix, patch, corridor, connectivity, disturbance, etc. – that contributed to a new way of seeing and analyzing ecological systems. With their work *Landscape Ecology*, Forman and Godron (1986) played a key role, comparable to that of the Odum brothers in ecosystem ecology. The classic thesis of the ecosystemic paradigm revolved around the "homogeneity" of ecological systems and their tendency to maintain an "equilibrium state". Attention was, moreover, focused mainly on the natural environment. Human interventions were minimized or even not observed. Landscape ecology brought about a radical change in the paradigm. The "heterogeneity" and "instability" of ecological systems are emphasized, and human actions are treated as factors in the transformation of the ecological process.

Landscape ecology was also influenced more than other ecological disciplines by the works of Allen and Starr (1982) and O'Neill *et al.* (1986), who proposed a hierarchical conception of reality. The imagination of these authors was nourished not so much by the work of Feibleman and Campbell as by Koestler (1967, 1978) and Koestler and Smythies (1969), whose influence has touched many disciplines. For Koestler, there is a hierarchical organization to reality. Any level of this hierarchy – *a holon* – has a *double face*, as did Janus, the divinity of Roman mythology. Thus the holon is at the same time a totality, characterized by self-regulation and autonomy, and a part, subordinate to the higher level of the hierarchy (Koestler, 1967, pp. 55-6, 341; Koestler and Smithies, 1969, pp. 196-7, 207-12, 1978, Ch. 1). Koestler rejects the possibility that a complex system can be reduced to the laws of the holons composing it. Nonetheless, although in the thought of Koestler the overlapping of levels determines the emergence of novelty, he does not propose a simultaneous study of different levels, as do Feibleman and Campbell, which signalled the rise of a true emergentist methodology.

Ultimately, the arguments of Allen and Starr (1982), and O'Neill *et al.* (1986) in favour of a hierarchical conception of reality promoted a greater attentiveness in some works of landscape ecology to the relationships between different integration levels and different scales of observation. In the first issue of the journal *Landscape Ecology*, Frank Golley (1987), who makes no reference to the works of Feibleman and Campbell, seeks to structure the methodological approach of landscape ecology, and tells us:

> Let me begin by restating the obvious. All studies involve three levels of attention: the object of interest, the components and functions within that object which explain its behavior, and the larger system of which the object is a part and which establishes its significance (p. 1).

All things considered, many researchers will undoubtedly have difficulty seeing "the obvious", because works that formally seem to be closest to a systemic and emergentist approach propose, in reality, a model of multi-level analysis that conceals a typical – and ultimately reductionist – systemic analysis. Indeed, this is generally an expression of an analytico-additional method that is essentially based on the lower integration levels. Even where a triadic approach is employed, the search for emergent properties is absent or misconstrued.

The paper of Urban *et al.* (1987) "Landscape ecology", for instance, represents the application of a hierarchical approach. It is a prime example of ambiguity of thought which, at least implicitly, should be logically structured around the concept of emergence, but which in fact employs a reductionist methodology. In this work, as in others (Risser, 1987, pp. 10-11), the central position of a hierarchical-emergentist perspective in landscape ecology is asserted. It is given great importance in the introduction, but then subsequently disregarded:

> . . . the hierarchical paradigm – Urban, O'Neill and Shugart tell us – provides the guidelines for defining the functional components of a system, and defines ways components at different scales are related to one another (e.g. lower-level units interact to generate higher-level behaviors and higher-level units control those at lower levels) (p. 121).

This perspective should represent a central assumption of landscape ecology, particularly as ". . . understanding a hierarchical phenomenon requires more than mechanism. Understanding requires that the mechanisms be considered in context" (Urban *et al.*, 1987, p. 122). Yet when they consider the concrete analysis of a landscape, a mechanistic analysis takes shape, focusing on the relationships between the landscape elements (*watershed, stand, gap*). This paper shows clearly that a hierarchical ontology is not sufficient to avoid an essentially analytic and reductionist approach.

