Artikuluak bizi-zientzietan erredukzionismoaren eta emergentismoaren arteko tentsioa aztertzen du, eta horrek eboluzio-teorian, bereziki hautespen-unitatearen eztabaidan, duen eragina. Erredukzionismo eta emergentziaren formak bereizten ditu, antolaketa biologikoa eta altruismoa aztertzen ditu, eta defendatzen du emergentzia sendoak eta beheranzko kausalitateak azalpen hertsiki erredukzionistak zalantzan jartzen dituztela, azalpenari eta kausalitateari buruzko konpromiso filosofiko sakonagoak agerian utziz.

Giltza-Hitzak: Erredukzionismoa. Emergentzia. Hautespen mailaniztuna. Altruismoa. Biologiaren filosofia. Eboluzioa.

El artículo analiza la tensión entre reduccionismo y emergentismo en las ciencias de la vida y su impacto en la teoría evolutiva, especialmente en el debate sobre la unidad de selección. Distingue formas de reduccionismo y de emergencia, examina la organización biológica y el altruismo, y sostiene que la emergencia fuerte y la causalidad descendente cuestionan las explicaciones estrictamente reduccionistas, revelando compromisos filosóficos más profundos sobre la explicación y la causalidad.

Palabras clave: Reduccionismo. Emergencia. Selección multinivel. Altruismo. Filosofía de la biología. Evolución.

L’article analyse la tension entre réductionnisme et émergentisme dans les sciences de la vie et ses implications pour la théorie de l’évolution, notamment le débat sur l’unité de sélection. Il distingue différentes formes de réductionnisme et d’émergence, examine l’organisation biologique et l’altruisme, et soutient que l’émergence forte et la causalité descendante remettent en cause les explications strictement réductionnistes, révélant des engagements philosophiques plus profonds concernant l’explication et la causalité.

Mots-clés : Réductionnisme. Émergence. Sélection multiniveau. Altruisme. Philosophie de la biologie. Évolution.

Reductionism, emergence, multilevel selection and the biological roots of altruism

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Reductionism

The Oxford Companion to Philosophy devotes an entry to reductionism, authored by Michael Ruse (2008). He introduces what he calls a tripartite division. That is, he distinguishes three types of reductionism: ontological, methodological, and theoretical or theory-related.

Ontological reductionism refers to the belief that reality can be reduced to a minimum number of basic entities or components. Since these basic entities are usually material in nature, ontological reductionism is equivalent to a form of materialistic monism or physicalism, as it denies the existence of anything that is not material in nature. According to this belief, reality would be composed solely and exclusively of entities of a material nature. By denying the existence of occult forces or entities of an immaterial nature, such as spirits or vital forces, ontological reductionism opposes any form of dualism. Therefore, this form of reductionism opposes vitalism, the philosophical doctrine that defends the belief that living beings are made up of a material part and an immaterial part, the vital spirit (Bergson's *élan vital*), or, in the same vein and as far as human nature is concerned, by body and soul (or something similar).

Methodological reductionism argues that in science, the best strategy is to seek explanations in terms of the basic constituent entities of the objects or processes under study. It can also be formulated as the attempt to characterize the processes studied at each level of organization based on the mechanisms of the underlying processes, that is, those corresponding to lower levels of organization. As its name suggests, this form of reductionism refers to the method, to the way of obtaining the knowledge necessary for understanding the phenomena under study.

The reductionism of theories is the process by which one or more theories (or laws) are subsumed into another of a more general nature or with broader explanatory power. An example of this type of reductionism is the assimilation of Kepler's laws of planetary motion and Galileo's theories on the motion of bodies by Newton's laws of universal gravitation and the three laws of dynamics or motion.

Antonio Diéguez (2012), discussing reductionism in biology, also points to the existence of three forms of reductionism: ontological, methodological, and theoretical. He defines ontological reductionism in terms like those set out by M. Ruse. He deals with methodological reductionism very briefly. And he also refers to theoretical reductionism (equivalent to the reductionism of theories, according to M. Ruse) as epistemological. By virtue of this type of reductionism, explanations of biological phenomena can and must always be made by resorting to explanatory factors belonging to more basic levels. Therefore, the reduction of some theories or laws to others would be conceptually equivalent to the reduction of any type of explanation of the phenomena under study to explanations of the phenomena corresponding to lower levels.

