Chapter 4

Multifaceted Ecology Between Organicism, Emergentism and Reductionism

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The classical holism-reductionism debate, which has been of major importance to the development of ecological theory and methodology, is an epistemological patchwork. At any moment, there is a risk of it slipping into an incoherent, chaotic Tower of Babel. Yet philosophy, like the sciences, requires that words and their correlative concepts be used rigorously and univocally. The prevalent use of everyday language in the holism-reductionism issue may give a false impression regarding its underlying clarity and coherence. In reality, the conceptual categories underlying the debate have yet to be accurately defined and consistently used. There is a need to map out a clear conceptual, logical and epistemological framework. To this end, we propose a minimalist epistemological foundation. The issue is easier to grasp if we keep in mind that holism generally represents the ontological background of emergentism, but does not necessarily coincide with it. We therefore speak in very loose terms of the "holism-reductionism" debate, although it would really be better characterised by the terms emergentism and reductionism. The confrontation between these antagonistic paradigms unfolds at various semantic and operational levels. In definitional terms, there is not just emergentism and reductionism, but various kinds of emergentisms and reductionisms. In fact, Ayala (1974; see also Ruse 1988; Mayr 1988; Beckermann et al. 1992; Jones 2000) have proposed a now classic trilogy among various semantic domains – ontology, methodology and epistemology. This trilogy has been used as a kind of epistemological screen to interpret the reductionist field. It is just as meaningful and useful, however, to apply the same trilogy to the emergentist field. By revealing the basic assumptions of each, we should be better able to understand the points that are similar and shared, as well as the incommensurable ones.

The first question regarding the emergentism and reductionism debate concerns the type of explanation the sciences are seeking. At present in the sciences – from physics to the human sciences – the ontological and epistemological foundation is essentially naturalistic and materialistic, meaning that all natural (or social) objects, events and processes can be understood without reference to extra- or supernatural (vitalistic or theological) entities,

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A. Schwarz and K. Jax (eds.), *Ecology Revisited: Reflecting on Concepts, Advancing Science*,
DOI 10.1007/978-90-481-9744-6_4,

causes, aims or explanations. The order and laws structuring natural reality are intelligible and, in principle, there is no limit to naturalistic explanations. The existence of this philosophical substrate – the existence of a scientific and naturalistic epistemology – should be taken into account every time the key words 'emergentism' and 'reductionism' appear.

In ecology – and, without exception, in the other natural and human sciences – the classical confrontation between emergentism and reductionism plays a very important and structuring role. It is necessary to be aware that their basic assumptions involve different and generally antinomian ontologies (worldviews, the "true" structures of reality, or in other words, our "bets" on the structure of reality), methodologies (research strategies) and epistemologies.[2] The existence of these specific semantic domains should be kept in mind every time we approach this issue.

Holism and Reductionism: An Epistemological Confrontation?

Today's perspective of reductionist cosmological ontology has its antecedents in the mechanistic worldview of previous centuries. Gradually, from Leucippus and Democritus to Dalton and, among others, Bohr, reality has been defined from an atomistic perspective: reality consists of distinct, discrete, indivisible atoms with a fixed spatio-temporal amplitude. Unlike reductionism, the holistic ontological perspective of emergentism is continuistic and relational: reality consists of acontinuum of events and processes that are intrinsically interconnected and interdependent.

At first sight both reductionism and emergentism currently share a common scientific philosophy, namely that all biological phenomena are fundamentally physico-chemical and that the laws of physics and chemistry are applicable to biological phenomena. Nevertheless, emergentism holds that the various levels of organisation (physical, biological and psycho-sociological) are characterised by the acquisition of new and specific properties (emergent properties). These properties increase the degree of complexity of a given level compared with the various levels of which it is composed (hierarchical organisation). For this reason, even if physics and chemistry are normally applicable to, say, ecological phenomena, each level of organisation requires appropriate laws and theories that allow for an understanding of

