HOLISM IN THE SCIENCES

M. Weber
Center for Philosophy and Ethics of Science, University of Hanover, Germany

M. Esfeld
Department of Philosophy, University of Konstanz, Germany

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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 spacetime, 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 spacetime: all physical properties are realized as properties of points or regions of spacetime. 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 todays 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 (18701950) 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 (384322 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 (16791754) or J. F. Blumenbach (17521840), who assumed the existence of special formative forces in living organisms (*vis essentialis*, *nisus formativus*). I. Kant (17241804) 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 (18091882) 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. Whler (18001882), 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. Whlers 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 *lan vital* operating in living organisms, or with the eminent embryologist H. Driesch (18671941). 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 Aristotles 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 (18521936). 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 (18871971). 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 Broads sense. Under Broads 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 (18061873) 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).

1.4 Examples: Physiology

Holistic thinking pervaded much of biology throughout the nineteenth century as well as the interwar period of the twentieth century and has found an especially strong resonance in physiology. For example, the French physiologist C. Bernard (18131878) urged that organisms always be considered as wholes, but without losing sight of the details of their organization. According to Bernard, the knowledge of isolated parts of an organism will never lead to a full understanding of the properties of the whole organism. The reason is that the properties of the whole organism are not a simple addition of the properties of its parts. To illustrate this, Bernard used J.S. Mills famous example that the properties of hydrogen and oxygen do not account for the properties of water (see , *section 1.3*). As a methodological consequence of his holism, Bernard suggested to always proceed in "vital synthesis" in physiological experimentation. A phenomenon that Bernard and later holistically oriented physiologists were particularly interested in was the ability of organisms to maintain a stable state under a great variety of external conditions, a phenomenon which later came to be known as "homeostasis". This kind of self-regulation could only be explained by considering the entire system, these physiologists thought.

1.5 Examples: Ecology

It might be thought that ecology is a fundamentally holistic science, as its subject are whole associations of organisms and their interactions with the environment. However, certain holistic doctrines have been controversial within ecology. For example, the botanist F. E. Clements (18741945) proposed a theory of succession according to which plant communities are to be analyzed as whole, complex super-organisms which display internal organization and cohesion. On this approach, the plant community is viewed as a natural unit which cannot be further decomposed. H. A. Gleason (18821975), by contrast, defended an individualistic conception of plant communities. According to Gleason, every plant community is the product of highly variable environmental conditions and lacks internal organizing principles of the sort which individual organisms have them. Accordingly, the view of plant communities as complex organisms in their own right was rejected by Gleason as a misguided metaphor.

We seem to have here a clear example of a disagreement between a holist, according to whom a plant community is a natural unit, and an individualist (see, *section 1.1*) according to whom only individuals constitute natural units and communities are relatively arbitrary. However, it must be emphasized that this was not merely a metaphysical dispute, since there was also disagreement on substantial biological issues. For example, according to Clements, there are general rules governing plant succession, whereas on Gleasons theory "every species of plant is a law unto itself". This demonstrates the difficulty of separating holism as an abstract, metaphysical notion from the theoretical context and specific subject matter of the biological discipline in question.

Another example is provided by ecosystems ecology, which was pioneered by the brothers E. P. Odum (1913 -) and H. T. Odum (1924 -). They postulated a hierarchy of organizational levels in ecosystems and assumed that each level displays emergent properties (see, *section 1.3*) which are absent at lower levels of organization. Only a holistic approach, which studies ecosystems at all levels of the hierarchy, would be able to identify the emergent properties. Contemporary ecologists reject these ideas and have attempted to show that the properties which the Odum brothers considered to be emergent are fully explainable in a reductionistic manner.

Another development which has been associated with holism and which was taken up by ecologists is the *systems-theoretic approach* (see, Systems Analysis and Modelling in Transdisciplinary Reserach) which originated around the middle of the twentieth century. Systems theorists have explored, in particular, possible analogies between biological systems such as, e.g., ecosystems and *cybernetic* systems. For instance, they have investigated whether ecosystems display homeostasis, an issue which is of some importance for environmental policy. This approach has been challenged, for the assumed homeostatic equilibria, although they certainly exist in an individual organism, may not exist in more inclusive systems such as whole ecosystems. Furthermore, it is questionable whether ecosystems actually display a cybernetic or a functional organization in the sense of having proper biological functions.