The works of Naveh (1982, 1984) and of Naveh and Lieberman (1984), for example, extensively review many typical holistic principles. In these works, cybernetics is mixed in with General System Theory and information theory (Shannon and Weaver, 1949). The paradigm propounded by Naveh (1982, p. 204), the "Total Human Ecosystem", is composed of all humanity and the total surrounding environment:

> This is a holistic, scientific theory of hierarchic order of open, living and ecological systems as holons with biocybernetic self-regulation and feedback control, and with the total human ecosystem as its highest level of integration.

The total human ecosystem should represent the last level of a hierarchy consisting of organisms, populations, communities and ecosystems; it integrates the geosphere, the biosphere and the technosphere, the totality of human artefacts. The ecosphere is the largest landscape entity, while the ecotope is the smallest (Naveh, 1982, pp. 207-8, and 230; 1984, pp. 40, 44-5; Naveh and Lieberman, 1984, pp. 81-4). In this context, landscape ecology would thus play a crucial role as an integrative discipline. Nevertheless, the attempt to provide the landscape with basically holistic theoretical foundations breaks down when productivity and biotic diversity are identified as emergent properties (Naveh and Lieberman, 1984, p. 78). These are instead unquestionably the results of an analytico-additional method.

The message of those who pointed out the inappropriateness of applying this method to ecological systems won an audience, particularly in the 1990s. Recently, a multi-level or triadic approach has been considered or applied in various works, while, of course, cybernetics and hierarchic conceptions have continued to be influential (Haber, 1990; Forman, 1995, pp. 9, 505; Dunnet, 1995, p. 80; King, 1997). We can thus consider research to be reductionist when the object of study is explained in terms of its components, and holistic (emergentist) when an effort is made to determine relationships with higher levels. Nevertheless, another problem is looming on the horizon: emergent properties are not at all taken into account in these works. A triadic methodology is the most realistic application of the concept of emergence. But does a hierarchy of integration levels that does not involve some emergent properties have any real meaning? Why must a given integration level be analyzed not only in terms of its components, but also in terms of those of the higher surrounding context? Why, that is, other than that the existence of emergent properties characterizes every integration level? This is all the more important since, if we accept the constructivist perspective (Foerster, 1981; Foerster and Stephen, 1995; see also Dewey and Bentley, 1949; Vallée, 1995, pp. 11-12), the delimitation (boundaries) of ecosystems and landscapes poses the epistemological question of the separation between the observed and the observer, in other words, the problem of the reality value of entities composing the hierarchies of integration levels in scientific research. What should be the criteria for identifying a given integration level? The existence of emergent properties, such as *inter alia* self-organization, coherence and relative autonomy, could be used as indicators identifying integration levels with a high degree of reality. For example, an ecosystem, or even a landscape, is not really detectable, since it has no borders, no well-defined limits. The ecosystem represents rather a kind of methodological abstraction, that is useful for understanding the elements constituting a minimal system of ecological relationships. Nevertheless, we can assume that in the eyes of researchers such "abstract" "fictitious" integration levels manifest the emergent properties of levels with a higher degree of reality. For example, the mechanisms of self-regulation that we find in the ecosystem levels should belong, in reality, to the biosphere.

Global ecology

In the development of scientific ecology, the organicist metaphor is repeatedly employed to identify the specific characteristics of the "basic units of nature". Entities such as, for example, the "biome" of Clements (1905, 1916) or the "biotic community" of Phillips (1931) have been analogized to organisms. Even though Tansley (1935) rejected the organicism of Clements and Phillips, his "ecosystem" was still termed a "quasi-organism". With the emergence of global ecology, for instance in the approach of James Lovelock (1979, 1988, 1991) – Vernadsky (1926) has been a precursor (see also Tagliagambe (1994)) – this metaphor took yet another step forward.