In relation to this type of reductionism (of theories or epistemological), I am interested in bringing up the approach of physicist Phil W Anderson, due to the great influence he has had, at least among scientists, on this subject. Anderson (1972) argues that the ability to reduce everything to simple fundamental laws does not imply the ability to reconstruct the Universe based on those laws. The reason for this inability is that the possibility of reconstructing the universe breaks down when faced with two difficulties, one of scale and the other of complexity. The first is because changes in scale lead to changes in properties that are not always predictable. And the second difficulty refers to the fact that when complexity increases, totally new properties appear, which we usually call emergent properties. Following Anderson's argument, psychology is not applied neuroscience, neuroscience is not applied molecular biology, nor is molecular biology applied chemistry. The whole is not, in his words, merely more than the sum of its parts, but, above all, very different from them.

Emergent properties

Emergent properties are new properties that arise in association with increased complexity. The time has therefore come to refer to emergence (the phenomenon) or emergentism (the philosophical position). Returning to the Oxford Companion to Philosophy, the author of the corresponding entry, Jaegwon Kim, states that a property of a complex system is emergent when it is not predictable from, nor reducible to, the characteristics or properties of its simplest components. This definition does not question that emergent properties are a consequence of the properties and relationships that characterize those more basic systems. they are, but they cannot be predicted from or reduced to the former.

Two versions of emergence are usually distinguished: weak and strong (Chalmers, 2006). Weak emergence refers to when the new properties that arise are indeed deducible from the properties of the basic elements. This does not mean that they are so at a given moment and under given conditions, but that they are potentially so. In other words, given the necessary capacity to do so, it is assumed that this type of emergent phenomenon generates properties that could be simulated by computer. Weak emergent phenomena are called epiphenomena. they would not be phenomena with unpredictable properties. The simulation of the pharmacological mode of action of certain molecules can be a good example of an epiphenomenon typical of weak emergence. With sufficient knowledge about the characteristics and sequence of the atoms that make up the molecule, computational methods being developed by theoretical chemists can simulate the three-dimensional conformation of that molecule and how it would interact with target molecules.

Strong emergence is characterized by downward causation, that is, the new properties of the system under study—which corresponds to the higher level—allow it to exert a causal action on the basic components that have originated them. The term "downward causation" was coined by Donald Campbell (1974). It is assumed that in a case of strong emergence, the emergent properties would not be anticipable in any way, since it would not be possible to predict how those properties would affect the lower levels. The system could not be simulated, even with all the computational power that might eventually be necessary. As we will see next, the life sciences offer good examples of downward causation.

Emergence in the Life Sciences

Virtually any leap in the level of biological organization leads to the emergence of new properties. The question is whether these new properties can be considered emergent in the sense described above or not. And whether it would be a case of strong emergence or simple epiphenomena and therefore considered cases of weak emergence.

In nature, there are countless biological systems, corresponding to all possible levels of organization. For this reason, it is not possible to assess all biological phenomena that can be analyzed under these premises, let alone establish the nature of the properties of biological systems corresponding to different levels of organization. However, certain relatively well-characterized systems, for the reasons pointed out by Anderson (1972) –scale and complexity– are more likely to exhibit emergent properties.

Examples of weak emergence are the relationship between the DNA molecule, the molecular structure of the double helix chain, and the functioning of the genome, as well as that of certain bodily apparatus or systems and their basic constituents. With regard to the DNA chain and genes, while it is true that the very notion of a gene is highly contested or admits different meanings depending on the context in which it is considered, it is also true that the degree of knowledge we have about the properties of DNA, its replication, and the sequence of events leading to protein synthesis allows us to predict with a relatively high degree of accuracy how heredity is transmitted and inherited traits are expressed. Given that chance affects some of the processes involved (errors in replication or transcription), it is not possible to make accurate predictions about the outcome of any of the genome's products, but that is not the point. rather, it is simply a matter of anticipating their general properties.

In the case of bodily systems, an example of weak emergence is that of the kidney and its fundamental constituents, the nephrons. Once their characteristics and arrangement are known, it is possible to deduce how the kidney functions as a whole and its main properties. Something similar could be said of the digestive system and its various constituents.

