Chapter 3 Essay Three

THE MULTIPLE MEANINGS OF TELEOLOGICAL

TELEOLOGICAL language is frequently used in biology in order to make statements about the functions of organs, about physiological processes, and about the behavior and actions of species and individuals. Such language is characterized by the use of the words *function, purpose,* and *goal,* as well as by statements that something exists or is done *in order to.* Typical statements of this sort are: "One of the functions of the kidneys is to eliminate the end products of protein metabolism," or "Birds migrate to warm climates in order to escape the low temperatures and food shortages of winter." In spite of the long-standing misgivings of physical scientists, philosophers, and logicians, many biologists have continued to insist not only that such teleological statements are objective and free of metaphysical content, but also that they express something important which is lost when teleological language is eliminated from such statements. Recent reviews of the problem in the philosophical literature (Nagel 1961; Beckner 1969; Hull 1973; to cite only a few of a large selection of such publications) concede the legitimacy of some teleological statements but still display considerable divergence of opinion as to the actual meaning of the word *teleological* and the relations between teleology and causality.

This confusion is nothing new and goes back at least as far as Aristotle, who invoked final causes not only for individual life processes (such as development from the egg to the adult) but also for the universe as a whole. To him, as a biologist, the form-giving of the specific life process was the primary paradigm of a finalistic process, but for his epigones the order of the universe and the trend toward its perfection became completely dominant. The existence of a form-giving, finalistic principle in the universe was rightly rejected by Bacon and Descartes, but this, they thought, necessitated the eradication of any and all teleological language, even for biological processes, such as growth and behavior, or in the discussion of adaptive structures.

The history of the biological sciences from the seventeenth to the nineteenth centuries is characterized by a constant battle between extreme mechanists, who explained everything purely in terms of movements and forces, and their opponents, who often went to the opposite extreme of vitalism. After vitalism had been completely routed by the beginning of the twentieth century, biologists could afford to be less self-conscious in their language and, as Pittendrigh (1958) has expressed it, were again willing to say "A turtle came ashore to lay her eggs," instead of saying "She came ashore and laid her eggs." There is now complete consensus among biologists that the teleological phrasing of such a statement does not imply any conflict with physicochemical causality.

Yet, the very fact that teleological statements have again become respectable has helped to bring out uncertainties. The vast literature on teleology is eloquent evidence for the unusual

difficulties connected with this subject. This impression is reinforced when one finds how often various authors dealing with this subject have reached opposite conclusions (Braithwaite 1954; Beckner 1969; Canfield 1966; Hull 1973; Nagel 1961). They differ from each other in multiple ways, but most importantly in answering the question: What kind of teleological statements are legitimate and what others are not? Or, what is the relation between Darwin and teleology? David Hull (1973) has recently stated that "evolutionary theory did away with teleology, and that is that," yet, a few years earlier MacLeod (1957) had pronounced "what is most challenging about Darwin, is his reintroduction of purpose into the natural world." Obviously the two authors must mean very different things.

Purely logical analysis helped remarkably little to clear up the confusion. What finally produced a breakthrough in our thinking about teleology was the introduction of new concepts from the fields of cybernetics and new terminologies from the language of information theory. The result was the development of a new teleological language, which claims to be able to take advantage of the heuristic merits of teleological phraseology without being vulnerable to the traditional objections.

Traditional Objections to the Use of Teleological Language

Criticism of the use of teleological language is traditionally based on one or several of the following objections. In order to be acceptable teleological language must be immune to these objections.

(1) Theological statements and explanations imply the endorsement of unverifiable theological or metaphysical doctrines in science. This criticism was indeed valid in former times, as for instance when natural theology operated extensively with a strictly metaphysical teleology. Physiological processes, adaptations to the environment, and all forms of seemingly purposive behavior tended to be interpreted as being due to nonmaterial vital forces. This interpretation was widely accepted among Greek philosophers, including Aristotle, who discerned an active soul everywhere in nature. Bergson's (1907) *elan vital* and Driesch's (1909) *Entelechie* are relatively recent examples of such metaphysical teleology. Contemporary philosophers reject such teleology almost unanimously. Likewise, the employment of teleological language among modern biologists does not imply adoption of such metaphysical concepts (see below).

