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The Idea of Teleology

Ernst Mayr

1. Philosophical Background

Perhaps no other ideology has influenced biology more profoundly than teleological thinking. In one form or another it was the prevailing world view prior to Darwin. (Indeed it is one of the relatively few world views seriously considered by western man.) Appropriately, the discussion of teleology occupies considerable space (10-14%) in several recent philosophies of biology.[1] Such a finalistic world view had many roots. It is reflected by the millenarian beliefs of many Christians, by the enthusiasm for progress promoted by the Enlightenment, by transformationist evolutionism, and by everybody's hope for a better future. However, such a finalistic world view was only one of several widely adopted Weltanschauungen.

Grossly simplifying a far more complex picture, one can perhaps distinguish, in the period prior to Darwin, three ways of looking at the world:

1. A recently created and constant world. This was the orthodox Christian dogma, which, however, by 1859 had largely lost its credibility, at least among philosophers and scientists.[2]

2. An eternal and either constant or cycling world, exhibiting no constant direction or goal. Everything in such a world, as asserted by Democritus and his followers, is due to chance or necessity, with chance by far the more important factor. There is no room for teleology in this world view, everything being due to chance or causal mechanisms. It allows for change, but such change is not directional; it is not an evolution. This view gained some support during the Scientific Revolution and the Enlightenment, but remained very much a minority view until the nineteenth century. A rather pronounced polarization developed from the seventeenth to the nineteenth centuries, between the strict mechanists,

[1] Morton Beckner, *The Biological Way of Thought* (New York, 1959); Alexander Rosenberg, *The Structure of Biological Science* (Cambridge, Mass., 1985); Michael Ruse, *The Philosophy of Biology* (London, 1973); Rolf Sattler, *Biophilosophy* (Berlin, 1986).

[2] Ernst Mayr, *The Growth of Biological Thought* (Cambridge, Mass., 1982).

who explained everything purely in terms of movements and forces and who denied any validity whatsoever of the use of teleological language; and their opponents—deists, natural theologians, and vitalists—who all believed in teleology to a lesser or greater extent.

3. The third view of the world was that of a world of long duration (or being eternal) but with a tendency toward improvement or perfection. Such a view existed in many religions, it was widespread in the beliefs of primitive people (e.g., the Valhalla of the old Germans), and it was represented in Christianity by ideas of a millennium or resurrection. During the rise of deism, after the Scientific Revolution and during the era of Enlightenment, there was a widespread belief in the development of ever greater perfection in the world through the exercise of God's laws. There was a trust in an intrinsic tendency of Nature toward progress or an ultimate goal. Such beliefs were shared even by those who did not believe in the hand of God but who nevertheless believed in a progressive tendency of the world toward ever-greater perfection.[3]

Although Christianity was its major source of support, teleological thinking gained increasing strength also in philosophy, from its beginning with the Greeks and Cicero up to the eighteenth and nineteenth centuries. The concept of the *Scala Naturae*, the scale of perfection,[4] reflected a belief in upward or forward progression in the arrangement of natural objects. Few were the philosophers who did not express a belief in progress and improvement. It also fitted quite well with Lamarck's transformationist theory of evolution, and it is probably correct to say that most Lamarckians were also teleologists. The concept of progress was particularly strong in the philosophies of Leibniz, Herder, their followers and of course among the French philosophes of the Enlightenment.

What struck T. H. Huxley "most forcibly on his first perusal of the *Origin of Species* was the conviction that teleology, as commonly understood, had received its deathblow at Mr. Darwin's hands."[5] However, Huxley's prophecy did not come true. Perhaps the most popular among the anti-Darwinian evolutionary theories was that of orthogenesis,[6] which postulated that evolutionary trends, even nonadaptive ones, were due to an intrinsic drive. Even though the arguments of the orthogenesists were effectively refuted by Weismann,[7] orthogenesis continued to be highly popular not only in Germany but also in France,[8] the United

[3] Ernst Mayr, *Toward a New Philosophy of Biology* (Cambridge, Mass., 1988), 234-36.

[4] Arthur O. Lovejoy, *The Great Chain of Being* (Cambridge, Mass., 1936).

[5] Thomas Henry Huxley, *Lay Sermons, Addresses and Reviews* (London, 1870), 330.

[6] Peter J. Bowler, *The Eclipse of Darwinism* (Baltimore, 1983), 141-81; Peter J. Bowler, *The Non-Darwinian Revolution* (Baltimore, 1987).

[7] Mayr, *Toward a New Philosophy,* 499, n. 3.

[8] Henri Bergson, *Creative Evolution* (London, 1911).

States,[9] and Russia.[10] The reason was that even though Darwin's demonstration of the non-constancy of species and of the common descent of all organisms made the acceptance of evolution inevitable, natural selection, the mechanism proposed by Darwin, was so unpalatable to his opponents that they grasped at any other conceivable mechanism as an anti-Darwinian strategy. One of these was orthogenesis, a strictly finalistic principle,[11] which did not really collapse until the Evolutionary Synthesis. Simpson,[12] Rensch,[13] and J. Huxley,[14] in particular, showed that perfect orthogenetic series as claimed by the orthogenesists, simply did not exist when the fossil record was studied more carefully, that allometric growth could explain certain seemingly excessive structures, and finally, that the assertion of deleteriousness of certain characters, supposedly due to some orthogenetic force, was not valid. These authors showed, furthermore, that there was no genetic mechanism that could account for orthogenesis.