The most recent and, at the same time, most extreme form of holism in ecology is exemplified by the so-called "Gaia hypothesis", according to which the surface of the earth is best viewed as a single, self-regulating organism. This hypothesis has been criticized for lack of testability.

1.6 Examples: Evolutionary Biology

The idea that evolution produces emergent properties has been discussed in section 1.3. A more recent manifestation of holism in evolutionary biology can be found in the continuing debate on the "units of selection" problem in the theory of natural selection. One of the starting points of this debate were the ideas collectively referred to as of *group selection*, which were entertained by a number of biologists to explain certain forms of social behavior in animals, namely altruistic behavior. Such behavior, it was argued, cannot be explained on the basis of Darwinian individual selection, since the fitness of an altruistic individual appears to be reduced in comparison to non-altruists. Therefore, one would expect altruistic behavior to be eliminated by natural selection. However, altruistic behavior seems to exist in a great variety of animal species. In order to overcome this theoretical difficulty (which had already been noticed by Darwin himself), several biologists postulated the operation of natural selection between *groups* of animals. Specifically, groups of altruistic individuals would be favored by natural selection over groups of animals lacking altruistic behavior, because, supposedly, they would cooperate and use resources more efficiently.

The theory of group selection was subsequently criticized by many biologists, who argued that the postulate of group selection is not admissible as long as some biological trait can be explained by ordinary Darwinian selection. Alternative explanations of altruistic behavior which do not require the postulate of group selection have, in fact, been found. For example, the "kin selection" theory of W. D. Hamilton (19362000) explains altruism by the effect of such behavior on genetically related individuals, which are likely to contain copies of the altruist's genes. As a consequence, all the altruist does is to maximize the transmission of its own genes, which explains how such behavior can evolutionarily establish itself in a population by natural selection. The approach which recognizes genes as the only things on which selection can act is also known as "gene selectionism" and has been criticized for its strong reductionistic character.

Furthermore, some palaeontologists have proposed that there exists selection between entire species. This theory of *species selection* was intended as an explanation for certain macro-evolutionary patterns, in particular the fact that certain periods in the history of life on earth seem to show a much stronger evolutionary diversification at higher taxonomic levels like phyla, while other periods are comparatively static (this phenomenon has been termed "punctuated equilibrium"). It is thus possible that certain phylogenetic lineages which show a high rate of speciation were selected over longer time periods and gave rise to the relatively few phyla of animals that exist today. It is controversial whether this theory is merely an extension of the Synthetic Theory of Evolution which emerged out of attempts to reconcile modern genetics with Darwinian evolutionary theory in the 1930s and 40s, or whether it is an alternative to the Synthetic Theory.

The debate between gene selectionists, individual selectionists (who believe that only individuals can be a target of selection), group selectionists, and species selectionists may be viewed as an instance of the more general opposition between holism and individualism. Species selectionism and group selectionism may be viewed as holistic theories, because they treat rather inclusive groups of organisms species and social groups, respectively as evolutionary units which behave like individual organisms in ordinary Darwinian selection. Furthermore, the debate concerning gene selectionism can be viewed as an instance of the more general reductionism debate. Again, it is clear that these debates are not merely metaphysical but involve specific empirical issues from the biological subject domain in question. For example, whether or not group selection or species selection exist must be decided empirically, it cannot be decided on purely metaphysical grounds.

Holistic ideas have also been defended in systematics and taxonomy. For example, it has been suggested that species should not be viewed as types or classes, but as *individuals* instead. Classes are abstract entities which are not spatially or temporarily localized. By contrast, individuals are concrete entities and exist only in a certain spatio-temporal region. Furthermore, they show internal cohesion. Some philosophers and biologists have argued that species fulfill these criteria. They are like super-organisms crawling across a certain geographical area for a limited stretch of time, namely from their speciation event until their extinction (the latter is statistically extremely likely for any species). Accordingly, the relationship between a biological individual and the species it belongs to should be viewed as a part-whole relation, not as a relation of class membership. The view of species as individuals (which, in addition, lends itself as a conceptual basis for the theory of species selection mentioned above) thus accords a special ontological status, namely individuality and real existence in space and time, to a whole (the species) where the more traditional view of species as classes only sees an abstract grouping of individual organisms. This debate therefore may be viewed as an instance of the more general opposition between holism and individualism (see , *section 1.1*). Although this may seem confusing, in this example the view of species as individuals represents the holistic position, while the view of species as classes or groupings of individual organisms represents the individualistic position.