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[2] In this context the word 'epistemology' connotes the more limited and specific meaning of the research domain concerning the relationships among theories and laws that belong to different different organisational levels. In other words, it is characterised by the epistemic challenge of "heterogeneous reduction", or "theoretical reductionism" (Ruse 1988).

the specific properties of that particular level. By contrast, reductionism denies the existence of emergent properties or else considers them an epiphenomenon strictly dependent on the state of our knowledge – what is emergent today will lose its emergent character tomorrow (Hempel and Oppenheim 1948, pp. 149–151). These ontological assumptions have, of course, significant consequences in the methodological and epistemological domains. In the methodological domain, the two perspectives view the analytical method in a very different way.

Reductionism considers that at a given level of organisation, analytical study of constituent parts and their relationships is necessary and sufficient to predict, or at least explain, all the properties of that level. Fundamentally, reductionism is a "bottom-up" strategy. It takes into account the level at which the events to be explained occur (ecological phenomena, for instance) as well as the lower levels that contribute to that explanation (for example, genetics, chemistry or physics). An analytical and additive method, therefore, dissects the entity, or decompose the process, under examination into its component parts, or phases, and attempts to take into consideration the relationships among them. A successive summation of the individual component properties or interactional properties should allow extrapolation of the global properties of the entity as a whole. In some cases, this dissective and synthetic process should allow us to formulate some more general theories or laws.

Methodologically, the emergentist approach, while recognising the need for analysis, considers its explanatory power limited. In fact, according to an emergentist and hierarchical perspective, the feedback loops that link different levels of organisation play a role of utmost importance in the determination and causation of the emergent properties. From a methodological point of view, the higher and lower levels adjacent to the primary object of study are considered differently than in methodological reductionism. This approach does not limit the analysis to the constitutive parts of – or their relationships in – a specific level of organisation. In other words, for this "top-down" approach, both the higher levels (downward causation) and the lower ones participate in determining the properties of specific levels. Thus, a multi-level triadic approach – where at least three levels of organisation are considered simultaneously – is held to be a methodological necessity and is the main characteristic of the emergentist methodology (Feibleman 1954; Campbell 1974; Salthe 1985; Bergandi 1995; El-Hani and Pereira 2000).

Epistemologically, reductionism is a mono-directional bottom-up explanatory strategy. This approach is directly descended from nineteenth century positivism and from neo-positivism

(1920s and 1930s). In its struggle against the intrusiveness of metaphysics in science, neo-positivism sought a unification of science based on the language, laws and theories of physics. Epistemological reductionism maintains that the theories and laws of a specific organisational level can be – and sometimes must be – "reduced" to the theories and laws of a more "fundamental" field of science (Woodger 1952; Nagel 1961; Levins and Lewontin 1980; Bunge 1991; Jones 2000).

According to this epistemological perspective, an ideal scientific development will involve, in the long run, the "de-substantialisation" of non-fundamental sciences. For instance, taking into account the relationships between ecology (secondary science) and physics (primary science), ecological laws and theories could be reduced to physical laws and theories (heterogeneous reduction). Were this to occur, the process of integration, incorporation and absorption of ecological phenomena in the physical domain would provide a larger and clearer understanding of all the phenomena that previously constituted the objects of ecological research. Such a hypothetical reduction would determine the birth of a new and more meaningful physical science, emerging from the "dilution" of biology into physics. And, as Popper already pointed out, such a successful reduction is substantially unattainable because it would imply a "complete" theoretical understanding of life in physical terms (1972).

Epistemological holism, on the other hand, posits a more dialectical relationship between laws and theories belonging to different organisational levels. On the one hand, this perspective holds that there is no scientific domain to which the other sciences should be reduced. According to emergentist ontology, every organisational level has one or more emergent properties that are correlated to specific laws and theories which, in turn, are assumed to be intrinsically non-reducible. On the other hand, according to Quine (1961, p. 42) "the unit of empirical significance is the whole of science".[3] This means that the existence of anomalies that cannot be explained in terms of existing knowledge requires us to make adjustments to science as a whole. In other words, a transformation in any scientific domain, and not only in the "fundamental" sciences, can determine changes in any other domain of science.