According to the Gaia hypothesis, the Earth should not be viewed merely as if it *were* an organism, because *it is an organism*. For Lovelock, Gaia is the largest living being (1979, p. 34; 1988, pp. 8 and 43), a "complex system", an "individual organism"; by controlling the physical and chemical environment, he argues, the biosphere functions as a self-regulating entity that maintains life on the planet (Lovelock, 1979, p. 9). In other words, Gaia is a cybernetics system that maintains homeostasis – the capacity of living beings to keep their internal environment constant – at the planetary level (Lovelock, 1979, pp. 11, 131-2). To comprehend the characteristics of this complex system that is the Earth, Lovelock proposed a multitude of cybernetics models. Here we will merely outline a simplified version of the Daisyworld model (Lovelock, 1988, II chap.). Daisyworld is a planet whose environment consists of one variable, the temperature, and two populations of daisies (white and black). The optimal temperature for growth is 20°C, while temperatures below 5°C or above 40°C are deadly; of course, warmer temperatures favour the white flower. At the beginning, the populations are uniformly distributed. Owing to temperature changes, a gradual succession of two populations should occur, a succession determined by positive feedback that, in accordance with the temperature, favours either the white or black daisies. Lovelock intends that this model should show Gaia's capacity for self-regulation, and emphasizes the automatic modifications of the physical environment by the biotic component, without invoking any sort of internal finalism.

He also considers that his exposition of a theory of a living planet is neither holistic nor reductionist. Nevertheless, in proposing a systemic, "physiological" study of the planet, considered as an entity composed of interdependent ecosystems (Lovelock, 1988, p. 181), references to holistic principles form a basic cornerstone of his work. In particular, he treats the concept of feedback as emblematic of a holistic approach (Lovelock, 1988, p. 216). Lovelock holds that cybernetics is structured around a set of holistic concepts, as did Odum. Indeed, Lovelock clearly acknowledged the Odumian influence on his work: ". . . I have felt a special empathy with the writings of the ecologist Eugene Odum" (Lovelock, 1988, Preface, p. xix). The cybernetic regulation of the planet is expressed in statements that, at first glance, certainly do appear to employ holistic principles:

> . . . the entire range of living matter on Earth, from whales to viruses, and from oaks to algae, could be regarded as constituting a single living entity, capable of manipulating the Earth's atmosphere to suit its overall needs and endowed with faculties and powers far beyond those of its constituent parts (Lovelock, 1979, p. 9; see also: Lovelock, 1988, p. 19).

Even more explicit is his definition of cybernetics systems: "the key to understanding cybernetic systems is that, like life itself, they are always more than the mere assembly of constituent parts" (Lovelock, 1979, p. 52). Furthermore, in relation to the planet's capacity for self-regulation Lovelock states that: "Gaia as a total planetary being has properties that are not necessarily discernible by just knowing individual species or populations of organisms living together" (Lovelock, 1988, p. 19). He thus seems to identify self-regulation as an emergent property. However, probably owing to the influence of Odum, he too makes an amalgam between collective and emergent properties, by treating homeostasis as a collective property (Lovelock, 1988, p. 18), and thus miring himself in contradiction. Lovelock subsequently came to acknowledge homeostasis as an emergent property (Lovelock, 1991), but the basic confusion persisted. Moreover, Lovelock, in line with his organicist worldview, pointed out that to consider life as a passive adaptation to environmental changes was simplistic and ultimately wrong. In contrast, he ventured the notion of a Gaia system wherein a relational continuity between the totality of biotic and abiotic complexes leads to the emergence of a self-regulating entity. Nonetheless, Lovelock did not manage to clearly situate the Gaia system within the higher integration level, the solar system. This necessity is, however, dealt with more cogently in *Global Change*, edited by Malone and Roederer (1985), which grew out of the Symposium held under the auspices of the International Council of Scientific Unions (Ottawa, 1984). In 1986, this international body launched the International Geosphere-Biosphere Programme (IGBP). For example, the gravitational influences of the other planets have an impact on the obliquity of the Earth's axis of rotation and thus significantly affect the climate (Friedman, 1985, pp. 365-66). Likewise, the sun's role with regard to changes in the emission of electromagnetic radiation and sub-atomic particles is crucial to understanding, among other processes, terrestrial electromagnetism and the specific mixture of atmospheric gases (Cole, 1985).

