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Teleological Explanations *versus* Teleology

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Teleological Explanations in Biology

Biologists make statements such as the following ones (*emphasis* added): '[E]cological compatibility is one of the most important species characteristics. *In order to* survive, each species must be supreme master in its own niche.'[1] 'Hingston has described many similar spider tricks, all *designed to* lead predators astray.'[2] 'Fig wasps don't transport pollen for food. They deliberately take it on board, using special pollen-carrying pockets, *for the sole purpose* of fertilizing figs (which benefits the wasps only in a more indirect way).'[3] 'It is folly or ignorance to deny that the *purpose* of nests is to protect the relatively helpless young of birds and mammals ... The *purpose* of teeth ... is mastication; of eyes to see, and of ears to hear.'[4]

No similar statements are found in the writings of physical scientists. The configuration of sodium chloride depends on the structure of sodium and chlorine, but no chemist is likely to write that sodium chloride has been *designed* for certain purposes, such as tasting salty. The earth's continents move, but geologists do not claim that this is for the *purpose* of facilitating vicariant evolution. The motion of the earth around the sun results from the laws of gravity, but astrophysicists do not state that this happens *in order to* produce the seasons.'

In the 1960s, I asked myself why is it that biologists use functional and, more generally, teleological accounts while physical scientists do

[1] E. Mayr, *Animal Species and Evolution*, Cambridge, MA: Harvard University Press, 1963: 69.
[2] W. Wickler, *Mimicry in Plants and Animals* (1968), New York: McGraw Hill, reprinted 1974, 1978: 58.
[3] R. Dawkins, *Climbing Mount Improbable*, New York: W.W. Norton, 1996: 302.
[4] P.B. Medawar and J.S. Medawar, *Aristotle to Zoos*, Cambridge, MA: Harvard University Press, 1983: 256.

not. Is this because biologists are soft-headed or because biology is an immature science[5], or is there a radical difference between the physical and the biological sciences in this respect? My interest in the subject of teleology was, from the beginning, epistemological rather than metaphysical or semantic. Thus, I wrote in 1966 a paper on 'Teleological Explanations in Evolutionary Biology', arguing that teleological explanations are appropriate and, indeed, indispensable in biology. Further, I wrote in 1967 a paper on 'Biology as an Autonomous Science', where I developed the argument that biology is irreducible to the physical sciences because it uses teleological patterns of explanations, which are not appropriate in the physical sciences. Biology and physics are, therefore, epistemologically incommensurate, at least in this respect (there may be others). I again