This perspective entails rejecting the physical explanation as the fundamental and preferred form of explanation to which the other sciences have to be reduced. In sum, it is possible to

[3] It is worth pointing out that, unlike the Quine thesis, the holistic reference of the Duhem thesis is the whole of physics. Its working has been described according to an organicist perspective: in physics, as in an organism, all the theories work together, even if they are not all called into play at the same level of intervention (1977, pp. 187–188).

identify the foundational, philosophical core of all materialistic emergentist views of reality using the following criteria, which correspond to different semantic domains:

Ontology

1. *Holism*: Not all holistic positions are emergentist, but all emergentist views are holistic. *Holism fundamentally means the intrinsic, structural, spatio-temporal interdependence of phenomena* [4] and constitutes the major and inescapable ontological presupposition of emergence.

2. *Levels of organisation*: *Reality is a hierarchical, multi-layered, multi-level process*. According to this interpretation of reality every level of organisation (or integration) is characterised by specific emergent properties, qualities or behaviours. This ontological perspective can be interpreted according to a realistic view – the levels with their emergent properties definitely represent reality – or a constructivist one – the levels of organisation are "*levels of description*" of reality: we identify levels, and attribute specific properties to them, according to the purpose of our research.

3. *Novelty*: *The emergent properties of every level of organisation express new qualities and a new order of phenomena compared with the level of organisation on which they depend and from which they emerge.*

Methodology

4. *Avoiding the fallacy of "misplaced concreteness"* (Whitehead 1925; Dewey and Bentley 1949). This is a basic prerequisite for any emergentist constructivist methodology. There is a preliminary heuristic assumption that all analytical distinctions concerning "wholes", "parts", and "relations" are pure theoretical "mind constructions" which have meaning only in relationship to the specific aims of the inquiry. Consequently, wholes, parts and relations must not necessarily be considered to have an intrinsic ontological reality, merely an epistemic one (see Bergandi 2007).[5]

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[4] To avoid any risk of misunderstanding, it would be more appropriate to use the term 'holism' to indicate specifically the relational view of reality according to which natural (or social) reality is constituted by spatio-temporal interdependent entities. Its logical opposite is the ontological atomistic view.

[5] It is worth recalling that constructivism does not deny the existence of a reality (natural, social, and so on). Rather, this perspective foregrounds the idea that within this reality, thanks to our epistemic constructs, we identify or recognise certain characteristics, aspects and processes thatare functional to our aims and objectives (scientific, social, and so forth).

5. *Multi-level approach*: To explain the emergent properties of a specific level of organisation or system, the adjacent lower and higher levels must be considered as significant as, and simultaneously with the level of the primary object of research. This triadic approach is not a luxury but a necessity for any research claiming an emergentist approach. In fact, to restrict to take into consideration the lower level relationships among elements is equivalent to enacting a reductionist methodology.

6. *Fallacious attribution of emergent properties*: The constructivist background (see (4) above) should always be borne in mind in the attribution of emergent properties to a level of organisation. The hypothesis that these properties cannot, in reality, be effectively attributed to the constituent parts, sub-systems or higher inclusive levels must be carefully refuted. In fact, any potentially erroneous attribution of an emergent property could result from an incomplete or wrongheaded analysis of the whole hierarchical structure.

Epistemology

7. *Unpredictability*: The emergent properties of a level of organisation cannot be predicted, even in principle, by even the most complete knowledge of the parts, properties and relationships among the parts.[6] In other words, a specific organisation of matter is correlated to exclusive properties. To be able to explain them would require the constitution of a new or reorganised scientific discipline which would use new postulates, theories and laws that introduce new terms and patterns suited to the emergent phenomena and properties.[7]

From Organicism to the Oxymoronic "Reductionist Holism" of Ecosystem Ecology

From its beginning, ecology has been structured within a holistic ontological framework. Ecology is most widely known as the science that concerns the relationships between organisms and their environment, that is, a science interested in all the conditions that permit

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[6] This is an elliptic formulation; the correct one is the following: the laws concerning the emergent properties of a level of organisation cannot be predicted, even in principle, by the laws concerning the lower level relations between the constituent parts.