Both friends and opponents of Darwin occasionally classified him as a teleologist. It is true that this is what he was early in his career, but he gave up teleology soon after he had adopted natural selection as the mechanism of evolutionary change. Whether this was as late as the 1850s, as claimed by some authors, or already in the early 1840s, as indicated by the researches of R. Eisert, is unimportant. There is certainly no support for teleology in the *Origin of Species*, even though, particularly in his later years and in correspondence, Darwin was sometimes somewhat careless in his language.[15] I have previously presented a rather full history of the rise and fall of teleology in evolutionary biology, particularly in Darwin's writings.[16]

All endeavors to find evidence for a mechanism that would explain a general finalism in nature were unsuccessful or, where it occurs in organisms, it was explained strictly causally (see below). As a result, by the time of the Evolutionary Synthesis of the 1940s, no competent biologist was left who still believed in any final causation of evolution or of the world as a whole.

Final causes, however, are far more plausible and pleasing to a layperson than the haphazard and opportunistic process of natural selection. For this reason, a belief in final causes had a far greater hold outside of

[9] Henry Fairfield Osborn, "Aristogenesis, the Creative Principle in the Origin of Species," *American Naturalist*, 68 (1934), 193-235.

[10] L. S. Berg, *Nomogenesis, or Evolution determined by Law* (London, 1926).

[11] See note 3 above.

[12] George Gaylord Simpson, *Tempo and Mode in Evolution* (New York, 1944); George Gaylord Simpson, *The Meaning of Evolution* (New Haven, 1949).

[13] Bernhard Rensch, *Neuere Probleme der Abstammungslehre* (Stuttgart, 1947).

[14] Julian Huxley, *Evolution: The Modern Synthesis* (London, 1942).

[15] David Kohn, "Darwin's Ambiguity: The Secularization of Biological Meaning," *British Journal for the History of Science*, 22 (1989), 215-39.

[16] Mayr, *Toward a New Philosophy*, 235-55.

biology than within. Almost all philosophers, for instance, who wrote on evolutionary change in the one hundred years after 1859, were confirmed finalists. All three philosophers closest to Darwin—Whewell, Herschel, and Mill—believed in final causes.[17] The German philosopher E. von Hartmann[18] was a strong defender of finalism, stimulating Weismann to a spirited reply. In France, Bergson[19] postulated a metaphysical force, *élan vital*, which, even though Bergson disclaimed its finalistic nature, could not have been anything else, considering its effects. There is room for a good history of finalism in the post-Darwinian philosophy, although Collingwood[20] has made a beginning. Whitehead, Polanyi, and many lesser philosophers, were also finalistic.[21]

Refutation of a finalistic interpretation of evolution or of nature as a whole, however, did not eliminate teleology as a problem of philosophy. For the Cartesians any invoking of teleological processes was utterly unthinkable. Coming from mathematics and physics, they had nothing in their conceptual repertory that would permit them to distinguish between seemingly end-directed processes in inorganic nature, and seemingly goal-directed processes in living nature. They feared, as shown particularly clearly by Nagel,[22] that making such a distinction would open the door to metaphysical, nonempirical considerations. All their arguments, based on the study of inanimate objects, ignored the common view, derived from Aristotle and strongly confirmed by Kant, that truly goal-directed and seemingly purposive processes occur only in living nature. Yet the (physicalist) philosophers ignored the study of living nature and the findings of the biologists. Instead they used teleology in order to exercise their logical prowess. Why this was so has been explained by Ruse: "What draws philosophers toward teleology is that one has to know, or at least it is generally thought that one has to know, absolutely no biology at all! . . . philosophers want no empirical factors deflecting them in their neo-Scholastic pursuits."[23] The irony of this jibe against his fellow philosophers is that, having said this, Ruse himself promptly ignored the literature on teleology written by biologists and concentrated on reviewing the books of three philosophers known for their neglect of biology. Yet Ruse is not alone. One paper or book after the other dealing with teleology continues to be published in the philosophical literature in which the author attempts

[17] David L. Hull, *Darwin and His Critics* (Cambridge, Mass., 1973).

[18] Eduard v. Hartmann, *Das Unbewusste vom Standpunkt der Physiologie und Deszendenzlehre* (Berlin, 1872).

[19] See note 8 above.

[20] R. G. Collingwood, *The Idea of Nature* (Oxford, 1946).

[21] Mayr, *Toward a New Philosophy*, 247-48.

[22] Ernest Nagel, *The Structure of Science* (New York, 1961); E. Nagel, "Teleology Revisited: Goal Directed Processes in Biology," *Journal of Philosophy*, 74 (1977), 261-301.

[23] Michael Ruse, "The Last Word on Teleology, or Optimality Modes Vindicated," in Michael Ruse, *Is Science Sexist?* (Cambridge, 1981), 85-101.

to solve the problem of teleology with the sharpest weapons of logic, while utterly ignoring the diversity of the phenomena to which the word teleology has been attached, and of course ignoring the literature in which biologists have pointed this out.