1.7 Examples: Genetics

Early twentieth century theories of the gene viewed the units of inheritance as indivisible, corpuscular entities, which are lined up on chromosomes like beads on a string. Developments in the first half of the twentieth century led to considerable revisions in this atomistic picture of the gene. For example, genes were shown not to be indivisible, i.e., intragenic recombination is possible. Furthermore, a plethora of genetic phenomena were discovered which led to further revisions in the concept of the gene. One such discovery, which was made in the 1930s in the laboratory of T. H. Morgan (18661945) using the fruit fly *Drosophila melanogaster* as an experimental organism, came to be known as "position effect". This term refers to the phenomenon that a gene's phenotypic effect can depend on its location on the chromosome. R. Goldschmidt (18781958) suggested that all gene mutations are really position effects and called the entire notion of corpuscular genes into question. According to Goldschmidts genetic theory, chromosomes cannot be meaningfully partitioned into "genetic atoms" or genes. Instead, he proposed that chromosomes function as wholes in genetically controlling an organisms development. Thus, Goldschmidts theory has a decidedly holistic appearance.

Each chromosome, according to Goldschmidt, represents a continuum or "reaction system" on which mutations may occur anywhere. A special kind of mutations, which Goldschmidt referred to as "systemic mutations" and which he envisioned as particularly drastic changes in the "reaction system", can even give rise to new species by a process of saltational evolution.

Goldschmidt thus opposed the prevailing scientific opinion of his time in both genetics and evolutionary theory. Following T. Dobzhansky (19001975), most biologists eventually accepted the "Synthetic Theory of Evolution", which viewed genes as particulate and, at the same time, species formation as gradual. The extent to which Goldschmidts genetic theory is a consequence of previously held holistic predilections is difficult to determine (it might simply be a consequence of Goldschmidts experimental research).

1.8 Recurring Themes

As this brief review shows, the history of biology shows a few recurring themes related to the more general opposition between holism on the one, and reductionism, mechanism and individualism on the other side. One of these themes is the pervasive tendency, shown by many biological holists, to postulate various kinds of *super-organisms*. What these holists do, more precisely speaking, is to apply properties which are originally exemplified by the individual organism (like my dog or Socrates) to aggregates of individuals like plant communities (section 1.5), ecosystems (section 1.5), animal groups (section 1.6), or species (section 1.6). These properties include a functional organization (i.e., the possession of a set of integrated biological functions in the proper sense of the term), cohesion in space and time, the ontological status of individuals (as opposed to types or classes), and homeostasis. It could be argued that these applications of the concept of organism should be rejected as metaphorical, since it is a necessary condition for something to be an organism that it is capable of self-reproduction. It is unclear in which sense communities or ecosystems reproduce themselves. However, there are borderline cases where it is not entirely obvious how the concept of individual organism is correctly applied, for example, insect colonies (groups of closely cooperating individuals or one big individual with many extremely similar parts?) or organisms which reproduce asexually.

The historical examples discussed show that the metaphysical issues associated with holism in biology cannot always be sharply separated from the empirical issues which arise from the specific subject matter of a biological sub-discipline. What "holism" exactly means thus depends, to some extent, on the theoretical context. An example is provided by the question of whether ecological units such as communities or ecosystems display homeostasis (section 1.5). Whether or not such systems have stable equilibrium states, i.e., whether they return to the initial state after a disturbance, is clearly an empirical one, but it has consequences for the more metaphysical question of whether they are correctly viewed as some kind of super-organism or functionally organized system. Similarly, the holistic theory of chromosomal reaction systems in genetics (section 1.7) was based on the empirical assumption that all apparent gene mutations are caused by position effects, which was clearly shown to be false by later developments in genetics.

In other cases, the connection between holistic metaphysical ideas and substantive biological theories is much looser. For example, emergentism (in contrast to vitalism) seems to be more of a philosophical doctrine which was adopted by a few philosophically minded biologists than an idea which has greatly influenced biological theorizing, for the extent to which emergentism has influenced the historical development of biological thought appears to be minor at best. An exception, perhaps, are recent theories of "self-organization", which try to explain the emergence of biological order on the basis of non-linear dynamics and related mathematical methods. According to some theorists, self-organization represents a set of fundamental principles of nature which complement the laws of physics and which are emergent with respect to the latter.