[7] For instance, even the most radical reductionist could not explain biological evolution by referring only to the overall theoretical package of physics and chemistry; according to Williams: "at least the one additional postulate of natural selection and its consequence, adaptation, are needed" (Williams 1966, p. 5; see also 1985, p. 1).

organisms to live (Haeckel 1866). Early on, this holistic framework mainly took the form of an organicist worldview. Representative in this regard are the works of Stephan A. Forbes, Frederic E. Clements and John Phillips.

Some years after the far-sighted definition of ecology by Ernst Haeckel, Stephan Alfred Forbes wrote two papers that vividly portrayed the complex, intricate relationships between organisms and their environments. In On some interactions of organisms (1880) and The lake as a microcosm (1887; for the concept of "microcosm" as a central metaphor in ecology, see Schwarz 2003), Forbes was among the first to put forward the idea that natural systems exist in a state of equilibrium and must be studied "as a whole". He also delineated a strict connection between natural selection and the laws of oscillation of plant and animal species. He suggested that the functional relations among organisms were comparable to the relations between organs within an animal's body. Any change (in numbers, habits or distribution) within a specific plant or animal group will impact various other groups "in a far extending circle" (1880, p. 3). In the struggle for existence under the influence of natural selection, predator and prey species ordinarily find a balance and, to a certain extent, adjust their rates of reproduction accordingly. They have common interests: an excessive increase in a predator species will inevitably determine a decrease in the very species that constitute its food supply and consequently a decrease in its own species. However, Forbes also thought that in the intricate network of relationships between organisms on the one hand and between organisms and their environments on the other, the real limits to excessive multiplication of a species are to be found in the inorganic features of its environment (Ivi, 11, p. 16).

The "lake" was presented by Forbes as the paradigmatic case of a relatively isolated system in which the "organic complex", the species assemblage, could not be studied without taking into account all the forms of relationship between different species (predator/prey, competition, mutualism, and so forth) belonging to the lake and the surrounding terrestrial system (1887, p. 537). In other words, prior to the trophic ecology of Elton (1927) and Lindeman (1942), Forbes considered that when studying a carnivorous lake fish, one must also take into account the species upon which it depends for its existence, the organic and inorganic conditions upon which these species depend, the other competitor species, as well as the entire system of conditions affecting the existence of the plant and animal species that contribute to the existence of a specific group of related species (see also Forbes 1914).

The work of other ecologists, including Frederic E. Clements, John Phillips, Henry A. Gleason and Arthur G. Tansley, shows traces of the influence of a specific version of what we nowadays call the holism-reductionism debate. In the competition over the epistemological determination of ecology, individualistic (Gleason), anti-organicist and anti-emergentist (Tansley) supporters were ranged against the upholders of organicist holism (Clements, Phillips; Bergandi 1999; see also Chap. 5).

In the search for the fundamental units of nature, plant ecology played a role of utmost importance. Various units succeed each other: the biome, the climax, plant associations and the biotic community. According to Clements (1916) the climax formation is an organic entity. The formation grows, develops and dies as an organism. Later, Phillips, following his committed organicist position (1931, 1934, 1935a, 1935b), was to consider the same biotic community as an organism. The analogy between the organism and the unit of vegetation, the formation or the biotic community enabled Clements and Phillips to extrapolate certain characteristics from the first element to the second, albeit with the risk of transforming a relative similarity into an identity relationship for all aspects – in doing so, there is always the danger of running into an intellectual dead end. While we have never seen an organism grow younger, an environmental modification (soil desegregation, for example) can determine an ecological regression, in other words, species impoverishment.