Some of the difficulties of the philosophers are due to their misinterpretation of the writings of the great philosophers of the past. Aristotle, for instance, has often been recorded as a finalist, and cosmic teleology has been called an Aristotelian view. Grene is entirely correct when pointing out that Aristotle's *telos* has nothing to do with purpose "either Man's or God's. It was the Judaeo-Christian God who (with the help of neo-Platonism) imposed the dominance of a cosmic teleology upon Aristotelian nature. Such sweeping purpose is the very opposite of Aristotelian [philosophy]."[24] Modern Aristotle specialists (Balme, Gotthelf, Lennox, and Nussbaum) are unanimous in showing that Aristotle's seeming teleology deals with problems of ontogeny and adaptation in living organisms, where his views are remarkably modern.[25] Kant was a strict mechanist as far as the inanimate universe is concerned, but provisionally adopted teleology for certain phenomena of living nature, which (in the 1790s) were inexplicable owing to the primitive condition of contemporary biology.[26] It would be absurd, however, to use Kant's tentative comments two hundred years later as evidence for the validity of finalism.

The reasons for the unsatisfactory state of the teleology analyses in the philosophical literature are now evident. Indeed, one can go so far as to say that the treatment of the problems of teleology in this literature shows how not to do the philosophy of science. For at least fifty years a considerable number of philosophers have written on teleology basing their analyses on the methods of logic and physicalism, "known to be the best" or at least the only reliable methods for such analyses. These philosophers have ignored the findings of the biologists, even though teleology concerns mostly or entirely the world of life.

They ignored that the word *function* refers to two very different sets of phenomena; and that the concept of *program* gives a new complexion to the problem of goal-directedness; they confounded the distinction between proximate and evolutionary causations, and between static (adapted) systems and goal-directed activities. Even though there is an enormous philosophical literature on the problems of teleology, those recent books and papers are quite useless which still treat teleology as a unitary phenomenon. No author who had not tried to articulate the differences between the significance of cosmic teleology, adaptedness, programmed goal-

[24] Marjorie Grene, "Aristotle and Modern Biology," *JHI*, 33 (1972), 395-424.

[25] Mayr, *Toward a New Philosophy*, 55-60.

[26] Ernst Mayr, "The Ideological Resistance to Darwin's Theory of Natural Selection," *Proceedings of the American Philosophical Society*, 135 (1991), 123-39.

directedness, and deterministic natural laws, has made any worthwhile contribution to the solution of the problems of teleology.

The principal endeavor of the traditional philosopher was to eliminate teleological language from all descriptions and analyses. They objected to such sentences as "the turtle swims to the shore in order to lay her eggs," or "the wood thrush migrates to warmer climates in order to escape the winter." To be sure, questions that begin with "what?" and "how?" are sufficient for explanation in the physical sciences. However, since 1859 no explanation in the biological sciences has been complete until a third kind of question was asked and answered: "why?" It is the evolutionary causation and its explanation that is asked for in this question. Anyone who eliminates evolutionary "why?" questions, closes the door on a large area of biological research. It is therefore important for the evolutionary biologist to demonstrate that "why?" questions do not introduce a metaphysical element into the analysis, and that there is no conflict between causal and teleological analysis, provided it is precisely specified what is meant by "teleological." I have elsewhere[27] presented a detailed analysis of "the multiple meanings of teleological" but must present here at least the gist of my findings. Nagel[28] and Engels[29] have criticized some of my views. Engels's monograph is the most complete treatment of the teleology problem in the German language. In the following account I have included an answer to their objections. Before doing so I want first to clear up a number of assumptions that have been a confusing element in the recent literature. This will allow me to show that the following assertions are invalid.

1. *Teleological statements and explanations imply the endorsement of unverifiable theological or metaphysical doctrines in science.* This criticism was indeed valid in former times, particularly in the eighteenth and early nineteenth centuries, as well as for most vitalists right up to modern times, including Bergson and Driesch. It does not apply to any Darwinian who uses teleological language (see below).

2. *Any biological explanation that is not equally applicable to inanimate nature constitutes rejection of a physico-chemical explanation.* This is an invalid objection, since every modern biologist accepts physico-chemical explanations at the cellular-molecular level, and furthermore, since, as will be shown below, seemingly teleological processes in living organisms can be explained strictly materialistically.

3. *Teleological language introduces anthropomorphism into biology.* Many philosophers, indeed, have made human intentions and purposive acts the starting point of their analysis of goal-directed activities in other

[27] Mayr, *Toward a New Philosophy*, 38-66.

[28] Ernest Nagel, "Teleology Revisited: Goal Directed Processes in Biology," *Journal of Philosophy*, 74 (1977).

[29] Eve-Marie Engels, *Die Teleologie des Lebendigen* (Berlin, 1982).

organisms. This introduces concepts such as purpose, intention, and consciousness into the discussion and ties the whole problem to human psychology; but it seems to me that this is a poor foundation for an analysis of goal-directed activities in the non-human living world. In my own treatment I have therefore refrained from using anthropomorphic language, particularly the terms purpose and intention, when explaining teleonomic phenomena in animals and plants. The term goal-directed is strictly descriptive, while terms like purpose or intention introduce psychological problems that are irrelevant to our immediate objective.

4. *Teleonomic processes are in conflict with causality because future goals cannot direct current events.* This objection, frequently raised by physicalists, is due to their failure to apply the concept of program, a concept not existing in the classical framework of physicalist concepts and theories.

5. *Teleological explanations must qualify as laws.* Actually the attempt to insert laws into teleological explanations has led only to confusion.[30]

6. Telos *means either end point or goal; they are the same.* By contrast, for the evolutionary biologist there is a great difference between *telos* as goal and *telos* as endpoint. If one asks whether natural selection and, more broadly, all processes in evolution have a telos, one must be clear which *telos* one has in mind.