2. Holism in physics

2.1 Holism in spacetime theories

Holism in physics is opposed to atomism. Atomism in classical, Newtonian physics is the view that

there are small, indivisible bodies that have a few basic properties each. Position, momentum (mass times velocity), and mass count among these properties. These are intrinsic properties in the sense that the way in which each physical system has these properties is independent of the way in which all the other physical systems have these properties. All complex physical systems consist of atoms. Atoms move in space and time. In atomism including Newtonian physics, space and time are supposed to be absolute entities that exist on their own independently of whether or not there are material systems such as atoms. The main problem for this position is the ontological status of space and time. How could we conceive of space and time as some sort of a substance even in the absence of matter?

One reply to that problem is a relational theory of space and time, as proposed by Gottfried W. Leibniz (16461716) in opposition to Isaac Newton (16421727). The traditional form of holism in physics is another reply to that conceptual problem. The idea is to identify matter with space and time so that there is only one thing in the physical realm, spacematter or matterspace. Space thus is indeed absolute and a substance, but only insofar as space and matter in space are one and the same thing. This conception can be traced back to Ren Descartes (15961650). He can be read as identifying matter with spatial extension in the second book of his *Principles of Philosophy*. Baruch de Spinoza (16321677) can be taken to elaborate on that conception in the scholium to proposition 15 of book one of his *Ethics*. According to this conception, bodies are identical with points or regions of space. All physical properties are realized as properties of points or regions of space. This position is a holism, because, in the last resort, there is only one thing, spacematter, and all physical properties are properties of that one thing. The main problem for this conception is to spell out what the physical properties of points or regions of space are on the basis of which it may be possible to reconstruct the ordinary physical properties that not only Newtonian physics, but also common sense ascribes to bodies moving in space.

If we take the development from Newtonian space to the spacetime of special relativity (1905) into account, it is possible to put forward a defensible reconstruction of what we take to be the motion of bodies in space within this position. Consider a continuous string of spacetime regions whose physical properties are similar. One can regard this string of regions as one bigger region within spacetime. What we take in common sense to be the motion of a body through space is in fact a continuous string of points or regions of spacetime whose physical properties are similar and which can for that reason be considered as one individual.

It could seem that physical field theories in general, which originate in nineteenth century physics, support the holism in physics that identifies matter with space or spacetime. Field theories are often described in such a way that the field properties are predicated of spacetime points. Hence, it could seem that the field properties are properties of spacetime points. However, a physical field theory says merely that the field has the properties in question *at* spacetime points, but not that these are properties *of* spacetime points. Therefore, the holism under consideration cannot be based upon field theories alone. It depends on an argument which establishes that these theories do not require an ontological commitment to physical systems (such as fields) in addition to spacetime. Given physical field theories, in philosophy of science, we also have the option to begin with fields and to construct a relational theory of spacetime on the basis of an ontology of fields. Furthermore, as far as classical fields are concerned, they can be conceived as being built up on the basis of local field sources. It is a matter of dispute to say the least whether the properties which make something a local field source are relational in the sense that they depend on there being other local field sources which build up a whole field. Hence, physical field theories do not in general support a holism.

The holism in physics that identifies matter with space or spacetime gathered momentum when general relativity (1916) achieved a combination of a theory of spacetime with a theory of matter insofar as matter is subject to gravitation. Matter in the sense of mass determines the geometrical structure of spacetime: as a result of the presence of mass, spacetime is curved. The curvature of spacetime, in turn, influences the path of physical systems in spacetime. Gravitation (the gravitational field) and the curvature of spacetime are the same thing. The identity of a theory of curved spacetime with a theory of the gravitational aspect of matter is the basis for an interpretation of general relativity along the lines of the sort of holism under consideration.

Some forty years ago, the physicist John Wheeler introduced the program of geometrodynamics. Whereas in general relativity only the theory of gravitation can be built on a geometrical description of spacetime, geometrodynamics envisages constructing electromagnetism and elementary particle physics solely on the basis of a geometrical description of empty curved spacetime. Empty spacetime means in this context a spacetime without additional physical systems such as particles or fields. Geometrodynamics envisages reconstructing all physical properties on the basis of a description of the geometrical properties of spacetime such as its curvature. As John Graves in particular makes clear, the ontological claim of geometrodynamics is that the physical realm is identical with the four-dimensional spacetime continuum with its geometricali.e., physicalproperties. Therefore, geometrodynamics is a sort of holism in physics subsequent to general relativity.