However, the phenomenological reading of ecological organicism hides a more fundamental level of interpretation. These authors, in reality, wanted to point out the holistic ontological dimension of ecological entities. In other words, they sought to underscore the "organisational" idea that is inherent in biotic entities. From this point of view, the influence of philosophical organicism is not to be completely ruled out. It is interesting to note that the organicist and emergentist philosophical works of Herbert Spencer, Alfred N. Whitehead, Samuel Alexander, Conwy L. Morgan and Jan Smuts are all quoted by Phillips and Clements, even if in relatively late papers (Phillips 1931, 1935b; Clements 1935: see Bergandi 1999). Moreover, it is noteworthy that Forbes on the one hand and Clements and Phillips on the other support different forms of organicism. Forbes supports a conception of a biotic community that, while certainly holistic and expressed in organicist terms, is substantially pre-emergentist. His analysis stresses the interactional dimension between organisms and between organism and environment, whereas Clements and Phillips are proponents of an organicist perspective which clearly involves the idea of emergence. For instance, Clements emphasises not only that: (1) a plant formation is of itself an organism; (2) the climax is the mature stage of the formation; but also that (3) "the reaction of a community is usually more than the sum of the reactions of the component species and individuals", in the sense that the community naturally produces a cumulative amelioration of the habitat that would not be possible without the combined action of the individual plants belonging to the group (1916, pp. 3, 79, 106).

By contrast, Tansley, in a highly paradoxical way, departed from Clements and Phillips' organicist perspective by proposing the "ecosystem" concept, which revealed itself to be a more integrative, holistic entity – the physical system constituted by the organisms and physical factors. But this proposition neither involved the disappearance of the other proposed units nor, in its refusal of organicism, was it able definitively to overcome this epistemological framework (on the definitions of ecological units, see Jax et al. 1998 ; Jax 2006). In fact, Tansley identified the ecosystem as a "quasi-organism" (1935). In reality, what was at stake was not only the potentially misleading use of the word "organism", but above all the principle's unpredictability as implied in the organicist community worldview of Clements and Phillips (Tansley 1935, pp. 297–298). According to Tansley, even if the community is composed of organisms in mutual association, examination of this entity must be conducted using an analytic and anti-emergentist perspective. The Tansley refusal of the Clementsian worldview followed in the footsteps of Gleason's refusal.

Gleason (1917, 1926) maintained an atomistic and individualistic point of view on plant association. The lack of limits and structure of the associations was the fundamental reason that pushed him to see in these ecological entities the result of random immigration and environmental variations. This unoriented, random juxtaposition of plants determined structurally different forms of associations, and that required the total acceptance of analysis as a direct methodological consequence. Organisms and populations were studied separately, and their association was reducible to the various isolated plant functions. The Tansleyan ecosystem concept has had a decisive influence upon successive phases of the development of ecology. His categorisation of the "basic unit of nature" was later to be rendered dynamic thanks to Lindeman's energetic thermodynamics approach (1942), an analytical and additive method that explained the ecosystem in terms of energy exchanges among the different compartments in the biotic community and between the community and the physical environment.

Between the 1950s and 1960s, the Odum brothers developed an ecological paradigm that combines this energetic ecosystem framework with a holistic and emergentist ontology (1953, 1959, 1971: see also 1983, 1993). The following phrase clearly sums up Eugene Pleasants Odum's ontological, methodological and epistemological assumptions.

> 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 generalization the 'theory of integrative levels'. (1971, pp. 5–6).

In other words, ecosystems are complex entities characterised by emergent properties that cannot be predicted by strictly applying the analytical method. At the same time, Odum considers his ecology to be the true expression of a holistic approach: "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." (Odum 1971, p. VII). The issue here is the following: the Odumian holistic approach takes into account "the ecosystem as a whole"; but what, precisely, is this "whole"? Is it a matter of ecology, physics or some other scientific discipline?