The word *telos* has been used in the philosophical literature with two very different meanings. When Aristotle uses it, it refers to a process that has a very definite goal, a goal ordinarily anticipated when the process is initiated. The *telos* of the fertilized egg is the adult into which it develops. For the deistic teleologist, cosmic teleology also had a definite goal, i.e., the world in its final perfection as conceived by its creator and effected by His laws. But *telos* has also been used simply to refer to the termination of an end-directed process. The telos of a rainstorm is when it stops raining. Day is the *telos* of the night. All processes caused by natural laws sooner or later have an endpoint, but it is misleading to use for this termination the same word *telos*, that is ordinarily used for the goal in goal-directed processes. The endpoint of a non-teleological process is, so to speak, an a posteriori phenomenon. Pierce[31] realized that the term "teleological" is too strong a word to apply to natural processes in the inorganic world. He therefore suggested that "we might invent the term finious to express their tendency toward a final state" (7.471).

Teleology and function: many philosophers of science have felt that the problem of teleology could be solved by explaining goal-directedness

[30] David L. Hull, "Philosophy and Biology," *Contemporary Philosophy*, 2 (1982), 298-316.

[31] Charles Sanders Pierce, Arthur W. Burks (eds.), *Collected Papers,* VII (Cambridge, Mass., 1958).

in terms of function, i.e., by translating teleological statements[32] into function statements,[33] but also implicitly Hempel,[34] Nagel,[35] and numerous authors since. Whether they recognize six meanings of the term function, as does Nagel, or ten, as does Wimsatt, all these proposals suffer from the fatal flaw not to have recognized that the word function is used in biology in two very different meanings, which must be carefully distinguished in any teleological analysis. Bock and von Wahlert[36] have admirably clarified the situation by showing that function is sometimes used for a physiological process and sometimes for the biological role of a feature in the life cycle of the organism. "For example, the legs of a rabbit have the function of locomotion . . . but the biological role of this faculty may be to escape from a predator, to move toward a source of food, to move to a favorable habitat, to move about in search of a mate." Descriptions of the physiological functioning of an organ or other biological feature are not teleological. Indeed, in favorable cases, they can be largely translated into physico-chemical explanations, they are due to proximate causations. What is involved in an analysis of teleological aspects is the biological role of a structure or activity. Such roles are due to evolutionary causations. For this reason I carefully avoid the word function when my concern is the biological role of a feature or process (see below, p. 14).

2. Categories of Teleology

The majority of philosophers have treated teleology as a unitary phenomenon. This ignores that the term teleological has been applied to several fundamentally different natural phenomena. Under these circumstances it is no surprise that the search for a unitary explanation of teleology has so far been entirely futile. Beckner[37] thinks he can distinguish three kinds of teleology, characterized by the terms function, goal, and intention. Although this proposal leads to some ordering of the phenomena, it does not represent a successful solution, particularly in view of the relevance of intention only to man, and the ambiguity of the term function. Woodger[38] also saw the diverse meanings of the word teleological, and

[32] W. Wimsatt, "Teleology and the Logical Status of Function Statements," *Studies in the History and Philosophy of Science*, 3 (1972), 1-80.

[33] Robert Cummins, "Functional Analysis," *Journal of Philosophy,* 72 (1975), 741-65.

[34] Carl G. Hempel, *Aspects of Scientific Explanation* (New York, 1965).

[35] Ernest Nagel, *The Structure of Science* (New York, 1961).

[36] Walter J. Bock and G. von Wahlert, "Adaptation and the Form-function Complex," *Evolution,* 19 (1969), 269-99.

[37] Morton Beckner, *The Biological Way of Thought* (New York, 1959).

[38] J. H. Woodger, *Biological Principles* (London, 1929).

attempted to recognize some categories but did not carry the analysis very far. A careful study of all the uses of the term teleological in the philosophical and biological literature led me to propose a four-fold division.[39] One of the major features of my proposal was to divide the category of function into genuine functional activities and the category of adaptedness, corresponding to the history of features with a biological role (see Bock and von Wahlert).[40]

i. Teleomatic Processes

Several philosophers have designated as teleological any processes which "persist toward an end point under varying conditions" or in which "the end state of the process is determined by its properties at the beginning."[41] These definitions would include all processes in inorganic nature that have an endpoint. A river would have to be called teleological because it flows into the ocean. To place such processes in the same category as genuine goal-directed processes in organisms is most misleading.

All objects of the physical world are endowed with the capacity to change their state, and these changes strictly obey natural laws. They are end-directed only in a passive, automatic way, regulated by external forces or conditions, that is by natural laws. I designated such processes as *teleomatic*[42] to indicate that they are automatically achieved. All teleomatic processes come to an end when the potential is used up (as in the cooling of a heated piece of iron) or when the process is stopped by encountering an external impediment (as when a falling object hits the ground). The law of gravity and the second law of thermodynamics are among the natural laws which most frequently govern teleomatic processes.

Aristotle clearly distinguished teleomatic processes from the teleological ones encountered in organisms, and referred to them as caused "by necessity."[43] These are most of the processes called finious by Pierce.[44] They may have an end point but they never have a goal. The question "what for?" (*wozu*?) is inappropriate for them. One cannot ask for what

[39] Ernst Mayr, "Teleological and Teleonomic. A New Analysis," *Boston Studies in the Philosophy of Science*, 14 (1974).

[40] See note 36 above.

[41] C. H. Waddington, *The Strategy of the Genes* (London, 1957).