(2) The belief that acceptance of explanations for biological phenomena that are not equally applicable to inanimate nature constitutes rejection of a physicochemical explanation. Ever since the age of Galileo and Newton it has been the endeavor of the "natural scientists" to explain everything in nature in terms of the laws of physics. To accept special explanations for teleological phenomena in living organisms implied for these critics a capitulation to mysticism and a belief in the supernatural. They ignored the fact that nothing exists in inanimate nature (except for man-made machines) which corresponds to DNA programs or to goal-directed activities. As a matter of fact, the acceptance of a teleonomic explanation (see below) is in no way in conflict with the laws of physics and chemistry. It is neither in opposition to a causal interpretation, nor does it imply an acceptance of supernatural forces in

any way whatsoever.

(3) The assumption that future goals were the cause of current events seemed in complete conflict with any concept of causality. Braithwaite (1954) stated the conflict as follows: "In a [normal] causal explanation the explicandum is explained in terms of a cause which either precedes it or is simultaneous with it; in a teleological explanation the explicandum is explained as being causally related either to a particular goal in the future or to a biological end which is as much future as present or past." This is why some logicians up to the present distinguish between causal explanations and teleological explanations.

(4) Teleological language seemed to represent objectionable anthropomorphism. The use of terms like *purposive* or *goal-directed* seemed to imply the transfer of human qualities, such as intent, purpose, planning, deliberation, or consciousness, to organic structures and to subhuman forms of life.

Intentional, purposeful human behavior is, almost by definition, teleological. Yet I shall exclude it from further discussion because use of the words *intentional* or *consciously premeditated*, which are usually employed in connection with such behavior, runs the risk of getting us involved in complex controversies over psychological theory, even though much of human behavior does not differ in kind from animal behavior. The latter, although usually described in terms of stimulus and response, is also highly "intentional," as when a predator stalks his prey or when the prey flees from the pursuing predator. Yet, seemingly "purposive," that is, goal-directed behavior in animals can be discussed and analyzed in operationally definable terms, without recourse to anthropomorphic terms like *intentional* or *consciously*.

As a result of these and other objections, teleological explanations were widely believed to be a form of obscurantism, an evasion of the need for a causal explanation. Indeed some authors went so far as to make statements such as "Teleological notions are among the main obstacles to theory formation in biology" (Lagerspetz 1959:65). Yet, biologists insisted on continuing to use teleological language.

The teleological dilemma, then, consists in the fact that numerous and seemingly weighty objections against the use of teleological language have been raised by various critics, and yet biologists have insisted that they would lose a great deal, methodologically and heuristically, if they were prevented from using such language. It is my endeavor to resolve this dilemma by a new analysis, and particularly by a new classification of the various phenomena that have been traditionally designated as teleological.

The Heterogeneity of Teleological Phenomena

One of the greatest shortcomings of most recent discussions of the teleology problem has been the heterogeneity of the phenomena designated as teleological by different authors. To me it would seem quite futile to arrive at rigorous definitions until the medley of phenomena designated as teleological is separated into more or less homogeneous classes. To accomplish this objective will be my first task.

Furthermore, it only confuses the issue to mingle a discussion of teleology with such extraneous problems as vitalism, holism, or reductionism. Teleological statements and

phenomena can be analyzed without reference to major philosophical systems.

By and large all the phenomena that have been designated in the literature as teleological can be grouped into three classes:

(1) Unidirectional evolutionary sequences (progressionism, orthogenesis).

(2) Seemingly or genuinely goal-directed processes.

(3) Teleological systems.

The ensuing discussion will serve to bring out the great differences between these three classes of phenomena.

UNIDIRECTIONAL EVOLUTIONARY SEQUENCES

Already with Aristotle and other Greek philosophers, but increasingly so in the eighteenth century, there was a belief in an upward or forward progression in the arrangement of natural objects. This was expressed most concretely in the concept of the *scala naturae,* the scale of perfection (Lovejoy 1936). Originally conceived as something static (or even descending, owing to a process of degradation), the Ladder of Perfection was temporalized in the eighteenth century and merged almost unnoticeably into evolutionary theories such as that of Lamarck. Progressionist theories were proposed in two somewhat different forms. The steady advance toward perfection was either directed by a supernatural force (a wise, creator) or, rather vaguely, by a built-in drive toward perfection. During the flowering of natural theology the "interventionist" concept dominated, but after 1859 it was replaced by so-called orthogenetic theories widely held by biologists and philosophers (see Lagerspetz 1959:11-12 for a short survey). Simpson (1949) refuted the possibility of orthogenesis with particularly decisive arguments. Actually, as Weismann had said long ago (1909), the principle of natural selection solves the origin of progressive adaptation without any recourse to goal-determining forces.