[5] The perception of biology as a soft or immature discipline, one which does not quite meet the methodological standards expected in the physical sciences, has in the past prevailed in certain circles, although the attitude is gradually evanescing. A. Rapoport in 'Methodology in the Physical, Biological and Social Sciences' (E.O. Attinger [ed.], *Global Systems Dynamics*, New York: S. Karger, 1970: 14-27) contrasts the hypothetico-deductive method of the physical sciences with the methodology prevailing in the biological disciplines, which he perceives as consisting primarily of acts of 'recognition rather than measurement'. According to Rapoport, taxonomy, the discipline of classification, is the central discipline in biology. Geneticists, molecular biologists, population biologists, neurobiologists, and all other sorts of biologists are likely to read such claims with disbelief that they are displayed in scholarly publications. The method used by biological disciplines is essentially the same hypothetico-deductive method practiced in the physical sciences (see my 'On the Scientific Method, Its Practice and Pitfalls', *Hist. Phil. Life Sci.*, 16 [1994], 205-240). In response to Rapoport one can, first, make the obvious observation that taxonomy is just one of the score or so biological disciplines presently recognized in practice, and is not in any way the 'central' or 'prototype' discipline. One need only examine a college-level biology textbook, or the curriculum offered in a research university, to see the evidence. But even taxonomy depends on testing hypotheses by means of observation and experiment. Consider, for example, the hypothesis that chimpanzees are more closely related to humans than to gorillas (the relationships on which classification in based). The hypothesis leads to the prediction that human and chimp genes and proteins will be more similar to one another than they are to gorilla genes and proteins. The hypothesis is tested by making the relevant observations. As an example from a different discipline, we may consider Mendel's experiments published in 1866, to which the beginnings of the modern discipline of genetics can be traced. Mendel studied in peas the transmission of seven different characters. The two parental plants differed in clear-cut ways; if one parent had, say, green seeds, the other parent had yellow seeds, and so on. In all seven characters, the first generation progeny consisted entirely of plants resembling one of the parents; and the second generation consisted of plants some of which resembled one and others the other grandparent. The parental character missing in the first generation appeared in about one-fourth of the individuals in the second generation, the other three-fourths resembled the other grandparent. Mendel saw that these results can be explained if the following assumptions are made: 1, there is in each plant a pair of hereditary 'factors' controlling each character; 2, the two 'factors' in each plant are derived from the individual's parents, one member of the pair from each; 3, the two 'factors' in each pair segregate during the formation of germ cells, so that each germ cell receives only one 'factor'; 4, one of the two 'factors' of each pair dominates over the other, so that when the two 'factors' of a pair are different from each other only one of them is expressed. Mendel had thus put forward a hypothesis. From this hypothesis he deduced several specific and testable predictions. One prediction was that if hybrid plants of the first generation were crossed to plants of the types in equal numbers. Another prediction deduced from his hypothesis was that one third of the plants of the second generation similar to the hybrid generation should breed true, the other two thirds should be hybrids and produce progenies one quarter of which would be like one of the original parents while the other three-quarters would be like the other parent. He also derived the correct generalization that starting with hybrid plants, after n generations of self-fertilization, the ratio of true-breeding to hybrid plants should be 2^n-1 to 1. Mendel tested his hypothesis by making the appropriate experiments which led to the verification of these predictions.

pursued the matter in 1969, in a paper entitled 'Comments on Methodology in the Physical, Biological, and Social Sciences.'[6] I explained in these papers that teleological explanations are compatible with causal explanations and that, indeed, a teleological explanation can be reformulated as a causal account, as had been proposed by Ernest Nagel.[7] But I argued against Nagel that the translation of a teleological into a causal account left out some 'surplus' meaning. Reformulation is possible, but the translation leaves out essential information about the phenomenon to be explained.

Why is it that we apply to organisms teleological accounts, such as encased above in the phrases 'in order to', 'designed to', and 'for the purpose of', but we don't do so for physical processes or objects (other than those made by humans)? The reason is that the biological phenomena that call for teleological explanations are adaptations, which have come about because they are useful to the organisms in their essential functions of survival and reproduction. Structures like a wing or a hand, organs like a kidney or a heart, behaviors like chimpanzee grooming or the courtship displays of a peacock are features that have come about by natural selection because they serve certain functions that increase the reproductive success (Darwinian fitness) of their possessors.

Inanimate objects and processes (other than those created by humans) do not call for teleological explanations because they are not directed toward specific ends, they have not come about because they serve certain purposes. We may use sodium chloride as food, a mountain for skiing, and take advantage of the seasons for growing crops, but the use that we make of these objects or phenomena is not

[6] I wrote 'Teleological Explanations in Evolutionary Biology' in 1966. I received extensive written comments dated December 7, 1966 from Professor Ernst Mayr, and December 12, 1966 from Professor Ernest Nagel. On January 4, 1967, Nagel wrote again 'urging' me to publish the paper and suggested the journals *Philosophy of Science*, *Journal of Philosophy*, and the British *Journal for the Philosophy of Science*. Richard S. Rudner, editor-in-chief of *Philosophy of Science* acknowledged receiving my manuscript on September 28, 1967. It was published 30 months later, in the March 1970 issue of *Philosophy of Science*, 37 (1970), 1-15. I wrote 'Biology as an Autonomous Science' in 1967 and read it at the 'International Colloquium II' on 'Biology-History-Philosophy' on November 27, 1967 in Denver, Colorado. I received extensive written comments, dated February 22, 1968, from Professor George Gaylord Simpson (who had also read a paper at the same Colloquium) expressing the 'hope' that I publish the manuscript 'before long'. The 'Board of Editors' of *American Scientist* acknowledged receipt of the manuscript on March 25, 1968, and accepted it on April 4, 1968. It appeared five months later in the Autumn issue, in September 1968, *American Scientist*, 56 (1968), 207-221. In the spring of 1969, I contributed a paper, 'Comments on Methodology in the Physical, Biological, and Social Sciences' to a Symposium celebrating the Sesquicentennial of the University of Virginia in Charlottesville, where I discuss, inter alia, the use of teleological patterns of explanation in biology and claim that they are distinctive of biology, where they are indispensable while they are inappropriate in the physical sciences. (E.O. Attinger [ed.], *Global Systems Dynamics*, New York: S. Karger, 1970: 28-32).