[42] See note 39 above.

[43] A. Gotthelf, "Aristotle's Conception of Final Causality," *Review of Metaphysics*, 30 (1976), 226-54.

[44] See note 31 above.

purpose lightning had struck a particular tree, or for what purpose a flood or an earthquake had killed thousands of people.

Radioactive decay is a teleomatic process, it is not controlled by a program. Any chunk of uranium will experience radioactive decay governed by the same physical laws as any other, in contrast to programs that are highly specific and often unique. The natural laws interact with the intrinsic properties of the material on which they act. Different materials have different properties, and the rate of cooling may differ from one substance to the next. But inherent properties that are the same for any sample of the same substance are something entirely different from a coded program. This is true right down to the molecular level. A given macromolecule has inherent properties, but this by itself is not a program. Programs are formed by a combination of molecules, and other organic components.

Prediction is not the defining criterion of a program. If I release a stone from my hand, I can predict that it will fall to the ground. Therefore, says Engels,[45] it is programmed to fall to the ground, and there is no difference between teleomatic and teleonomic processes. This is the same argument Nagel[46] made with reference to radioactive decay. An example will show how misleading this argument is: somewhere in the mountains a falling stone kills a person. Engels would have to say that this stone was "programmed" to kill a person. The very general terminal situations effected by natural laws are something entirely different from the highly specific goals coded in programs. The existence of programs, of course, is in no way in conflict with natural laws. All the physico-chemical processes that take place during the translation and execution of a program strictly obey natural laws. But to neglect the role of information and instruction inevitably results in a most misleading description of a program. Could one explain a computer strictly in terms of natural laws, carefully avoiding any reference to information and instruction?

ii. Teleonomic Processes

The term teleonomic has been used with various meanings. When Pittendrigh[47] introduced the term, he failed to provide it with a rigorous definition. As a result various authors used it either for programmed functions or for adaptedness as did for instance B. Davis,[48] G. G. Simp-

[45] See note 29 above.

[46] See note 28 above.

[47] Colin S. Pittendrigh, "Adaptation, Natural Selection, and Behavior," in Anne Roe and George Gaylord Simpson (eds.), *Behavior and Evolution* (New Haven, 1958), 390-416.

[48] Bernard D. Davis, "The Teleonomic Significance of Biosynthetic Control Mechanisms," *Cold Spring Harbor Symposia*, 26 (1961), 1-10.

son,[49] Monod,[50] and Curio.[51] I restricted the term teleonomic to programmed activities[52] and now provide the following definition: *a teleonomic process or behavior is one that owes its goal-directedness to the operation of a program*. The term teleonomic thus implies goal-direction of a process or activity. It deals strictly with proximate causations. They occur in cellular-developmental processes, and are most conspicuous in the behavior of organisms. "Goal-directed behavior . . . is extremely widespread in the organic world; for instance, most activities connected with migration, food-getting, courtship, ontogeny and all phases of reproduction are characterized by such goal orientation. The occurrence of goal-directed processes is perhaps the most characteristic feature of the world of living organisms."[53] It is sometimes stated that Pittendrigh and I introduced the term teleonomic as a substitute for the term teleological. This is not correct, rather it is a term for only one of the four different meanings of the highly heterogeneous term teleological.

In my original proposal[54] I suggested that one might expand the application of the term teleonomic to include also the functioning of human artifacts (e.g., loaded dice) that are fixed in such a way as to assure a wanted goal. This extended use of the term has been criticized, and I now consider that human artifacts are only analogs. Truly teleonomic activities depend on the possession of a program.

All teleonomic behavior is characterized by two components. It is guided by "a program" and it depends on the existence of some end point, goal, or terminus which is foreseen in the program which regulates the behavior. This end point might be a structure (in development), a physiological function, the attainment of a geographical position (in migration), or a "consummatory act"[55] in behavior. Each particular program is the result of natural selection, constantly adjusted by the selective value of the achieved end point.

The key word in the definition of teleonomic is *program*. The importance of the recognition of the existence of programs lies in the fact that a program is (1) something material and (2) something existing prior to the initiation of the teleonomic process. This shows that there is no conflict between teleonomy and causality.

A program might be defined as *coded or prearranged information that*

[49] George Gaylord Simpson, "Behavior and Evolution," Anne Roe and George Gaylord Simpson (eds.), *Behavior and Evolution* (New Haven, 1958), 507-35.

[50] Jacques Monod, *Le Hasard et la Necessité* (Paris, 1970).

[51] Eberhard Curio, "Towards a Methodology of Teleonomy," *Experientia*, 29 (1973), 1045-58.

[52] See note 39 above.

[53] Mayr, *Toward a New Philosophy*, 45.

[54] See note 39 above.

[55] Wallace Craig, "Appetites and Aversions as Constituents of Instincts," *Biological Bulletin*, 34 (1916), 91-107.

controls a process (or behavior) leading it toward a goal. The program contains not only the blueprint of the goal *but also the instructions of how to use the information of the blue print.* A program is not a description of a given situation but a set of instructions.

