

HOLISM IN THE SCIENCES

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Summary

Arguments for the holistic character of transdisciplinary knowledge relate transdisciplinarity with holism in the history of thinking (see *Unity of Knowledge and Transdisciplinarity: Contexts of Definition, Theory and the New Discourse of Problem Solving*). Forms of holism in the sciences are considered in particular in biology, in the physics of space–time, the physics of quantum systems, and in the social sciences.

Holism in biology takes many different forms, it is not a single idea. The metaphysical and epistemological assumptions which biological holism typically opposes include those of reductionism, mechanism, and individualism. The oldest holistic idea in biology is vitalism, the view that life forms contain an immaterial formative force which is absent in non-living matter. Emergentism is an attempt to avoid both reductionism and vitalism. As an examination of historical examples shows, the relationship between

holistic ideas and substantive biological issues is complex. There are some recurring themes in the history of biological holism, for example, the tendency to postulate super-organisms above the level of traditionally conceived individual organisms.

Holism in physics is traditionally associated with the idea that matter is identical with space–time: all physical properties are realized as properties of points or regions of space–time. However, the attempt to build our current physical theories on that idea failed. Nonetheless, there is evidence for some sort of holism in another area of today's physics, namely quantum physics: quantum systems have some of their basic properties not in separation from each other, but only in the form of correlations of entanglement among them.

Social holism is to be distinguished from trivial claims to the effect that social roles can only be exercised in a community and that social interactions are necessary for the development of thought and rationality in a human being. Social holism as a substantial and controversial thesis is the claim that a human being is a thinking being only in virtue of its membership in a social community of persons. Social holism goes back to romanticism and Hegel.

1. Holism in biology

The term “holism” was coined by J. C. Smuts (1870–1950) in order to capture a general approach to the study of complex systems which grants the whole a special ontological and epistemological significance which the parts of the system lack. A related notion which was popular especially in early twentieth century biology is the “organismic” (also: organismal) approach, which stressed the importance of studying whole organisms in order to understand life processes. Although these terms are relatively new, some of the ideas which are associated with holism today are much older and can be traced back as far as ancient Greek philosophy, especially Aristotle (see section 1.2). Since then, holistic thinking has manifested itself in the biological sciences in very different forms. In fact, the heterogeneity of holistic ideas in biology is so great that it is dubious whether they are meaningfully classified under a single concept. Probably the best way of defining holism in biology is negatively, in opposition to some contrary doctrines. Three such doctrines which various forms of holism have tried to oppose can be discerned in the history of biology: reductionism, mechanism, and individualism. These are now briefly discussed.

1.1 Reductionism, Mechanism, and Individualism

Reductionism in biology can have different meanings. A helpful distinction is the one between ontological, methodological, and epistemological reductionism. *Ontological reductionism* refers to the claim that no substances or fundamental forces exist in biology which are not also present in non-living matter. Ontological reductionism is basically equivalent with the negation of *vitalism* (see section 1.2). *Methodological reductionism* denotes the belief that biologists need only investigate phenomena at the micro-level, for instance, the level of molecules. *Epistemological reductionism*, finally, asserts that theories describing phenomena at a higher level can be derived or explained from theories treating more fundamental phenomena (in conjunction with sufficient initial and boundary conditions). Further distinctions can be drawn within

epistemological reductionism. If the term "reductionism" is used with a multitude of different meanings, which is evidently the case, then so is the term "holism" if understood as the opposite to reductionism. Three kinds of holism could be defined on the basis of ontological, methodological and epistemological reductionism by simply asserting the contrary doctrines. *Ontological holism*, then, would be equivalent with vitalism (see section 1.2). *Methodological holism* would stress that biological phenomena be studied at the macro- or organismic level, and epistemological holism would assert that higher-level theories are not derivable or explainable from lower-level ones. In fact, all of these possible holistic doctrines can be found in the history of biology in various forms and combinations.