It is somewhat surprising how many philosophers, physical scientists, and occasionally even biologists still flirt with the concept of a teleological determination of evolution. Teilhard de Chardin's (1955) entire dogma is built on such a teleology and so are, as Monod (1971) has stressed quite rightly, almost all of the more important ideologies of the past and present. Even some serious evolutionists play, in my opinion, rather dangerously with teleological language. For instance Ayala (1970:11) says,

> the overall process of evolution cannot be said to be teleological in the sense of directed towards the production of specified DNA codes of information, i.e. organisms. But it is my contention that it can be said to be teleological in the sense of being directed toward the production of DNA codes of information which improve the reproductive fitness of a population in the environments where it lives. The process of evolution can also be said to be teleological in that it has the potentiality of producing end-directed **DNA** codes of information, and has in fact resulted in teleologically

oriented structures, patterns of behavior, and regulated mechanisms.

To me this seems a serious misinterpretation. If teleological means anything, it means *goal-directed.* Yet, natural selection is strictly an a posteriori process which rewards current success but never sets up future goals. No one realized this better than Darwin, who reminded himself "never to use the words higher or lower." Natural selection rewards past events, that is the production of successful recombinations of genes, but it does not plan for the future. This is, precisely, what gives evolution by natural selection its flexibility. With the environment changing incessantly, natural selection—in contradistinction to orthogenesis—never commits itself to a future goal. Natural selection is never goal oriented. It is misleading and quite inadmissible to designate such broadly generalized concepts as survival or reproductive success as definite and specified goals.

The same objection can be raised against similar arguments presented by Waddington (1968:55-56). Like so many other developmental biologists, he is forever looking for analogies between ontogeny and evolution. "I have for some years been urging that quasi-finalistic types of explanations are called for in the theory of evolution as well as in that of development." Natural selection "in itself suffices to determine, to a certain degree, the nature of the end towards which evolution wilt proceed, it must result in an increase in the efficiency of the biosystem as a whole in finding ways of reproducing itself." He refers here to completely generalized processes, rather than to specific goals. It is rather easy to demonstrate how ludicrous the conclusions are which one reaches by over-extending the concept of goal-direction. For instance, one might say that it is the purpose of every individual to die because this is the end of every individual, or that it is the goal of every evolutionary line to become extinct because this is what has happened to 99.9% of all evolutionary lines that have ever existed. Indeed, one would be forced to consider as teleological even the second law of thermodynamics.

One of Darwin's greatest contributions was to make it clear that teleonomic processes involving only a single individual are of an entirely different nature from evolutionary changes. The latter are controlled by the interplay of the production of variants (new genotypes) and their sorting out by natural selection, a process which is quite decidedly not directed toward a specified distant end. A discussion of legitimately teleological phenomena would be futile unless evolutionary processes are eliminated from consideration.

SEEMINGLY OR GENUINELY GOAL-DIRECTED PROCESSES

Nature (organic and inanimate) abounds in processes and activities that lead to an end. Some authors seem to believe that all such terminating processes are of one kind and "finalistic" in the same manner and to the same degree. Taylor (1950), for instance, if I understand him correctly, claims that all forms of active behavior are of the same kind and that there is no fundamental difference between one kind of movement or purposive action and any other. Waddington (1968) gives a definition of his term *quasi-finalistic* as requiring "that the end state of the process is determined by its properties at the beginning."