Accepting the concept of program seems to cause no difficulties to a biologist familiar with genetics or any scientist familiar with the working of computers. However, programs, such as those that control teleonomic processes, do not exist in inanimate nature. Traditional philosophers of science, familiar only with logic and physics, therefore have had great difficulty in understanding the nature of programs, as is well illustrated by the writings of Nagel.[56]

References to the presumed existence of something like a program in the cells or the genome of organisms can be found in the biological literature far back into the nineteenth century. E. B. Wilson, after describing the remarkably teleonomic manner in which the cleavage of an egg takes place, continues: "such a conclusion need involve no mystical doctrine of teleology or of final causes. It means only that the factors by which cleavage is determined are in greater or in less degree bound up with an underlying organization of the egg that precedes cleavage and is responsible for the general morphogenic process. The nature of this organization is almost unknown, but we can proceed with its investigation only on the mechanistic assumption that it involves some kind of material configuration in the substance of the egg."[57] It is important once more to emphasize, because this is almost consistently misunderstood in the classical literature on teleology, that the goal of a teleonomic activity does not lie in the future, but is coded in the program. Not enough is known about the genetic-molecular basis of such programs to permit us to say much more than that they are innate or partly innate. The existence of the program is inferred from its manifestations in the behavior or the activities of the bearer of the program.

Concepts, corresponding to program, go back all the way to antiquity. After all, Aristotle's eidos had many of the properties we now ascribe to the genetic program, as was pointed out by Jacob[58] and Delbrück.[59] So did Buffon's *moule intérieur*[60] as well as the many speculations about inborn memories from Leibniz and Maupertuis to Darwin, Hering, and Semon. As sound as the intuition of these thinkers had been, it required an understanding of the DNA nature of the genotype, before the genetic program could be considered a valid scientific concept.

[56] See note 22 above.

[57] E. B. Wilson, *The Cell in Development and Heredity* (3rd ed., New York, 1925), 1005.

[58] François Jacob, *La Logique du Vivant* (Paris, 1970).

[59] Max Delbrück, "Aristotle-totle-totle," J. Monod and E. Borek (eds.), *Of Microbes and Life* (New York, 1971), 50-55.

[60] Jacques Roger, *Buffon* (Paris, 1989).

The study of teleonomic programs has shown that several kinds can be distinguished. A program in which complete instructions are laid down in the DNA of the genotype is called a *closed program*.[61] Most programs which control the instinctive behavior of insects and lower invertebrates seem to be closed programs. There is, however, another type of program, *open programs*, which are constituted in such a way that additional information can be incorporated during lifetime, acquired through learning, conditioning, or other experiences. Most behavior in higher animals is controlled by such open programs. Their existence has long been known to ethologists without their introducing a special terminology. In the famous case of the following reaction of the young gosling, the open program provides for the following reaction, but the particular object (the "parent") to be followed is added by experience (by "imprinting"). Open programs are very frequent in the behavior program of higher organisms, but even in some invertebrates there is often opportunity to make use of individual experience in filling out open programs, for instance with respect to suitable food or potential enemies, or the nest site in solitary wasps.

The programs controlling teleonomic activities were initially thought of exclusively in terms of the DNA of the genome. However, in addition to such genetic programs it might be useful to recognize *somatic programs*. "For instance, when a turkey gobbler displays to a hen, his display movements are not directly controlled by the DNA in his cell nuclei, but rather by a somatic program in his central nervous system. To be sure, this neuronal program was laid down during development under the control of instructions from the genetic program. But it is now an independent somatic program."[62] Somatic programs are particularly important in development. Each stage in ontogeny represents, so to speak, a somatic program for the next step in development. Most of the embryonic structures that have been cited as evidence for recapitulation, like the gill arches of tetrapod embryos, are presumably somatic programs. The reasons why they have not been removed by natural selection is that this would have seriously interfered with subsequent development. The existence and role of somatic programs has been understood by embryologists at least since Kleinenberg.[63]

To borrow the term program from informatics is not a case of anthropomorphism. There is a strict equivalence of the "program" of the information theorists, and the genetic and somatic programs of the biologist. The origin of a program is quite irrelevant for its definition. It can be the

[61] Ernst Mayr, "The Evolution of Living Systems," *Proceedings of the National Academy of Sciences*, 51 (1964), 934-41.

[62] Mayr, *Toward a New Philosophy*, 64.

[63] Nicolaus Kleinenberg, "Über die Entwicklung durch Substitution von Organen," *Zeitschrift für wissenschaftliche Zoölogie* (1886), 212-24.

product of evolution, as are all genetic programs, or it can be the acquired information of an open program.

An objection that has been raised against the concept of program is that reflexes would then also be teleonomic activities. Why not? Some of them undoubtedly are. Sherrington[64] was fully aware of the significance of the reflex as an adapted act. He said "the purpose of a reflex seems as legitimate and urgent an object for natural enquiry as the purpose of the coloring of an insect or blossom. And the importance to physiology is, that the reflex can not be really intelligible to the physiologist until he knows its aim." The eyelid clearly is programmed to close by reflex when a threatening object or disturbance approaches the eye. A similar adaptive function is evident for numerous reflexes. Other reflexes, like the knee-jerk reflex so beloved by physicians, seem to be merely an irrelevant property of certain nerves, as irrelevant as the heart sounds are for the functioning of the heart. It would be most useful if a neurophysiologist would someday analyze the better known reflexes for their possible adaptive significance.

The directedness of a teleonomic action is effected by a number of devices—first of all, of course, by the program itself; but the program does not induce a simple unfolding of some completely preformed gestalt, for it always controls a more or less complex process that must allow for internal and external disturbances. Teleonomic processes during ontogenetic development, for instance, are constantly in danger of being derailed even if only temporarily. Waddington[65] has quite rightly called attention to the frequency and importance of homeostatic devices that correct such deviations; they virtually guarantee the appropriate canalization of development.