[7] E. Nagel, 'Types of Causal Explanation in Science'. In: D. Lerner (ed.), *Cause and Effect*, New York: Free Press, 1965: 24-25.

the reason why they came into existence or why they have certain configurations. On the other hand, a knife and a car exist and have particular configurations precisely in order to serve the ends of cutting and transportation. Similarly, the wings of birds came about because they permitted flying, which was reproductively advantageous. The mating display of peacocks came about because it increased the chances of mating and thus of leaving progeny.

The previous observations point out the essential characteristics of phenomena whose existence and configuration can be explained teleologically. Thus, I have proposed by way of definition that 'Teleological explanations are those that account for the existence of a certain feature in a system by demonstrating the feature's contribution to a specific property or state of the system, in such a way that this contribution is *the reason why* the feature or behavior *exists at all.*' The essential component of a teleological explanation is that the feature or performance could not have come about were it not for the particular purpose that it serves. This purpose is, therefore, the explanatory reason for the existence of the feature or performance and its distinctive characteristics.

The configuration of a molecule of sodium chloride contributes to its property of tasting salty and therefore to its use as food, not vice versa; the potential use of sodium chloride as food is not the reason why it has a particular molecular configuration. The motion of the earth around the sun is the reason why seasons exist; but the existence of the seasons is not the reason why the earth moves about the sun. On the other hand, the sharpness of a knife can be explained teleologically because the knife has been created precisely to serve the purpose of cutting. Motorcars and their particular configurations exist because they serve transportation, and thus can be explained teleologically.

Many features and behaviors of organisms meet the requirements of teleological explanation. The wings of birds, the structure and behavior of kidneys, the mating displays of peacocks are examples already given. In general, as pointed out above, those features and behaviors that are considered adaptations are explained teleologically. This is simply because adaptations are features that come about by natural selection. Among alternative genetic variants that may arise by mutation or recombination, the ones that become established in a population are those that contribute more to the reproductive success of their carriers. The effects on reproductive success are usually mediated by some function or property, such as flying or regulating the composition of the blood. Wings and kidneys acquired their

present configuration through long-term accumulation of genetic variants adaptive to their carriers.

Not all features of organisms need to be explained teleologically, since not all come about as a direct result of natural selection. Some features may become established by random genetic drift, by chance association with adaptive traits, by physical constraint, by historical contingency, or in general by processes other than natural selection.

Teleological explanations, formulated in terms of function and of adaptive value, are necessary to fully understand living systems. The structure and even the operation of a bird's wings can be explained in causal, non-teleological terms. Yet an essential element of the explanation of wings will be left out if it is not pointed out that wings serve for flying, and if the appropriate account is not given that wings gradually developed through an evolutionary process precisely *because* wings serve for flying. Wings exist because wings and their ancestral structures increased the adaptive value of the organisms possessing them.

Natural selection is the ultimate source of explanation in biology. Natural selection is a mechanistic process defined in genetic and statistical terms as differential reproduction. Some genes and genetic combinations are transmitted to the following generations on the average more frequently than others. The genetic variants which increase in frequency in a population through the generations are those that are useful as adaptations to the environment of the organisms which possess them. As a consequence of natural selection the structures and processes of living things are end-directed: wings are adapted for flying; green leaves are adapted to absorb radiant energy; the kidneys are adapted to regulate the chemical composition of the blood. The adaptation of organisms to their environments, and the adaptation of living structures and processes to the functions they serve can be explained scientifically. Standard scientific methodology, the so-called called 'hypothetico-deductive method' is used in formulating and testing these explanations.

