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Reduction

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Synonyms

decrease, simplification, downward looking

Definition

On the one hand, reduction is a relation between objects or properties in the world (*ontological reduction*). For instance, a gene can be said to be reduced to (in the sense of "being nothing but" or of "being identical with") a particular DNA-sequence; or cells can be said to be reduced to certain cell organelles and proteins organized and interacting with each other in a specific way. On the other hand, reduction is a relation between parts of our knowledge about the objects and properties in the world (*epistemic reduction*), for example between theories from different biological fields (e.g. between classical genetics and molecular biology) or between the two parts of an explanation (i.e. between the representation of the phenomenon to be explained (explanans) and the representation of those factors that are taken to be explanatorily relevant (explanandum)).

Characteristics

Questions about reduction and reductionism belong to the most frequently disputed topics in philosophy of biology and in the biological sciences itself.

1. Historical Background

The historical roots of the debate about reduction(ism) can be traced back to the 16th and 17th century when René Descartes, Robert Boyle, and others established their *mechanical philosophy* (mechanism). Their central idea was that all natural phenomena (even the traits of living beings) can be explained by appealing only to a few mechanical principles that invoke only the simple properties of material particles (e.g. size, shape, and motion). Another important precursor of the contemporary debate about reduction(ism) is the dispute about *vitalism* in the 19th and early 20th century.

2. The Rise of the Contemporary Debate about Reduction(ism)

The origin of the contemporary debate about reduction(ism) falls together with the emergence of philosophy of biology as a distinct discipline in the 1960s. Two major factors influenced the early years of the debate:

First, the central impetus behind the debate was and partly still is the rise and impressive success of *molecular biology* from the 1950s on. The success story of molecular biology motivated several philosophers to defend a reductionist position with respect to biology (e.g. Rosenberg 1985). It seemed as if any biological phenomenon could be illuminated by identifying its underlying molecular structure. Thus, the reduction of all of biology to molecular biology and in the end to physics appeared achievable. The unity of science had come in reachable distance. However, the success of molecular biology caused not all philosophers to become reductionists. Many adopted an antireductionist position and challenged the feasibility and the merit of reductions. They emphasized the *autonomy* of biology compared to other fields like chemistry and physics (e.g. Kitcher 1984).

A second factor that influenced the debate not only in its early years but for quite a long time was Ernest Nagel's *formal model of theory reduction* (1961). Nagel characterizes reduction as a deductive relation that holds between scientific theories, which he takes to be sets of law statements. In line with the deductive-nomological (D-N) model of explanation, Nagel conceives reduction as a special case of explanation. For reduction to occur two conditions must be satisfied: first, the reduced theory has to be logically derived (deduction) from the reducing theory (*condition of derivability*). Second, this presupposes that the different terms of the reduced and the reducing theory can be connected via so called bridge principles (*condition of connectability*). The attempt to apply Nagel's account to biology (in particular, to the relation between classical genetics and molecular biology) marks the origin of the contemporary debate about reduction(ism). And even though it has also attracted much criticism (e.g. Hull 1974; Kitcher 1984), this specific understanding of reduction remained the focus of the debate for a long time.

The objections to Nagel's account can be summarized as follows: First, Nagel's assumption that theories consisting of law statements are the relata of reduction is problematic because there are no or only a few laws in biology (at least in the strict sense of laws). Second, the fact that many biological types are multiple realized (*multiple realization*) on the molecular or physical level makes it difficult or impossible to establish the bridge principles that are needed to connect the terms of the reduced theory (i.e. the biological theory) to the terms of the reducing theory (e.g. molecular or physical theories). Third, in the course of the debate several authors (most notably, Schaffner 1993) have proposed ways to refine Nagel's model. But even if one allows that Nagel's model is revised in several respects, two problematic core assumptions remain: first, the claim that the adequate relata of reduction are theories, and second, the thesis that the relation of reduction is a formal relation of logical derivation. The first assumption is problematic because theories are neither the only nor the most important epistemic units in biology, particularly not in the context of reduction. The second assumption, that is, the exclusive focus on formal issues gives rise to the criticism that Nagel's model neglects those substantive issues (e.g. level relations and system-context relations; cf. Kaiser 2011) that are most important for understanding actual cases of reduction in biological science. Both objections reveal that even a revised version of Nagel's model still is inadequate to biological practice (Kaiser 2012).

3. Current Status of the Debate

Since the 1990s the situation in the debate about reduction(ism) has started to change. Nowadays, most philosophers of biology agree that Nagel's classical model of theory reduction is inadequate because it does not account for the cases of reduction that occur in biological practice (e.g. Sarkar 1998; Rosenberg 2006; Kaiser 2012). In response to the inadequacy of Nagel's model some philosophers propose alternative views of what reduction in the biological science is, for example by specifying reductionist strategies that can be found in biological practice (Wimsatt 2007), by defending a new version of explanatory reductionism (Rosenberg 2006), or by analyzing the reductive character of explanations (Kaiser 2011; Hüttemann and Love 2011).

In addition, also the situation in the biological sciences itself has changed. In the post-genomic era the euphoria about the achievements of molecular biology and genomics has mitigated. Instead, more and more researchers recognize and try to account for the complexity that many biological phenomena exhibit. As a consequence, in the biological literature critical voices of reductionism have become louder. Biologists emphasize the "limits of reductionism" (Ahn et al. 2006, 709) and call for a move "beyond reductionism" (Gallagher and Appenzeller 1999, 79) towards a more "whole-istic" (holism) biology (Chong and Ray 2002, 1661). However, in many papers biologists adopt a stance that is not merely negative. They concede that reductive methods and explanations have been and still are of value – they just emphasize that this value is *limited*, especially when it comes to the behavior of complex systems. Arguments like these are widespread in systems biology, too. For instance, it is argued that reductive strategies provide insights into the behavior of the parts in isolation, but not into the "dynamics of a system as a whole" (Sorger 2005, 9) and not into "how all these things [i.e. the system's parts] are integrated" (Service 1999, 81).