There is a gap between Lovelock's emergentist phraseology and his analytical methodology, which is concentrated in his conflation of or confusion between emergentist and collective properties. Underlying this is a fundamental methodological problem. It must be acknowledged that some similarity exists between cybernetics logic and certain theoretical kernels of emergentist thought. It is possible, for instance, to view feedback as a mechanism that determines the emergence of properties or behaviors that are not characteristic of the elements taken separately. However, a methodology is only genuinely emergentist when it treats the constraints of higher levels as a priority, and thus when it is not limited to taking the analysis of the lower levels alone as determinant (Feibleman, 1954; Campbell, 1974). Three objections need to be dealt with if we are to accept Lovelock's equivalence between cybernetics systems and systems endowed with emergent properties. First, a system that contains one or more feedback loops is not necessarily a cybernetics system. To be a cybernetics system, a permanent information web is necessary (Engelberg and Boyarsky, 1979, p. 320; according to these authors, neither the ecosystem nor the biosphere are cybernetics systems). Second, when a system is composed of an indefinite number of feedback loops, it is impossible to decompose it (Ashby, 1956, pp. 53-4). Third, for an approach to be holistic and emergentist, it is not sufficient that it is structured around the search for feedback loops. While feedback does lend itself to emergentist interpretation, at the same time an analysis is emergentist only when it is multi-level and attentive to the constraints of higher levels.

In other words, to seek an explanation of planetary self-regulation simply in terms of the feedback of physico-chemical elements means avoiding, or at least underestimating, an analysis of the bio-socio-ecological levels (including human intervention), and winds up embracing a reductionist approach. Lovelock's litany of holistic refrains ultimately cannot drown out a constant temptation to circumvent the ecological problem by reducing the relationships of living beings to their environment, to an assemblage of physico-chemical processes interwoven into a complex cybernetics (see Deléage, 1991, p. 244).

Conclusions

The different expressions of scientific ecology – ecosystem, landscape and global ecology – have felt the lasting influence of systems and cybernetics models, and of ontological, methodological and epistemological emergentism. Moreover, the concept of emergent properties, a classic topic in the philosophy of science, has played an important role in (mature) cybernetics and systems thinking, and has found a methodological application in the triadic, multi-level approach of Feibleman and Campbell. In ecosystem ecology, the Odumian paradigm structured the methods and objects of research. Eco-cybernetics models, centred on flows of matter and energy, have been considered emblematic of an emergentist approach.

These models are instead the concrete offspring of a physicalist approach that "forgets" or misunderstands the specific emergent properties of ecosystems. Ecosystems are of course analyzed as systems, but not as ecological systems – their essential characteristics are reduced to the laws of physics.

In landscape ecology, instead, it is possible to observe an ontological and methodological development that incorporates the triadic, multi-level approach. Nonetheless, while accepting a hierarchical perspective, on the one hand, leads the researcher to focus attention on processes that involve different integration levels, on the other, in practice, it leads to underestimating or misconstruing the importance of emergent properties. With landscape ecology, researchers felt the need for an analytical entity that was spatially larger in order to avoid losing information about the element and the totality. Nevertheless, a new problem arose: the reality value of the entities composing the hierarchies. In particular, are the landscape and the ecosystem entities with a high reality value? The possibility that these integration levels are mere "constructs" or "fictions" might be discarded if some clearly defined emergent properties could be identified. For the moment, it is more realistic to consider that the ecosystem and landscape "incorporate" the emergent properties of the biosphere, an integration level with a high reality value.

According to the Gaia hypothesis, the biosphere is the result of numerous interactions between its biotic and abiotic components. For ecologists, this observation sets the obvious framework for their discipline. Ultimately, it is little more than a restatement of Tansley's concept of an "ecosystem". With Gaia, the model of relations has been extended to include the entire planet, yet the emergentist jargon and cybernetics models overlie an essentially reductionist approach centred on energy flows. Indeed, Lovelock's global ecology recapitulates all the main trends that have marked ecological thought and praxis, with all the inherent contradictions. And yet again, a holistic worldview proves to be independent of the methodology actually used.

Finally, eco-cybernetics is an expression of a "reductionist systemism" that, in the case of the Odumian paradigm and the Gaia hypothesis, has become a form of "hyper-reductionism", with all forms of energy reduced to heat. In landscape ecology, on the other hand, the recognition of the importance of a multi-level, triadic approach has nonetheless gone hand in glove with an underestimation of the importance of emergent properties in identifying a specific integration level.

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