Patterns of Teleological Accounts

Adaptations are those features of organisms that are ultimately explained by natural selection. As pointed out, their existence is accounted for in terms of their contribution to the reproductive fitness of the individuals which possess them. Teleological accounts are needed in biology for biological explanation to be complete.

We can identify in organisms three general categories of biological phenomena where teleological explanations are pertinent, although the distinction between the categories need not always be clearly defined; and it is also possible to reformulate or subdivide them in a different or more prolific array. (1) When the purpose or goal is consciously anticipated by the agent. This is purposeful activity and it occurs in humans and, with a lesser degree of intentionality, in other animals. A person going to the movies or a lion chasing a deer are examples. (2) Self-regulating systems, such as the regulation of body temperature in mammals or the development of an egg into a chicken. These are called homeostatic processes, which can be, as in the examples given, physiological or developmental. (3) Structures anatomically and physiologically constituted to perform a certain function. The human hand is made for grasping, and the eye for vision. The distinction between the (3) and (2) categories of teleological systems is sometimes blurred. Thus, the human eye is able to regulate itself within a certain range according to the conditions of brightness and distance so as to perform its function more effectively.

The organismic features identified in the previous paragraph are all *particular*, or *specific*, they must individually be accounted for in each case, by teleological explanations that may also be considered particular, or specific. Evolutionary biologists also use a *generic* or *ultimate* mode of teleological account, when they explain the presence of particular features in an organism in terms of their contribution to the Darwinian fitness of the organisms. In this sense, we may speak of survival and reproductive success as the ultimate purpose served by individual biological adaptations, i.e., the reason why they have come about.

Based on the reasoning just advanced, I suggested in the past that natural selection could be said to be a teleological process in a *causal* sense, namely as a distinctive process, uniquely acting in the living world, which accounts for the adaptive features of organisms.[8] Professor Mayr has criticized this as inappropriate and likely to be misunderstood. I could have said that natural selection is a *teleology-inducing* process, intending to convey the same idea. But this might also be misunderstood and it might be best altogether to discard these designations. Natural selection is not an entity or an agent, and thus it is not a cause in the usual sense. Nor does natural selection result in pre-determined or pre-conceived features or organisms. Natural selection is a purely

[8] F.J. Ayala, 'Teleological Explanations in Evolutionary Biology', *Philosophy of Science*, 37 (1970), 1-15.

mechanistic process governed by natural laws. In any case, the process of natural selection is not at all teleological in the particular sense that it is not in any way directing toward the production of specific kinds of organisms or toward organisms having certain specific properties. The over-all process of evolution cannot be said to be teleological in the sense of proceeding toward certain specified goals, preconceived or not. Natural selection is an opportunistic process; and its final result for any species may be extinction, as shown by the fossil record.

The teleological account that we can provide of the features of a knife points out that a sharp edge, a metallic blade, and a wooden handle are all purposefully designed to fulfill best the knife's function of cutting. The features of organisms, on the contrary, have not been purposefully designed at all; rather they have come about contingently and opportunistically as a result of natural selection. In order to highlight this important difference, it may be helpful to use the term *natural* or *internal* to refer to teleological accounts of organisms and their features (because these come about by natural processes rather than being imposed by an external agent). In contraposition, the teleological account of the features of a knife might be called *artificial* or *external* (because the features come about as contraptions specifically designed by an agent strange to the knife itself).

I have made in the past other distinctions for clarifying the disparate use of teleological explanations in biology and in engineering. I referred to the teleology of the eye or the wing as *indeterminate* or *unbound*, because eye and wing did not evolve as specifically intended and designed. In contraposition, the teleological account of a knife is *determinate* or *bounded*, since the knife and its features are intended and specifically designed. Developmental homeostasis (and to some extent physiological homeostasis) is a teleological process that exists in organisms, and thus is natural, but is also bounded: a chicken egg becomes invariably a chicken and nothing else, in spite of environmental fluctuations (unless it dies before completing development).