However, geometrodynamics failed. It proved not to be possible to reduce electromagnetism and elementary particle physics to a description of the geometrical properties of points or regions of spacetime. Wheeler repudiated geometrodynamics in the sense of a program that sets out to build physics solely on spacetime without acknowledging additional physical systems in 1973. That is to say: The traditional sort of holism in physics, namely to identify matter with space or spacetime, is not a viable option in the philosophy of science. Nonetheless, there is another area in todays physics in which there is strong evidence for a substantial holism, namely quantum physics.

2.2 Holism in quantum physics

Quantum physics is widely seen as exhibiting a sort of holism. Quantum physics treats elementary material systems such as electrons, neutrons, protons and the like in the first place. Quantum physics was developed in the form of quantum mechanics by Niels Bohr (18851962) and his collaborators in the nineteen twenties. Todays quantum physics encompasses quantum mechanics and quantum field theory. Quantum field theory develops quantum physics in the spacetime framework of special relativity and includes electromagnetism.

The first remarkable feature of quantum physics is that, in distinction to classical physics, some of the basic properties of each quantum system are interdependent. These properties are called incompatible or complementary observables. In any state of a quantum system, at most one of two or more incompatible observables has a definite numerical value. The most famous example of incompatible observables is position and momentum. These observables are interdependent in the following sense: The more position comes close to having a definite numerical value, the greater is the dispersion of momentum (and *vice versa*). This is the content of the well-known Heisenberg inequality. This interdependence of position and momentum has the following consequence: Quantum systems usually do not have a precise localization. Their properties are thus not instantiated at points or point-seized regions of space.

Furthermore, if we make a measurement one of two or more incompatible properties, the measuring apparatus does not register the value of a property that the system has independently of its interaction with the apparatus. On the contrary, the quantum system acquires a definite numerical value of the property in question only relative to the apparatus acquiring the property of indicating such a value.

This point has nothing to do with a disturbance of quantum systems by macroscopic measuring instruments. It is a consequence of the incompatibility of properties of quantum systems.

What is much more, if we consider two or more quantum systems that have incompatible properties each, it is to be expected that the states of these quantum systems are entangled. That is to say: None of these systems is in a well-defined state, that is, a pure state. Only the whole of these systems taken together is in a pure state. The simplest example of entanglement is this one: The spin is a physical property that is treated only in quantum theory. The properties of spin in all three orthogonal spatial directions of a quantum system are incompatible observables. There are systems of spin 1/2 such as electrons and neutrons. In this case, the spin in any of the three orthogonal spatial directions can take only two definite numerical values. These values are known as spin up and spin down. Imagine that two systems of spin 1/2 are emitted together from a source. After the emission, their interaction ends, because they fly apart in opposite directions. Nonetheless, however far apart in space these two systems are removed, the spin state of the whole, i.e. the joint spin state of these two systems taken together, is a superposition of the first system having spin up and the second system having spin down with the first system having spin down and the second system having spin up in any direction. This state is known as the singlet state.

The point is that neither of the two systems is in a state of either spin up or spin down in any direction. Consequently, neither system has a definite numerical value of any local spin observable. A local observable is an observable that relates only to one of the two systems. Spin in *z*-direction of the one system and spin in *z*-direction of the other system are examples of local observables. Only the whole, which consists of these two systems, has a definite numerical value of a global spin observable, namely the total spin. A global observable is an observable that relates to the whole.

Assume that we measure the spin of one of two such systems in an arbitrary direction. Given the direction measured and the outcome of this measurement, the probability for the outcome of a spin measurement on the other system is changed (unless the spin is measured on both systems in orthogonal directions), regardless of whatever spatial or spatiotemporal distance there may be between the two systems. As far as a spin measurement on the other system in the same direction is concerned, it is even possible to predict the outcome with certainty: either spin up or spin down has probability one. These correlations are well confirmed by experiments even by experiments which carry out measurements on two such systems at a space-like distance. The famous theorem of John Bell (1964) says, to put it in a nutshell, that the emission of these two systems from the source cannot be a common cause that screens the one measurement outcome off from the other measurement outcome.

Cases such as the mentioned example of the singlet state are not at all exceptional. A conceptually similar example can be built up with two systems whose states are entangled with respect to position and momentum. Neither system has a definite numerical value of position or momentum. But the two systems taken together have a definite numerical value of the global observables relative distance and total momentum. These global observables contain correlations among the possible values of the respective local observables of the two systems that can be acquired in measurement. If position or momentum of one system is measured, the probabilities for the outcome of a measurement of the respective observables of the other system are changed. These correlations are contained only in the pure state of the whole.