Further study indicates, however, that the class of end-directed processes is composed of two entirely different kinds of phenomena. These two types of phenomena may be

characterized as follows:

Teleomatic processes in inanimate nature. Many movements of inanimate objects as well as physicochemical processes are the simple consequences of natural laws. For instance, gravity provides the end-state for a rock which I drop into a well. It will reach its end-state when it has come to rest on the bottom. A red-hot piece of iron reaches its end-state when its temperature and that of its environment are equal. All objects of the physical world are endowed with the capacity to change their state, and these changes follow natural laws. They are end-directed only in a passive, automatic way, regulated by external forces or conditions. Since the end-state of such inanimate objects is automatically achieved, such changes might be designated as *teleomatic.* 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 a falling stone hitting the ground). Teleomatic processes simply follow natural laws, i.e. lead to a result consequential to concomitant physical forces, and the reaching of their end-state is not controlled by a built-in program. The law of gravity and the second law of thermodynamics are among the natural laws which most frequently govern teleomatic processes.

Teleonomic processes in living nature. Seemingly goal-directed behavior in organisms is of an entirely different nature from teleomatic processes. Goal-directed *behavior* (in the widest sense of this word) is extremely widespread in the organic world; for instance, most activity connected with migration, food-getting, courtship, ontogeny, and all phases of reproduction is characterized by such goal orientation. The occurrence of goal-directed processes is perhaps the most characteristic feature of the world of living organisms.

For the last 15 years or so the term *teleonomic* has been used increasingly often for goal-directed processes in organisms. I proposed in 1961 the following definition for this term: "It would seem useful to restrict the term teleonomic rigidly to systems operating on the basis of a program, a code of information" (Mayr 1961). Although I used the term *system* in this definition, I have since become convinced that it permits a better operational definition to consider certain activities, processes (like growth), and active behaviors as the most characteristic illustrations of teleonomic phenomena. I therefore modify my definition, as follows: A *teleonomic process or behavior is one which owes its goal-directedness to the operation of a program.* The term teleonomic implies goal direction. This, in turn, implies a dynamic process rather than a static condition, as represented by a system. The combination of teleonomic with the term system is, thus, rather incongruent (see below).

All teleonomic behavior is characterized by two components. It is guided by a "program," and it depends on the existence of some endpoint, goal, or terminus which is foreseen in the program that regulates the behavior. This endpoint might be a structure, a physiological function, the attainment of a new geographical position, or a "consummatory" (Craig 1918) act in behavior. Each particular program is the result of natural selection, constantly adjusted by the selective value of the achieved end-point.

My definition of *teleonomic* has been labeled by Hull (1973) as a "historical definition." Such a designation is rather misleading. Although the genetic program (as well as its individually acquired component's) originated in the past, this history is completely irrelevant

for the functional analysis of a given teleonomic processes. For this it is entirely sufficient to know that a "program" exists which is causally responsible for the teleonomic nature of a goal-directed process. Whether this program had originated through a lucky macromutation (as Richard Goldschmidt had conceived possible) or through a slow process of gradual selection, or even through individual learning or conditioning as in open programs, is quite immaterial for the classification of a process as "teleonomic." On the other hand, a process that does not have a programmed end does not qualify to be designated as teleonomic (see below for a discussion of the concept *program).*

All teleonomic processes are facilitated by specifically selected executive structures. The fleeing of a deer from a predatory carnivore is facilitated by the existence of superlative sense organs and the proper development of muscles and other components of the locomotory apparatus. The proper performing of teleonomic processes at the molecular level is made possible by highly specific properties of complex macromolecules. It would stultify the definition of *teleonomic* if the appropriateness of these facilitating executive structures were made part of it. On the other hand, it is in the nature of a teleonomic program that it does not induce a simple unfolding of some completely preformed gestalt, but that it always controls a more or less complex process which 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. There exist innumerable feedback devices to prevent this or to correct it. Waddington (1957) has quite rightly called attention to the frequency and importance of such homeostatic devices which virtually guarantee the appropriate canalization of development.

We owe a great debt of gratitude to Rosenblueth et al. (1943) for their endeavor to find a new solution for the explanation of teleological phenomena in organisms. They correctly identified two aspects of such phenomena: (1) that they are seemingly purposeful, being directed toward a goal, and (2) that they consist of active behavior. The background of these authors was in the newly developing field of cybernetics, and it is only natural that they should have stressed the fact that goal-directed behavior is characterized by mechanisms which correct errors committed during the goal seeking. They considered the negative feedback loops of such behavior as its most characteristic aspect and stated "teleological behavior thus becomes synonymous with behavior controlled by negative feedback." This statement emphasizes important aspects of teleological behavior, yet it misses the crucial point: *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.* It is not the thermostat which determines the temperature of a house, but the person who sets the thermostat. It is not the torpedo which determines toward what ship it will be shot and at what time, but the naval officer who releases the torpedo. Negative feedback only improves the precision of goal-seeking, but does not determine it. Feedback devices are only executive mechanisms that operate during the translation of a program.