Ernst Mayr (1998) on Teleology

Professor Mayr[9] distinguishes 'five entirely different kinds of phenomena ... to which the term teleological had been applied in the

[9] E. Mayr, 'The Multiple Meanings of Teleological', *History and Philosophy of Life Sciences*, 20 (1998), XX-XX.

past': (1) 'teleomatic processes' ('processes in inanimate nature which reach an end stage determined by the universal laws of physics'); (2) 'teleonomic processes' (a process or behavior 'that owes its goal-directedness to the operation of a program ... [which] is not a description of a given situation but a set of instructions'); (3) 'adapted features' (their designation as teleological is 'misleading because these features are stationary systems. For me, the word teleological is not appropriate for the phenomena that do not involve movements'); (4) 'purposive behavior' (human and animal behavior 'that is clearly purposive, revealing careful planning'); and (5) 'cosmic teleology' ('a belief ... that changes in the world [are] teleological in nature, leading to ever greater perfection'). Mayr proposes 'to restrict the use of the word teleological to cosmic teleology and to use other more specific terms instead for the other phenomena.'

I have no quarrel with Mayr's distinction of five meanings of teleology. Teleology has, nevertheless, been used with other meanings as well, including in earlier pages of this essay. A quick look at three dictionaries that I have at hand (*Oxford Dictionary*, *Webster Third New International Dictionary*, and *Merriam Webster's Collegiate Dictionary Tenth Edition*) reveals several meanings not mentioned by Mayr.

In any case, my own interest in this context is not semantics, but epistemology. I am concerned with unraveling patterns of explanation that are teleological in structure; i.e., those patterns that (as explained above) account for the presence of a feature or behavior in a system in terms of the goal it serves or the purpose it seeks. These patterns of explanation are extensively used in biology. It is my contention that teleological explanations are appropriate only in biology among the natural sciences, and thus that they are distinctive of the discipline. Because teleological explanations cannot be translated into causal explanations without loss of explanatory content, it follows that biology cannot be reduced to the physical sciences.

It seems to me unlikely that the use of 'teleology' will become generally limited to Mayr's fifth sense of 'cosmic teleology', nor do I see a reason why it should be so. I see not why such restriction would, in practice, avoid confusion. The genteelism 'teleonomy' was coined by Pittendrigh[10] and has been endorsed

[10] C.S. Pittendrigh, 'Adaptation, Natural Selection and Behavior'. In: A. Roe and G.G. Simpson (eds.), *Behavior and Evolution*, New Haven, CT: Yale University Press, 1958: 390-416. Pittendrigh considered 'unfortunate' that the term 'teleology' should be resurrected. "The biologists' long-standing confusion would be more fully removed if all end-directed systems were described by some other term, like 'teleonomic,' in order to emphasize that the recognition and description of end-directedness does not carry a commitment to Aristotelian teleology as an efficient causal principle." According to Pittendrigh, the Aristotelian concept

by others[11] to purge the term teleology, as P.B. and J.S. Medawar put it, from any 'pretensions to providing causal explanations, and restricted exclusively to putting on record the purposes which biological structures and performances do in fact fulfill.' I stated in 1970 that 'should the term "teleology" eventually be discarded from the scientific vocabulary, or restricted in its meaning ... I shall welcome such an event. But the substitution of a term by another does not necessarily clarify the issues at stake'.[12] I thought unlikely that such substitution would occur in practice. Indeed, 'the word "teleonomy" has not caught on, perhaps because corruption of biology by teleology is not ... so grave or so imminent a danger'.[13]

Mayr restricts the meaning of various terms in idiosyncratic ways that are far from common. He writes that ' "ordained" is strictly theological language'. I don't see why the statement, 'The development of an insect from egg to adult is a precisely ordained sequence of events' should be considered theological, strictly or otherwise. Dictionaries do not so restrict the meaning of 'ordained' either. Mayr further writes that 'purpose, as far as I can see can be attributed legitimately only to a thinking organism'. Peter Medawar, who can hardly be accused of being soft-headed, has written: 'It is folly or ignorance to deny that the purpose of nests is to protect the relatively helpless young of birds and mammals, and of the amnion to provide the embryos of land vertebrates with the aquatic environment they need in order to develop. The purpose of teeth, moreover, it can now be revealed, is mastication; of eyes, to see, and of ears to hear'.[14]