Whenever we consider a quantum whole which has two or more quantum systems as proper parts, quantum theory tells us that, apart from very exceptional cases, the states of these systems are entangled. This point applies also to the whole of nature at the level of quantum systems. In the last resort, it can only be claimed of the whole of all quantum systems taken together that it is in a pure state. Therefore, physicists and philosophers of science speak of holism with respect to quantum systems: Quantum systems are tied together by relations of entanglement. These relations can in no way be traced back to intrinsic properties of quantum systems, that is, properties that each quantum system has independently of the other quantum systems. People therefore say that quantum systems are non-separable: They do not have properties such as position, momentum, or spin in any direction each in distinction from the other ones. Instead, there are correlations among them such as the mentioned ones. Relations of quantum entanglement are distinct from causal relations. Entanglement is to be expected to obtain irrespectively of whether or not there is any particular causal connection between the quantum systems under consideration. The correlations of entanglement are determined only by the whole of the quantum systems in question taken together. In the last resort, these correlations are completely determined only by the pure state of all quantum systems taken together. These correlations are not accessible to a local observer.

The latter point explains why the quantum correlations of entanglement are not manifest, but sophisticated experiments are required to make them manifest. The reason is what is known as decoherence. Decoherence theories show that entangled quantum systems rapidly develop in such a way that it seems for any local observer that there are systems that are in a pure state each. Thus, although according to quantum theory there is ubiquitous entanglement, quantum theory also contains the means to explain why the entanglement is not manifest. However, decoherence theories are on their own not sufficient to account for the definite numerical values that are the outcome of measurements. One can therefore go beyond decoherence and assume that there is a state reduction in the sense of a dissolution of entanglement in certain types of interaction such as measurement. However that may be, the point is this one: Starting from quantum theory, what is to be explained is not entanglement, but cases of the absence of entanglement, if there are such cases. If quantum theory is endorsed, entanglementand thus the holism that entanglement constituteshas to be acknowledged, whatever stance one takes on the issue of measurement.

Coming from classical physics, one can in quantum mechanics hold on to the single physical systems of classical mechanics. Quantum mechanics considers only cases in which there is a definite number of quantum systems. These are single physical systems, because properties are predicated of themand be it relational properties such as "being entangled with other systems". One has to transform what is regarded as intrinsic properties in classical physics into relations of entanglement among the systems in question. Thus, for instance, instead of the systems having a value of position each, there are correlations among them with respect to all possible values of position. However, as a result of entanglement, quantum systems are not individuals. Whenever we consider in quantum mechanics systems of the same kind whose states are entangled, these systems are indistinguishable. There are no qualitative properties whatsoever by means of which one could distinguish one system from the other ones. Consequently, quantum systems do not have any inter-temporal identity. It is not possible to mark one of them and to recognize that one system.

Quantum field theory goes even further in that respect. What is regarded as single physical systems in quantum mechanics is treated as field quanta in quantum field theory. Field quanta are properties of quantum fields instead of being physical systems themselves. There are states of quantum fields that are a superposition of different numbers of field quanta. Nonetheless, the importance of entanglement and thus the holism of quantum physics is confirmed by quantum field theory. The correlations in which entanglement consists occur even in the vacuum state. In quantum field theory, these correlations are consequently not conceived with respect to single physical systems as the entities among which they occur; they are conceived in terms of field operators at spacetime points.

3. Holism in the social sciences

3.1 What is social holism?

Holism in the social sciences is the view that persons have properties such as thought and intentional action only in virtue of being part of a social community of persons. Social holism, conceived in this way, is a substantial and controversial thesis. It is to be distinguished from two types of trivial claims. The first type of trivial claims emphasizes the various social roles that persons haveroles such as being a mother, being a student, being a salesman, being a major, etc. It is evident that such roles can only exist within society. It is furthermore uncontroversial that such roles are important for the individual identity of a person: If a person is asked who she is, she is likely to mention some social roles in her reply. There may be some controversy as to the scale of the importance of social roles for individual identity, but that is not the point at issue. The issue of social holism is whether or not those properties that are a prerequisite for a person to exercise whatever social rolesnamely the properties of thought and intentional actionare dependent on social relations as well. A social atomist concedes that social roles contribute to the individual identity of a person. The atomist claims, however, that a human being can be a person in the full sense even if there are no social relations. The holist, by contrast, maintains that it is not possible for something to be a person in the full sense without being part of a social community of persons. Something is a person in the full sense if and only if that being has thought, that is intentional attitudes that have a propositional contentsuch as, for instance, believing that it is raining now. Having thought makes it that behavior is intentional action. The issue of social holism thus is the question whether or not a human being is dependent on social relations in order to be a thinking being.