In addition, it is interesting to note that Odum considers that "the findings at any one level aid in the study of another level, but never completely explain the phenomena occurring at that level" (1959, p. 7; 1971, p. 5). Having said this, Odum seems to deny any value of epistemological reductionism, considering that ecosystem ecology is not reducible to physics. At the same time, it is a matter of fact that Eugene Pleasants Odum, collaborating with his brother Howard Thomas Odum, locates the theoretical core of systems ecology in energetic analysis:

> In ecology, we are fundamentally concerned with the manner in which light is related to ecological systems, and with the manner in which energy is transformed within the system. Thus, the relationships between producer plants and consumer animals, between predator and prey, not to mention the numbers and kinds of organisms in a given environment, are all limited and controlled by the same basic laws which govern nonliving systems, such as electric motors or automobiles. (1971, p. 37; see also Chap. 18).

The Odums' epistemological manifesto has been so effective that from then onwards ecology has been perceived and presented as the holistic science par excellence.[8] In referring to a philosopher of science, Jerome K. Feibleman, they outline a hierarchical worldview where every level of organisation is characterised by a specific degree of complexity and properties that are not predictable or explicable from the study of the lower levels alone (epistemological holism). Implicitly in their early works and explicitly in the later ones (Odum 1993), the

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[8] The term "holism" was to appear from the third edition (1971) onwards, even if the corresponding worldview had already been outlined in previous works.

emergence concept and an emergentist ontology are the cornerstones of the Odumian ecosystem paradigm.

Methodologically, however, they ran into an incoherence that unbalances their whole theoretical edifice. There are three reasons for this. First, the difference between collective and emergent properties escapes the Odum brothers, at least in their early work. Some population and community properties (density, age distribution, natality, mortality, species diversity, etc.) – even if expressed as statistical functions – are considered as unique characteristics of the group. In all these cases the properties, even if they must be considered as group statistical functions, are determined through the examination of the components using classical analytical and additive methodology (Salt 1979). Second, the physicalist background of the Odums' systems ecology stands in contradiction to emergentist ontological assumptions. For instance, they consider the outcome of the Eniwetok Atoll energy evaluation (Odum and Odum 1955; Odum 1977) to be an emergent property. Thus, they are considering ecological systems as structured physical entities, forgetting that their specificities are not reducible to the physical domain. Finally, a true emergentist approach will be necessarily a multi-level triadic approach that considers simultaneously at least the lower and higher adjacent levels in addition to the level at which the main object of research is to be studied phenomenologically. Instead, in the Odums' work the affirmed importance of the emergent properties of ecological systems is not coupled with a corresponding emergentist methodology — at least not until Odum and Barrett (2005, p. 8), where the necessity of a genuinely triadic emergentist methodology can be clearly recognised. However, the previous Odumian approach is fully legitimate (see the article by Chap. 15). It is nevertheless a kind of crypto-reductionist systemism or, to put it in oxymoronic terms, a kind of reductionist holism, that can at best be considered as "holological" (Hutchinson 1943), and not as the true expression of a holistic, emergentist methodology and epistemology. Hutchinson proposes making the distinction between holological and merological approaches. In a system investigated with a holological approach "(...) matter and energy changes across its boundaries are studied", whereas with a merological approach "(...) the behavior of individual systems of lower order composing (the system) S are studied" (1943, p. 152). However, it is worth noting that the holological approach is an expression of a systemic and yet physicalist perspective, while the mereological one, methodologically speaking, is a strict expression of an analytical-additive reductionist perspective. McIntosh (1985, pp. 199–213), Taylor and Blum (1991, p. 284; see also Taylor 2005) were among the first to analyse the Janus-like character of the ecosystem ecology represented by E.P. Odum: they saw it as a "functionally holistic” new ecology, which was essentially, however, expressed through system modelling involving the physical attributes of ecosystems.