Reductionism in biology has been controversial at all times and there exist a variety of historical and contemporary research programs which were more or less explicitly opposed to reductionism (see sections 1.4 – 1.7). The most successful reductionistic research program ever is clearly molecular biology, which originated at the interface of biochemistry and microbial genetics towards the middle of the twentieth century. The discovery of the structure of the genetic material (DNA) by J. D. Watson (1928 –) and F. Crick (1916 –) in 1953 and the subsequent elucidation of the molecular mechanisms of DNA replication and protein synthesis is widely seen as a triumph of reductionism. However, it has proven to be rather difficult to specify exactly in what sense molecular biology has "reduced" classical Mendelian genetics to the molecular level.

Another traditional metaphysical doctrine that holists have opposed is *mechanism*, which generally refers to the idea that all systems can be explained in the manner in which classical physics treats mechanical systems. Classical mechanical systems consist of particles with a limited number of properties (e.g., mass, charge) which interact deterministically by mechanical or electromagnetic forces. All the properties that these systems display can (at least in principle, in other words, given unlimited computational power) be explained from the properties of the particles and the laws describing their interaction. Time and again, biologists have argued that the explanatory ideals of mechanism are unsuited for biology, for the following reasons: First, it has been questioned that biological systems behave deterministically. Second, biological entities (e.g., species) are highly variable and do not seem to have unchanging essences like physical and chemical entities (e.g., elements) do. Third, some think that biological systems display the phenomenon of *emergence* (see section 1.3). Fourth, biology is characterized by a special form of explanation, namely functional explanation, which may not fit into a mechanistic framework.

The third possible opposite to holism in biology is *individualism*, which denies any special status to wholes. Individualists typically assert that aggregates of individuals (e.g., social groups) are "nothing more" than the individuals they are composed of and their mutual interactions. Holists, by contrast, are fond of saying that the "whole is more than the sum of its parts". This formulation is problematic. If "sum" and "more" in this sentence are interpreted in a strictly arithmetic sense, then the sentence is self-contradictory. If the sentence is not so interpreted, then it is not clear what it means. For the same reasons, the individualists' talk of "nothing more than the sum of the individuals" is ambiguous (it is either trivial or unclear).

In spite of the difficulties to give the term “holism” a precise meaning or to identify an essence common to all forms of holistic thinking in biology, there are some recurring themes in the history of biology, which will be explored below. Next, two general types of holistic doctrines of a more metaphysical nature, which have played a role in the history of biology, will be discussed: vitalism (section 1.2) and emergentism (section 1.3). This will be followed by a presentation of some concrete examples of holistic thinking in various biological subdisciplines, namely physiology (section 1.4), ecology (section 1.5), evolutionary biology (section 1.6), and genetics (section 1.7).

1.2 Vitalism

In his biological writings, Aristotle (384–322 BC) postulated several kinds of immaterial souls (*psyche*) to explain the properties of living organisms, especially the fact that living organism seem to carry their own *telos* (goal, purpose) within themselves. This idea was taken up by eighteenth century thinkers such as C.F. Wolff (1679–1754) or J. F. Blumenbach (1752–1840), who assumed the existence of special formative forces in living organisms (*vis essentialis, nitus formativus*). I. Kant (1724–1804) rejected this form of vitalism, however, he also thought that some biological phenomena do not admit of mechanistic explanations. It is the cognitive limitation of human reason, according to Kant, which forces us to treat certain natural phenomena *as if* they were driven by an immanent *telos*. C. Darwin (1809–1882) is widely seen as having rendered natural teleology obsolete, since the functional adaptation of organisms is explained by the natural selection of the reproductively most successful organisms. As a consequence, natural teleology was replaced by the quasi-teleology represented by biological functions.