An example of strong emergence is the phenomenon of life itself, that is, the appearance and existence of complex self-organizing systems that process energy and self-replicate. There is a huge leap in complexity between the basic components of cells (constituent molecules) and cellular machinery, and if there is any case where we can speak of strong emergence, this could be a clear one. Ontogenetic development, that is, the process of differentiation and growth of different organs and tissues from a single cell, is also highly complex when compared to the starting point —the primordial cell— and to the genetic sequence of each of the resulting cells, which, let us not forget, is the same. The functioning of the mind is another case of strong emergence. Or also the evolutionary process and the functioning of ecosystems. In all of these, downward causation occurs, as the higher level of organization influences the way the lower levels function.

Evolution and the unit of selection

The evolution of living beings is a process that requires, on the one hand, a source of variation—random mutations and recombination—that generates genetic differences between individuals, and, on the other hand, natural selection and genetic drift, which are the mechanisms that cause the frequency of different genotypes in populations to change. At this point, to properly characterize the selective process, It is necessary to determine what the "unit of selection" is, that is, on which biological entity natural selection acts. This question has been and continues to be the subject of intense debate among evolutionary theorists. The question is relevant to our interests here, because whether evolution is a phenomenon with emergent properties depends, at least to some extent, on what the unit of selection is.

For the sake of simplicity, I will consider three possibilities. One is that advocated by G. C. Williams (1966), whose main defender and publicist has been and continues to be Richard Dawkins. I am referring to the gene. In Dawkins' terminology (1976), the gene is the replicator, the unit that multiplies and gives rise to the production of proteins and, with them, higher functional units, i.e., individuals and groups. These would be nothing more than vehicles for the replicators. If, indeed, the gene is the functional unit on which natural selection acts, the properties of the evolutionary process could be deduced from knowledge of the properties of the genome. Chance plays an important role in this process, since the probability of a gene persisting over time depends largely on events that affect other genes in the same population or species. For this reason, the future of each gene would not be predictable, but the properties of the process could be deduced from knowledge of the basic mechanisms of replication and functioning of the genome.

Some renowned evolutionary biologists, such as Ernst Mayr (2001), have flatly rejected the idea that selection acts on the gene, for the simple reason that the action of a gene depends, in many cases, on the action of others. Furthermore, since the effects caused by these genes interact with each other, they do not necessarily have the same effects in different organisms. Stephen Jay Gould (2002), for his part, argues that those who support the idea that selection acts on the gene effectively deny that the organism—the individual—possesses emergent properties. The philosopher Peter Godfrey-Smith (2014) has defended a similar idea. We must, therefore, consider the second possibility, the individual as the unit of selection.

When different selective pressures act on an individual, the genes on which the functions potentially relevant to the effects of those pressures depend are very varied. A relatively simple example of the joint action of two selective factors on the same individual or group is adaptation to life at high altitude. Life at high altitude poses two challenges to the physiology of mammals, and specifically to that of humans: with altitude, the environmental availability of oxygen decreases significantly and the environmental temperature drops. It is therefore predictable that people living at high altitudes tend to have a high metabolism and thus produce the heat necessary to compensate for the losses typical of cold places. But at the same time, with less oxygen available, it is more difficult to have enough to maintain a normal metabolism, and even more difficult to maintain a higher-than-normal metabolism to counteract the cold.

Situations such as the one above, in which conflicting demands may arise, are relatively normal, and in such cases, analyzing only the behavior of the genes on which metabolic intensity depends may be insufficient to understand how natural selection operates. In this case, the organism could be considered the unit of selection, since the fitness provided by one gene—which would determine the ability to survive with a low metabolism—may conflict with that provided by another—which would determine the ability to maintain a high metabolic level. In this case, the complexity resulting from the combined action of several selective pressures on the same physiological function makes it impossible to anticipate the properties of the organism adapted to life at high altitude in terms of its metabolic characteristics.

And things would become even more complicated if other bodily systems came into play, such as the muscular system. If an increase in muscle mass were to have adaptive value at high altitude, that increase could have negative effects in other respects, given that muscle cells are highly oxygen-demanding when they are in full activity. In short, emergent properties would result from phenomena of adaptation to conditions under which more than one function or more than one organ system has conflicting needs.

Multilevel selection theory and the conundrum of altruism

If, instead of the individual being the object of selection, selection acts simultaneously on several levels of organization—gene, individual, and group, for example—things become extremely complicated. David Sloan Wilson (2015) is the leading theorist of the so-called “multilevel selection theory”. This theory aims to account for situations in which there are reasons to think that it is not enough to focus on the individual, and even less so on the gene, but that the group can also be an entity on which selective pressures act (the third possibility).