Therefore it places the emphasis on the wrong point to define teleonomic processes in terms of the presence of feedback devices. They are mediators of the program, but as far as the basic

principle of goal achievement is concerned, they are of minor consequence.

Recent usages of the term teleonomic.

The term *teleonomic* was introduced into the literature by Pittendrigh (1958:394) in the following paragraph:

> Today the concept of adaptation is beginning to enjoy an improved respectability for several reasons: it is seen as less than perfect; natural selection is better understood; and the engineer-physicist in building end-seeking automata has sanctified the use of teleological jargon. It seems unfortunate that the term 'teleology' should be resurrected and, as I think, abused in this way. 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 [sic] causal principle.

It is evident that Pittendrigh had the same phenomena in mind as I do,[1] even though his definition is rather vague and his placing the term *teleonomic* in opposition to Aristotle's *teleology* is unfortunate. As we shall see below, most of Aristotle's references to end-directed processes refer precisely to the same things which Pittendrigh and I would call teleonomic (see also Delbriick 1971; Gotthelf 1976).

Other recent usages of the term that differ from my own definition are the following. B. Davis (1961), believing that the term denotes "the development of valuable structures and mechanisms" as a result of natural selection, uses the term virtually as synonymous with adaptiveness. The, same is largely true for Simpson (1958:520-521), who sees in *teleonomic* the description for a system or structure which is the product of evolution and of selective advantage:

> The words 'finalistic' and ‘teleological' have, however, had an unfortunate history in philosophy which makes them totally unsuitable for use in modern biology. They have too often been used to mean that evolution as a whole has a predetermined goal, or that the utility of organization in general is with respect to man or to some supernatural scheme of things. Thus these terms may implicitly negate rather than express the biological conclusion that organization in organisms is with respect to utility to each separate species at the time when it occurs, and not with respect to any other species or any future time. In emphasis of this point of view, Pittendrigh [above] suggests that the new coinage 'teleonomy' be substituted for the debased currency of teleology.

Monod (1971) likewise deals with teleonomy as if the word simply meant adaptation. It is not surprising therefore that Monod considers teleonomy "to be a profoundly ambiguous concept." Furthermore, says Monod, all functional adaptations are "so many aspects or fragments of a unique primary project which is the preservation and multiplication of the

species." He finally completes the confusion by choosing "to define the essential teleonomic project as consisting in the transmission from generation to generation of the invariance content characteristic of the species. All these structures, all the performances, all the activities contributing to the success of the essential project will hence be called teleonomic."

What Monod calls "teleonomic" I would designate as of "selective value." Under these circumstances it is not surprising when Ayala (1970) claims that the term *teleonomy* had been introduced into the philosophical literature in order "to explain adaptation in nature as the result of natural selection." If this were indeed true, and it is true of Simpson's and Davis's cited definitions, the term would be quite unnecessary. Actually, there is nothing in my 1961 account which would support this interpretation, and I know of no other term that would define a goal-directed activity or behavior that is controlled by a program. Even though Pittendrigh's discussion of *teleonomic* rather confused the issue and has led to the subsequent misinterpretations, he evidently had in mind the same processes and phenomena which I denoted as *teleonomic.* It would seem well worthwhile to retain the term in the more rigorous definition, which I have now given.

The Meaning of the Word "Program"

The key word in my definition of *teleonomic* is *program.* Someone might claim that the difficulties of an acceptable definition for teleological language in biology had simply been transferred to the term *program.* This is not a legitimate objection, because it fails to recognize that, regardless of its particular definition, a program is (1) something material, and (2) it exists prior to the initiation of the teleonomic process. Hence, it is consistent with a causal explanation.