Negative feedbacks play an important role not only in development but also in many other teleonomic processes. They are, however, not the essence of the teleonomic activity. As I pointed out earlier, "the truly characteristic aspect of goal-seeking behavior is not that mechanisms exist which improve the precision with which a goal is reached, but rather that mechanisms exist which initiate, i.e., 'cause' this goal-seeking behavior."[66]

iii. Adapted Features

Features that contribute to the adaptedness of an organism are in the philosophical literature usually referred to as teleological or functional systems. Both of these designations are potentially misleading. These

[64] Charles S. Sherrington, *The Integrative Action of the Nervous System* (New Haven, 1906), 235.

[65] See note 41 above.

[66] Mayr, *Toward a New Philosophy*, 46.

features are stationary systems, and as I pointed out previously,[67] the word teleological would not seem to be appropriate for phenomena that do not involve movements.

The designation teleological system is misleading for a second reason. It was adopted by the older philosophical literature under the assumption that these features had originated through some teleological force of nature. This assumption was largely a heritage of natural theology, with its belief that the usefulness of each feature had been given by God. The fallacy of this thinking has been refuted particularly effectively by Dawkins in his splendid book, *The Blind Watchmaker*.[68] Immanuel Kant's interest in teleology focussed on adapted features. On the basis of the scant knowledge of biology available at the end of the eighteenth century he was unable to provide a causal explanation. He therefore ascribed adaptedness to teleological forces by which he presumably meant the hand of God.[69] Since 1859 such defeatism has become unnecessary. Darwin has taught us that seemingly teleological evolutionary changes and the production of adapted features are simply the result of variational evolution, the production of great variation in every generation, and the probabilistic survival of those individuals with the temporarily fittest phenotype. Adaptedness thus is an a posteriori result rather than an a priori goal-seeking. For this reason the word teleological is misleading when applied to adapted features.

Nor should they be called functional systems owing to the confusing dual meaning of the word function. Indeed most of those who use the terminology functional systems were referring to the biological role of these features and their effectiveness in carrying out this role. Proximate and evolutionary causations were frequently confounded in functionalist discussions. Munson[70] and Brandon[71] have excellently stated the reasons why an adaptationist language, in connection with adapted features, and in connection with an answer to "what for?" questions, is to be preferred to teleological or functional language.

One of the characteristics of adapted features is that they can perform teleonomic activities. They are, so to speak, executive organs for teleonomic programs. I have therefore suggested[72] that they might perhaps be considered to be somatic programs.

More than anything else it is the existence of adapted features that led biologists to ask "why?" questions. The first area in biology where they were used was in physiological research. When Harvey was asked what

[67] *Ibid.*, 51-52.

[68] Richard Dawkins, *The Blind Watchmaker* (London, 1986).

[69] Mayr, *Toward a New Philosophy*, 57-59, and see note 26 above.

[70] Ronald Munson, "Biological Adaptation," *Philosophy of Science*, 38 (1971), 200-215.

[71] R. N. Brandon, "Biological Teleology: Questions and Explanations," *Studies in the History and Philosophy of Science*, 12 (1981), 91-105.

[72] Mayr, *Toward a New Philosophy,* 62-63.

had induced him to think of the circulation of blood, he answered, I wondered why there were valves in the veins.[73] Evidently they permit only a one-directional flow of the blood and this, almost automatically, led to an assumption of circulation. One physiological discovery after another resulted from asking "why?" questions concerning organs with unknown functions. Such "why?" or "what for?" questions eventually became equally productive in other branches of biology, and the heuristic value of this methodology has been by no means exhausted.

3. Natural Selection and Teleology

After Darwin had established the principle of natural selection, this process was widely interpreted to be teleological, both by supporters and opponents. Evolution itself was frequently considered a teleological process since it would lead to "improvement" or "progress."[74] Perhaps such an interpretation was not altogether unreasonable in the framework of the Lamarckian transformational paradigm. It is no longer a reasonable view when one fully appreciates the variational nature of Darwinian evolution, which has no ultimate goal and which, so to speak, starts anew in every generation. At best the process of natural selection may fit the definition of Pierce's "finious" processes;[75] but considering how often natural selection leads into fatal dead ends and considering how often during evolution its premium changes, resulting in an irregular zig zag movement of the evolutionary change, it would seem singularly inappropriate to use the designation teleological. To be sure, natural selection is an optimization process, but it has no definite goal, and considering the number of constraints and the frequency of chance events, it would be most misleading to call it teleological. Nor is any improvement in adaptation a teleological process, since it is strictly a *post hoc* decision whether a given evolutionary change qualifies as a contribution to adaptedness. None of fifteen authors contributing to a recent volume on natural selection and optimization during evolution[76] has used the term teleological.

This has to be remembered when one encounters teleological language in evolutionary interpretations.[77] If an author says species have evolved

[73] F. Krafft, "Die Idee der Zweckmässigkeit in der Geschichte der Wissenschaften," *Berichte zur Wissenschaftsgeschichte*, 5 (1982), 1-152.

[74] Francisco J. Ayala, "Teleological Explanation in Evolutionary Biology," *Philosophy of Science*, 37 (1970), 1-15.

[75] See above, note 31, and T. L. Short, "Teleology in Nature," *American Philosophical Quarterly* (1984), 311-20.