But what exactly are these reductive strategies and explanations? How can they be distinguished from non-reductive ones? For instance, what does it mean that reductive strategies provide knowledge only about the parts of a system "in isolation"? What are the merits of applying reductive strategies and explaining a phenomenon reductively? And where do their limitations or drawbacks lie? The current discussions about reductionism in biology reveal that questions like these are urgent and should occupy center stage in the philosophical debate. What kind of questions they are will be clarified in the next section.

4. Types of Reduction

When it comes to the issue of reduction(ism) it is important to keep apart different theses, namely to distinguish ontological from epistemic theses on the one hand, and to be clear about which of the several epistemic theses one endorses on the other hand.

4.1 Ontological vs. Epistemic Reduction

Consider the first difference. In philosophy it is crucial not to confound ontological theses with epistemic (or epistemological) ones. The first are claims about the objects and properties that exist in the world itself (ontology), whereas the latter are claims about our knowledge about these objects and properties (epistemology).

With regard to the issue of reduction we can either speak of reduction as a certain kind of relation between objects or properties in the world (*ontological reduction*). For instance, a gene can be said to be reduced to (in the sense of “being nothing but” or of “being identical with”) a particular DNA-sequence; or cells can be said to be reduced to certain cell organelles and proteins organized and interacting with each other in a specific way. Or we can speak about reduction as a relation between parts of our knowledge about the objects and properties in the world (*epistemic reduction*). We can, for example, claim that one theory (e.g. Mendel’s second law of independent assortment) can be reduced to another theory (e.g. certain statements in molecular biology), or we can argue that when a biological phenomenon (e.g. muscle contraction) is reductively explained its representation is reduced to the representation of those causal factors that explain the phenomenon (e.g. the interaction between actin, myosin, and other molecules).

Accordingly, when people dispute the correctness of reductionism on the one hand they argue about ontological issues. For example, reductionists claim that biological objects can be reduced to (in the sense of “being identical with”) physical objects and that, thus, in the natural world there exist nothing over and above physical objects. The reductionist’s ontological claim either concerns particular objects (token physicalism) or types of objects like properties (type physicalism). Because of the multiple realization of many biological types on the physical level the latter theses is far more controversial than the first. On the other hand, not ontological but epistemic questions are the subject of dispute about reductionism. Philosophers and biologists, for instance, argue about whether certain theories can be reduced to others, whether biological phenomena are most successfully investigated by applying reductive methods, and whether reductive explanations of particular phenomena are adequate or not. Although ontological and epistemic questions must be clearly distinguished, there are also various interconnections between them.

4.2 Subtypes of Epistemic Reduction

Depending on which parts of our knowledge are taken to be important for reduction different subtypes of epistemic reduction can be identified, namely theory, methodological, and explanatory reduction.

First, *theory reduction* is a relation between theories. Assuming that Nagel's model is correct, theory reduction can be characterized as a deductive relation between sets of (law) statements. However, it is questionable whether there actually occur cases of Nagelian theory reduction in biological practice (see Section 2).

Second, the term '*methodological reduction*' refers to reductive methods, strategies, or "heuristics" (as Wimsatt 2007 calls them) which are applied in biological practice in order to, for instance, develop an explanation of a particular phenomenon. Examples of reductive methods include decomposition, downward looking, ignoring or simplifying factors that are external to a system, and studying the parts of a system in isolation (i.e. in other contexts than *in situ*; Kaiser 2011). What is common to all reductive methods and distinguish them from non-reductive ones is that they decrease the kinds of factors that could be taken into account, for instance by completely ignoring some of them (e.g. higher-level factors) or by simplifying certain kinds of factors to a great extent (e.g. contextual factors).

Questions about methodological reductionism concern the virtues and limits of reductive methods. Methodological reductionists claim that biological phenomena are most successfully investigated by using reductive methods, whereas methodological antireductionists challenge the value of reductive strategies. More balanced, pluralistic views acknowledge the merit of reductive methods while also recognizing their limitations, for instance with regard to the investigation of complex systems (complexity).

Third, in case of *explanatory reduction* (or reductive explanation) the relation of reduction holds between the two parts of an explanation, namely between the representation of the phenomenon or behavior of a system to be explained (explanandum) and the representation of the factors that are identified as explanatorily relevant (explanans). An important philosophical question is what makes an explanation reductive and distinguishes it from non-reductive explanations. It has been argued that reductive explanations in biology exhibit three features (Kaiser 2011): they explain the behavior of a biological system, first, by referring only to factors that are located on a lower level of organization than the system, second, by focusing on factors that are internal to the system (i.e. that are parts of the system), and third, by appealing to parts only as "parts in isolation" (i.e. by appealing only to those relational properties of and interactions between parts that can be studied in other contexts than in situ).

Questions about explanatory reductionism concern the conditions of adequacy of reductive explanations. Explanatory reductionists argue that all biological phenomena can (at least in principle) be adequately explained in a reductive fashion. Proponents of explanatory antireductionism deny the adequacy of reductive explanations by pointing to the importance of higher-level factors and of contextual factors for explaining the behavior of many biological systems (e.g. for explaining emergent properties of systems; emergence).

Cross-references

autonomy; complexity; deduction; explanation; holism; mechanism; ontology; emergence

explanation, reductive; multiple realization

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