There is a second type of trivial claim here. In what sense is a person dependent on social relations in order to have thought according to social holism? Again, it is evident that the development of thought in a human being causally depends on social interactions with other human beings. However, the necessity in this case is a biological one. Social holism, by contrast, envisages a necessity or a dependence of persons on social relations that is not contingent upon the natural and biological laws that apply to us human beings. Social holism is a thesis about all possible personsindependently of whatever biological constraints there are in order that something can develop into a person. Using the vocabulary of contemporary philosophy, the claim of social holism is that there is no possible world in which there is only one finite thinking being. If there is one finite thinking being in a possible world, that being entertains social relations to other finite thinking beings so that there is a social community of thinking beings in that world. The dependency on social relations at issue is not a causal dependence that is contingent upon natural laws, but what is known as ontological dependence (see, *Philosophical Holism*, section 5.2). The claim of social holism thus is this one: With respect to having thought, any finite being is ontologically dependent on there being other finite beings with whom that being constitutes a social community. The limitation to finite beings is necessary, since social holism is not intended to be an argument against monotheism.

3.2 Two types of social holism

There are two main types of social holism. These types differ in the way in which the social relations that are necessary for something to be a thinking being are conceived. The type of social holism that used to be the main target of criticism emphasizes the community. The main claim is that the community has an ontological status of its own. This status is due to some sort of a social force that the community exerts on its members. Something is a thinking being owing to such social forces. The people who defend a position of this type can be referred to as collectivists. Collectivism is a top-down conception of social holism: social relations among individualsand properties that persons have insofar as they are social beingsare conceived on the basis of properties that apply to a social community as a whole. The position that opposes collectivism is social individualism. This is the claim that a social community does not have an ontological status of its own. All the statements that refer to a social community can in principle be analyzed in terms of statements that describe relations (interactions) among individuals.

Collectivism is no longer the focus of the debate about social holism. The best arguments for social holism in the current discussion seek to establish another type of holism that focuses on social relations among individuals. The claim is that social relations among individuals are necessary for something to be a thinking being. This type of social holism is compatible with individualism (see ,*Philosophical Holism, section 2.4*).

Social holism in this latter sense is opposed to social atomism. This is the view that social relations are determined by the intrinsic properties of the persons that stand in these relations. Intrinsic properties in this context are all and only those properties that a person can have independently of whether or not there are other persons with whom she interacts. A social atomist claims that it is possible for something to be a thinking being even if there are no social relations. In other words, there is a possible world in which there is only one finite thinking being. We have hence to distinguish between social holism as collectivism, social holism as focusing on social relations among individuals, social individualism, and social atomism.

3.3 The historical background of social holism

The issue of holism versus atomism in the social sciences is closely linked with philosophical reactions to what is perceived as the methodology of modern science. Thus, social atomism starts when Thomas Hobbes (15881679) applies the method of early modern physical science to social science. Hobbesin contrast to, for instance, Gassendis not a physical atomist: He does not commit himself to the thesis that there are smallest, indivisible bodies which have a few basic properties such as position and motion and of which every complex body is composed. However, he transfers to the social sciences the method of (1) dividing a complex system up into its constituent parts, (2) considering the parts and their properties in isolation from each other, and (3) understanding the nature and function of a complex system on the basis of the properties of its constituent parts considered in isolation. Hobbes is famous for applying this method to political science. He thereby commits himself to social atomism: in his political philosophy, he presupposes individuals each of whom is a thinking, rational being independently of the other ones. He reconstructs social and political relations on that basis.

Social holism emerges as an option when the supposition that the methodology of physical science is the paradigm for social science is challenged in romanticism and its predecessors. This development is linked with a focus on language and the thesis that language is essential to thought. Thus, for instance, Johann G. Herder (17441803) claims that (1) thought is tied to language and that (2) language is tied to social relations. Consequently, he comes to the conclusion that a human can be a thinking being only in virtue of social relations to other humans. Georg W. F. Hegel (17701831) systematizes this conception and integrates it into his holistic ontology according to which the world is the dialectical development of a spiritual substance. He goes as far as considering individual thinking beings as accidents of a collective substance. He can thus be seen as formulating social holism as collectivism. This line of thought is pursued in Karl Marx (18181883) and Marxism.