[76] J. Dupré, (ed.), *The Latest on the Best: Essays on Evolution and Optimality* (Cambridge, Mass., 1987).

[77] R. T. O'Grady, "Evolutionary Theory and Teleology," *Journal of Philosophy*, 74 (1984), 261-301.

isolating mechanisms in order to protect their genetic integrity, it simply means that individuals avoiding hybridization with individuals of other species had greater reproductive success than those which hybridized. Therefore, a genetic predisposition not to hybridize was rewarded with reproductive success.[78] Natural selection deals with the properties of individuals of a given generation; it simply does not have any long range goal, even though this may seem so when one looks backward over a long series of generations. Alas, some authors even in the most recent literature seem to endow evolution with a teleological capacity. As recently as 1985 J. H. Campbell said "It becomes increasingly evident that organisms evolve special structures to promote their capacities to evolve, and that these structures enormously expand the scope of the evolutionary process. Nevertheless, function is fundamentally a teleological concept, especially when applied to the evolutionary process."[79] As Munson[80] has rightly pointed out, such a dubious use of the word teleological can easily be avoided by using adaptationist language.

4. Cosmic Teleology

Prior to the nineteenth century the belief was almost universal that change in the world was due to an inner force or tendency toward progress and ever-greater perfection (see above). Gillispie,[81] Glacken,[82] and I[83] have described the immense power of this ideology. As late as 1876 K. E. von Baer made a passionate plea for the recognition of finalism to give pleasure to those people "who consider the world and particularly the organic world as the result of a development which tends toward higher goals and is guided by reason."[84] The most determined opponents of natural selection were teleologists, and teleological theories of evolution (orthogenesis, etc.) continued to be dominant until the beginning of the twentieth century.[85]

When it was being realized that the world was neither recent nor

[78] Mayr, *Toward a New Philosophy*.

[79] J. Campbell, "An Organizational Interpretation of Evolution," in D. Depew and B. H. Weber (eds.), *Evolution at a Crossroads* (Cambridge, Mass., 1985).

[80] See note 71 above.

[81] Charles C. Gillispie, *Genesis and Geology* (New York, 1951).

[82] Clarence J. Glacken, *Traces on the Rhodian Shore. Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley, 1967).

[83] See note 2 above.

[84] Karl Ernst von Baer, *Studien aus der Geschichte der Naturwissenschaften* (St. Petersburg, 1876), 240.

[85] Vernon L. Kellogg, *Darwinism Today* (New York, 1907), and see notes 2 and 6 above.

constant, three categories of explanations for seemingly finalistic changes were advanced:

1. These changes are due to the action of an evolutionary planner (theistic explanation).

2. These changes are guided by a built-in program, analogous to a teleonomic program in the genotype of an individual (orthogenetic explanations). Much of the post-Darwinian research resulted in providing evidence that such a cosmic program does not exist, and that the irregularities of cosmic evolution are far too great to be reconciled with the existence of a program. Indeed by the time of the evolutionary synthesis (1930s-40s) all support for orthogenetic theories had disappeared.

3. There is no cosmic teleology, there is no trend toward progress or perfection. Whatever changes in the kosmos are observed in the course of the world's history, are the result of the action of natural laws. This third explanation fits the observed facts so well that it makes it unnecessary to invoke explanations 1 or 2.

The recognition that three seemingly teleological processes, that is, teleonomic processes, teleomatic processes, and the achievement of adaptedness by natural selection, are strictly material phenomena, has deprived teleology of its former mystery and supernatural overtones. There is adaptedness (Kant's *Zweckmässigkeit*) in living nature but Darwin showed that its origin could be explained materialistically. Even though there are indeed many organic processes and activities that are clearly goal-directed, there is no need to involve supernatural forces, because the goal is already coded in the program which directs these activities. Such teleonomic processes can, in principle, be reduced to chemico-physical causes. Finally, there are all the end-achieving processes in inorganic nature that are simply due to the operation of such natural laws as gravity or the laws of thermodynamics. None of the three recognized teleological processes work backwards from a future goal, there is no backwards causation. This refutes the formerly frequently made claim of a conflict between causal and teleological explanations. Such a claim might be true if cosmic teleology existed, but it is invalid for the three kinds of teleology now accepted by science.

The removal of the mentioned three material processes from the formerly so heterogeneous category "teleological" leaves no residue. It has revealed the nonexistence of cosmic teleology, left after the three materially explained categories of "teleological" have been removed.

The refutation of cosmic teleology leaves us with one unsolved problem: how can one explain the seemingly upward trend in organic evolution? Author after author has referred to the progression from the lowest prokaryotes (bacteria) to the nucleated eukaryotes, the metazoans, warm-blooded mammals and birds, and finally man with his elaborate brain, speech, and culture. The defenders of orthogenesis never tired of claiming that this was irrefutable evidence for some intrinsic power in living nature

toward progress, if not even to an ultimate goal. Again, it was Darwin who showed that such an assumption was not inevitable. The process of natural selection, acting in every population, generation for generation, is indeed a mechanism that would favor the rise of ever better adapted species, it would favor the invasion of new niches and adaptive zones, and as the end-result of competition of species favor developments that are best described as advanced types. Descriptively there is no question as to what has happened during the diverse steps from the most primitive bacteria to man. Whether one is justified to refer to this as progress is still controversial. That much is clear, however, that natural selection provides a satisfactory explanation for the course of organic evolution and makes an invoking of supernatural teleological forces unnecessary.

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