In the nineteenth century, vitalism received a setback when F. Wöhler (1800–1882), in 1828, achieved the first chemical synthesis of urea from inorganic compounds. Urea is an organic compound, and some vitalists had thought that the production of such compounds already requires vital forces. Wöhler's synthesis showed that organic compounds can be produced without the involvement of living matter. Nevertheless, vitalism remained popular in some circles, especially in German *Naturphilosophie*. In the late nineteenth and early twentieth century it enjoyed various comebacks, for instance in the writings of the philosopher H. Bergson (1859–1941), who postulated a special *élan vital* operating in living organisms, or with the eminent embryologist H. Driesch (1867–1941). The latter two are commonly referred to as “Neo-Vitalists”. Driesch claimed to have “proofs” for the impossibility of mechanistic explanations of life processes. These alleged proofs were based on Driesch's own experiments on the regeneration of lost body parts in certain marine invertebrates. Driesch explained such phenomena by postulating an immaterial factor, which he termed “entelechy” (after Aristotle's term *entelecheia*, which is derived from *telos*). Driesch thought that the entelechy organizes or structures the physico-chemical processes occurring in living organisms and is necessary especially to explain certain forms of self-regulating and goal-directed behavior of living cells and multicellular organisms.

The connection between vitalism and holism is twofold. First, most forms of vitalism are holistic because the vital force or entelechy is assumed to constitute an indivisible whole which, in contrast to mechanical systems, cannot be analyzed into parts (similar to the Cartesian soul). Second, vitalism was one of the starting points of a holistic trend which gained some popularity in the twentieth century: emergentism.

1.3 Emergentism

Emergentism (from lat. *emergere*, to appear) arose in the late nineteenth/early twentieth century out of attempts to avoid both vitalism and reductionism. One of the classical works of emergentism was written by the animal psychologist C. L. Morgan (1852–1936). Morgan thought that, occasionally, evolution produces novel properties which could not (even in principle) be predicted or explained from combinations of the previously existing properties. He called such properties "emergent", and the general phenomenon as "emergence" or "emergent evolution". This idea was considerably refined by C. D. Broad (1887–1971). Broad started by considering properties of a complex system which can be explained by the properties of the parts in conjunction with suitable laws describing the interactions of these parts. If these laws are not *isolated*, i.e., if they are able to explain a variety of other phenomena as well, then Broad does not consider the properties in question as emergent, because they are entirely explainable in terms of the properties of their parts and their mutual interactions. Only properties for which no laws describing the interactions of the parts exist, or for which these laws are isolated, are emergent in Broad's sense. Under Broad's analysis, for example, the properties of an electric circuit are not emergent (even though it shows properties that its parts lack), while, from his early twentieth century perspective, some of the properties of the water molecule are. The latter example had already been discussed by J.S. Mill (1806–1873) and was used by some biologists in order support their holistic views (see section 1.4).

From the perspective of contemporary physical chemistry, however, it could be argued that the properties of the water molecule are not emergent either, because non-isolated quantum-mechanical laws are known today which can, at least approximately, explain the stability of the chemical bond between the oxygen and the two hydrogen atoms in the water molecule and its resultant properties. Therefore, some philosophers have argued that emergence is always relative to some transient state of scientific knowledge. However, the emergence debate is far from settled, and emergentism has been endorsed by some major twentieth century biologists as offering an attractive alternative to both reductionism and vitalism, e.g., by E. Mayr (1904 -).

The main difference between emergentism and vitalism is that the former is explicitly committed to *materialism*, in other words, it is a variety of substance monism. Vitalism, by contrast, is a form of substance dualism, as the vital force or entelechy is thought to be a substance of its own, which is ontologically distinct from inorganic matter. Emergentism avoids substance dualism, which is thought to be metaphysically problematic, but without endorsing reductionism or mechanism. Another way of putting the difference between vitalism and emergentism is by saying that the former is substance *and* property dualistic, while the latter is substance monistic but property dualistic (or even property pluralistic).

Another question is why there should be emergent properties. In order to answer this question, some emergentists have suggested that the behavior of complex systems is not fully determined by the behavior of their constituent parts. Instead, they have postulated the existence of *downward causation* or *macrodetermination*, i.e., the causal determination of the parts of a system by the whole. Whether or not macrodetermination is compatible with the laws of physics is still subject to debate, as is the question of whether macrodetermination in biology does not amount to vitalism (against the intentions of emergentists).

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Biographical Sketches

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