The romanticists do not go as far as developing a proper methodology for the social sciences. It was only from the beginning of the twentieth century that social holism was proposed as a proper methodology for the social sciences. Most prominent in that respect are the works of Emile Durkheim and George H. Mead. This development again links up with a development in the natural sciences, namely the emergence of systems theory. Systems theory seeks to understand a system on the basis of its constituent partsbut not on the basis of properties that these parts have independently of each other; on the contrary, systems theory sets out to understand a complex system on the basis of the relations into which its constituent parts enter. Applied to social systems, systems theory can therefore lead to social holism. Very influential in that respect is the work of Niklas Luhmann.

Related Chapters

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Glossary

Biological function: an activity which contributes to an organism's reproduction and which owes its presence in this organism to this fact
Biological individualism: the view that groups of biological organisms have no ontological status of their own
Biological holism: an approach to the study of biological systems which grants the whole an ontological and epistemological significance that the parts of the systems lack. This approach can be pursued at different levels of the biological order, e.g., individual organisms, populations, species, plant or animal communities, ecosystems.
Collectivism: the view that a social community has an ontological status of its own, because it exerts some sort of a force on its members due to which they are thinking beings.
Emergence: the phenomenon that complex systems have properties which are absent in the parts of the system, and which cannot be explained in terms of the properties of the parts
Entanglement: the states of quantum systems are entangled if and only if none of the systems in question has a pure state each
Epistemology: the study of how we can have knowledge about the world (including scientific knowledge)
Homeostasis: ability to maintain a stable state under a variety of external conditions
Mechanism/mechanistic: the view that everything can be explained like a system of interacting particles which have a limited number of properties
Non-separability: quantum systems are non-separable if and only if they do not have state-dependent properties such as position, momentum and spin in any direction each independently of the other ones; instead, there are correlations between these systems with respect to these properties
Ontology: the part of metaphysics that studies what categories of things exist in the world
Organismic: biological research that studies whole organisms (as opposed to cells, molecules, etc.)
Reductionism: the view that all systems can be understood in terms of the properties of their parts
Social atomism: the view that something can be a thinking being independently of social relations
Social holism: the view that a human being is a person in the full sense of the term (i.e., a being that has thoughts with a determinate content) only in virtue of being part of a community of thinking beings
Social individualism: the view that a social community does not have an ontological status of its own. All statements that refer to a social community can in principle be analyzed in terms of statements that describe interactions among individuals
Super-organism: an aggregate of individual organisms which behaves like an organism itself
Vitalism: the view that life forms (and only life forms) contain an immaterial substance which organises their development

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Biographical Sketches

Marcel Weber, born in 1964, is lecturer at the Centre for Philosophy and Ethics of Science, University of Hanover. His research interests include the general philosophy of science, the history and philosophy of biology, and the ethics of the biomedical sciences. His publications include a book on the Evolutionary Synthesis (*Die Architektur der Synthese: Entstehung und Philosophie der modernen Evolutionstheorie.* Berlin: Walter de Gruyter 1998), an edited volume on ethical issues in the biomedical sciences (*Ethische Probleme in den Biowissenschaften*, edited by M. Weber and P. Hoyningen-Huene, Heidelberg: Synchron 2001), and several articles on the history and philosophy of evolutionary biology, ecology, genetics, and molecular biology.

Michael Esfeld, born 1966, is Private-docent in Philosophy at the University of Konstanz and Heisenberg Fellow of the German Research Council. His main areas of research are epistemology, the philosophy of science, in particular physics, and the philosophy of mind. His main publications include a book on Holism in Philosophy of Mind and Philosophy of Physics, Dordrecht: Kluwer 2001, Synthese Library No. 298 (Habilitation Thesis), a book in German on Mechanismus und Subjektivitaet in der Philosophie von Thomas Hobbes, Stuttgart-Bad Cannstatt: Frommann-Holzboog 1995 (Ph.D. Thesis) as well as several papers on holism and other subjects in epistemology and the philosophy of science, among them "Holism and Analytic Philosophy" in Mind 107 (1998), pp. 365-380, and "Physicalism and Ontological Holism" in Metaphilosophy 30 (1999), pp. 319-337.