Conclusion

The holism-reductionism debate in ecology is, without a doubt, a protean issue. In ecological studies, first, the debate took a number of forms: an organicist worldview that expressed the holistic, systemic relations existing between organisms, and between organisms and their environment (Forbes); an organicist and emergentist view of plant communities (Clements, Phillips); a view of plant associations as individualistic, atomistic, randomly generated entities (Gleason); and, finally, Tansley’s integrative “ecosystem” concept that expressed the epistemological refusal of Clementsian organicism and emergentism. Second, it showed itself in the form of the acceptance or refusal of physicalism. If we broach the epistemological nature of ecology and come to the conclusion that ecology is fundamentally a holistic science, we would be mistaken in thinking that, methodologically, ecology necessarily embodies an emergentist approach. In fact, an “emergentist holistic” approach need be understood neither as a reiteration nor as a tautology. This distinction is of utmost importance. It enables us to avoid all the inconsistencies inherent in the Odumian paradigm and all paradigms that propose a holistic ontology but that, in practical methodological research, deploy the full panoply of reductionism. In fact, in the history of science, a holistic and emergentist ontology is not always applied consistently in emergentist methodology and epistemology. For instance, once we cease to consider ecosystem ecology as the expression of a “holistic” attitude and recognise in it instead a “hological” framework, a kind of oxymoronic “reductionist holism”, then we will avoid misunderstandings and be back on track. We will then be free to construct a truly consistent holistic and emergentist ontological, methodological and epistemological framework.

Finally, to sum up from a strictly epistemological point of view, one of the major implications of the holism-reductionism debate is the confrontation between two philosophies that at first sight support a shared hierarchical worldview of natural reality. However, there is one very important difference. From the reductionist point of view, the ideal point to reach is that all the scientific disciplines will, sooner or later, be formulated, interpreted and reduced to the more fundamental sciences, particularly physics. From the holistic or, more correctly, emergentist point of view, the supposed ontological natural hierarchy does not involve a hierarchical relationship between the scientific disciplines but rather a systemic one. The sciences with their specificities and particularities allow us to grasp different aspects of reality which we cannot reduce to one another, but which we can combine in order to arrive at a non-definitive, ever-changing picture of reality. For emergentists, the universe is a growing entity that generates ever new phenomena, events and qualities which can be neither predicted nor deduced from those that preceded them. We must remember, however, that an a priori unpredictability does not necessarily involve the refusal of an (ideal) a posteriori explanation.

On the contrary, according to anti-emergentists "nothing is new under the sun" and, above all, any so-called novelty is predictable and explicable: the same universe, yet two antinomic and incommensurable worldviews. Which paradigm is closer to reality? Are the reductionists correct when they claim emergents are epiphenomena? Are the emergentists wrong when they attribute an ontological status to emergence and, above all, axiomatically assert its a priori unpredictability? These are open questions to which the answers will probably never be given once and for all but always case by case.

Finally, to grasp the logical structure of alleged emergence, we must ask ourselves: what are the emergents – properties, relations, entities or laws? What is the level of organisation that bears the property which is supposed to be emergent? In addition, the levels of organisation – and among them, significantly, certain ecological levels such as the ecosystem or landscape – must be understood as levels of description, or "methodological abstractions". These epistemological fictions sometimes make it possible to develop models that allow us to approach natural reality "asymptotically". Otherwise we risk an insidious epistemological fallacy: a hypostatisation of our abstractions that brings us to project our hypotheses and theories onto reality, forgetting that they are merely notional tools by which to approach it. A metaphor may help to clarify this idea: it is like a dog that starts to play with you but forgets, in the excitement of the game, that it is playing and begins to bite in earnest. In other words, a constructivist epistemology prevents us from being bitten by the rock-hard certitudes of naive realism. Our scientific constructs make it possible to approach natural reality without ever fully grasping it. These constructs allow us to understand certain aspects of reality in a non-definitive way. They remain valuable until such time as new constructs allow us to get even closer. This is a genuine process of scientific knowledge where the syntagm "The End" will never be written.

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