Multilevel selection theory owes its existence, at least in large part, to altruism. Altruism has always been a headache for evolutionary theorists, since the altruistic individual sacrifices part of his or her "fitness" for the benefit of another individual, which is, at least in principle, incompatible with the idea that selection acts in favor of individuals (or genes) with a higher "fitness." A solution to the paradox of altruism seemed to be found in what is known as "kin selection" or “inclusive fitness” (Hamilton, 1964). Under this selective modality, altruism would be understandable if this transfer of fitness were made to individuals with whom a significant fraction of the genome is shared, that is, with whom a percentage of genes are shared. In the case of a son or daughter, that percentage is 50%, and in the case of grandchildren, 25%. Therefore, the altruistic action would aim to benefit the prospects of the shared part of one's own genome.

A second proposal to explain the evolution of altruism is due to Robert Trivers (1971). According to his proposal, called “reciprocal altruism”, an altruistic act makes perfect sense if there is a high probability that the individual who benefits from such an act will later return the favor to the person who performed it.

However, according to critics of kin selection and reciprocal altruism, when attempting to mathematically model the functioning of known cases of altruism using the assumptions on which those selective modalities are based, things do not work out. Elliot Sober and David Sloan Wilson (1998) were the first to propose that altruism is not rare in nature and that it is a genuine product of human nature.

The theory of multilevel selection, or group selection as it is also known, has been subsequently developed by various researchers, one of whom was Edward O. Wilson (Wilson & Wilson, 2007). This theory assumes the existence of several units of selection and, in its simplest form, argues that selection occurs both between individuals within a group and between groups. This theory assumes that within groups there are two opposing tendencies: one is to have the highest level of individual fitness, and the other is to collaborate with other members of the group so that the group has the highest level of group fitness. The first tendency allows individuals to compete with other individuals in the group, while the second allows the group to compete with other groups. For an individual, both forms of selection are important, but their effects are contradictory because what benefits the group benefits the individual as a member of the group but harms them as a competitor with other members, and vice versa. Edward O. Wilson (2012) has used the expression "In a group, selfish individuals beat altruistic individuals, but groups of altruistic individuals beat groups of selfish individuals" to illustrate the terms of this phenomenon. In short, this proposal contemplates the existence of selective pressures acting on various levels of organization and that the result of the process is a consequence of the combination of those acting on individuals and those acting on groups.

In this situation the degree of complexity of the process is much greater, given that very different elements are involved and located at different levels of organization. Furthermore, considering that the group is both the object of the process—because the group may or may not perpetuate itself as such, depending on its degree of suitability—and the subject of the process—because what happens to the group also determines what happens to the individuals that comprise it—in a system such as this, there is clearly downward causation. Therefore, if we consider scale, complexity, and sense of causation, we would be faced with a strong emergence phenomenon. The characteristics of the evolutionary process in species whose individuals form part of groups in which altruistic behaviors occur could not be deduced from knowledge of the properties of the genome of those species.

Concluding remarks

While ontological reductionism, with its implications in terms of rejecting the existence of supernatural entities, is clearly a philosophical or even ideological position, the choice between epistemological reductionism and emergentism—in either of its two forms, strong or weak—is a much more complex issue. In fact, although the positions—reductionism vs. emergentism—are usually considered antithetical, I find it very difficult to choose one or the other. Through the examples I have used, I have tried to show that phenomena are perceived very differently depending on the cases under study. But even in the most extreme cases, it is not easy to lean towards either of the two theoretical positions because, in a way, this means trying to anticipate the future.

Let me explain. Proponents of reductionism argue that their position does not imply that the new properties that "emerge" when moving from one level of organization to the next must be predictable from the properties of the basic components, or reducible to those at the present moment, but that they will be predictable when all the information relevant to the functioning of all the elements of the system is available, whatever that moment in the future may be. Advocates of emergentism, however, argue that these new properties are not only not deductible from those of the components or reducible to them now, but also—by virtue of downward causation—will never be. Therefore, in both cases, predictions are being made about the degree of knowledge that will be available in the future and the nature of that knowledge.

In short, I believe that, as in the case of the opposition between ontological reductionism (monism) and dualism, the positions do not so much obey an assessment of the available information as a philosophical or other position, with all that that implies.

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