of teleology implies that future events are active agents in their own realization. According to Mayr (E. Mayr, 'Cause and Effect in Biology'. In: D. Lerner (ed.), *Cause and Effect*, New York: Free Press, 1965: 33-50) Aristotelian teleology connotes that there exists an overall design in the world attributable to a Deity, or at least that nature exists only for and in relation to man, considered as the ultimate purpose of creation. But these views represent unfortunate misunderstandings of Aristotle's ideas. According to Aristotle, to fully understand an object we need to find out, among other things, its end; what function does it serve or what results it produces. An egg can be understood fully only if we consider it as a possible chicken. The structures and organs of animals have functions, are organized towards certain ends. Living processes proceed towards certain goals. Final causes, for Aristotle, are principles of intelligibility; they are not in any sense active agents in their own realization. Also, according to Aristotle, the ends of things are not consciously intended. Nature, man excepted, has no purposes. The teleology of nature is objective, and empirically observable. It does not require the inference of unobservable causes. Finally, for Aristotle, the teleology of nature is wholly 'immanent'. The end served by any structure or process is the good or survival of that kind of thing in which they exist. Animals, plants, or their parts do not exist for the benefit of any other thing but themselves. Aristotle makes it clear that nutritious as acorns may be for a squirrel, they do not exist to serve as a squirrel's meal. The natural end of an acorn is to become an oak tree. Anything else that may happen to the acorn is accidental and may not be explained teleologically.

[11] See, e.g., E. Mayr, ref. 6; G.G. Simpson, *This View of Life*, New York: Harcourt, Brace and World, 1964; G.C. Williams, *Adaptation and Natural Selection*, Princeton, NJ: Princeton University Press, 1966.

[12] F.J. Ayala, see ref. 7, p. 14.

[13] P.B. Medawar and J.S. Medawar, see ref. 4, p. 256.

[14] P.B. Medawar and J.S. Medawar, see ref. 4, p. 256.

Mayr writes that 'the end point of the non-random process of elimination sooner or later is extinction [of species], but I would hesitate to call selection a teleological process because, sooner or later, it has an end point (extinction). Almost anything on earth has an end: a book does, a vacation does, an opera does, the day does, etc. Are these telic phenomena? The life of an individual has an end, is life a telic process? This is why I said it was "dangerous" to classify telic phenomena as teleological'. These statements are puzzling. The dictionary definitions of 'telic' that I have seen either list it as a synonym of 'teleological' and 'purposive' (*Webster's Third New International Dictionary*) or do so by definition: 'Expressing end or purpose' and 'Directed or tending to a definite end; purposive' (*Oxford Dictionary*); 'tending toward an end' (*Merriam Webster's Collegiate Dictionary Tenth Edition*). In any case, who would think of calling 'selection', or anything else for that matter, a teleological process just because it has an end point?

I agree with Krieger that Mayr's definition of 'teleonomy' is circular, and have said so in the past.[15] His definition is: 'A teleonomic process or behavior is one that owes its goal-directedness to the operation of a program'; and adds, 'A program might be defined as coded or prearranged information that controls a process (or behavior) leading it toward a goal.' So, a process is teleonomic if governed by a program; and if we want to know what kind of programs govern teleonomic processes, Mayr says that they are those programs ('coded or prearranged information') that lead the process 'toward a goal'. There is not much enlightenment here. We are told, in effect, that a process is teleonomic if it seeks a goal guided by a program, namely the kind of program that guides a process toward a goal. Given this circularity, it is not surprising that the definition can be arbitrarily applied: 'I had first included man-made objects like loaded dice under teleonomic because they were "programmed" to behave in a particular way, but I later excluded such objects'. Why? If 'loaded dice' are programmed to behave in a particular way, why should not they be considered teleonomic according to Mayr's definition? And one may wonder why only 'loaded' dice might or might not be considered teleonomic. Why not just dice (or cars or telephones) are considered teleonomic by Mayr, since they are programmed to behave in particular ways?

[15] F.J. Ayala, 'Concepts of Biology', *Science*, 240 (1988), 1801-1802.