Nevertheless, it must be admitted that the concept of a program is so new that the diversity of meanings of the term has not yet been fully explored. The term is taken from the language of information theory. A computer may act purposefully when given appropriate programmed instructions. Tentatively, *program* might be defined as *coded or prearranged information that controls a process (or behavior) leading it toward a given end. As* Raven (1960) has remarked correctly, the program contains not only the blueprint but also the instructions of how to use the information of the blueprint. In the case of a computer program or of the DNA of the cell nucleus, the program is completely separated from the executive machinery. In the case of most man-made automata, the program is part of the total machinery.

My definition of program is deliberately chosen in such a way as to avoid drawing a line between seemingly "purposive" behavior in organisms and in man-made machines. The simplest program is perhaps the weight inserted into loaded dice or attached to a "fixed" number wheel so that they are likely to come to rest at a given number. A clock is constructed and programmed in such a way as to strike at the full hour. Any machine which is programmed to carry out goal-directed activities is capable of doing this "mechanically."

The programs which control teleonomic processes in organisms are either entirely laid down in the DNA of the genotype (closed programs) or are constituted in such a way that they can incorporate additional information (open programs) (Mayr 1964), acquired through

learning, conditioning, or other experiences. Most behavior, particularly in higher organisms, is controlled by such open programs.

Open programs are particularly suitable to demonstrate the fact that the mode of acquisition of a program is an entirely different matter from the teleonomic nature of the behavior controlled by the program. Nothing could be more purposive, more teleonomic than much of the escape behavior in many prey species (in birds and mammals). Yet, in many cases the knowledge of which animals are dangerous predators is learned by the young who have an open program for this type of information. In other words, this particular information was not acquired through selection and yet it is clearly in part responsible for teleonomic behavior. Many of the teleonomic components of the reproductive behavior (including mate selection) of species which are imprinted for mate recognition is likewise only partially the result of selection. The history of the acquisition of a program, therefore, cannot be made part of the definition of teleonomic.

The origin of a program is quite irrelevant for the definition. It can be the product of evolution, as are all genetic programs, or it can be the acquired information of an open program, or it can be a man-made device. Anything that does *not* lead to what is at least in principle a predictable goal does not qualify as a program. Even though its current gene pool sets severe limits on a species' future evolution, the course of that evolution is largely controlled by the changing constellation of selection pressures and is therefore not predictable. It is not programmed inside the contemporary gene pool.

The entire concept of a program of information is so new that it has received little attention from philosophers and logicians. My tentative analysis may, therefore, require considerable revision when subjected to further scrutiny.

HOW DOES THE PROGRAM OPERATE?

The philosopher may be willing to accept the assertion of the biologist that a program directs a given teleonomic behavior, but he would also like to know how the program performs this function. Alas, all the biologist can tell him is that the study of the operation of programs is the most difficult area of biology. For instance, the translation of the genetic program into growth processes and into the differentiation of cells, tissues, and organs is at the present time the most challenging problem of developmental biology. The number of qualitatively different cells in a higher organism surely exceeds one billion. Even though all (or most) have the same gene complement, they differ from each other owing to differences in the repression and derepression of individual gene loci and owing to differences in their cellular environment. It hardly needs stressing how complex the genetic program must be, to be able to give the appropriate signals to each cell lineage in order to provide it with the mixture of molecules which it needs to carry out its assigned tasks.

Similar problems arise in the analysis of goal-directed behavior. The number of ways in which a program may control a goal-directed behavior activity is legion. It differs from species to species. Sometimes the program is largely acquired by experience; in other cases it may be almost completely genetically fixed. Sometimes the behavior consists of a series of steps, each of which serves as reinforcement for the ensuing steps; in other cases the behavior,

once initiated, seems to run its full course without need for any further input. Feedback loops are sometimes important, but their presence cannot be demonstrated in other kinds of behavior. Again, as in developmental biology, much of the contemporary research in behavioral biology is devoted to the nature and the operation of the programs which control behavior and more specifically teleonomic behavior sequences (Hinde and Stevenson 1970). Almost any statement one might make is apt to be challenged by one or the other school of psychologists and geneticists. It is, however, safe to state that the translation of programs into telenomic behavior is greatly affected both by sensory inputs and by internal physiological (largely hormonal) states.

Teleological Systems

The word *teleological,* in the philosophical literature, is particularly offer combined with the term *system.* Is it justified to speak *of teleological systems?* Analysis shows that this combination leads to definitional difficulties.

The Greek word *telos* means end or goal. Teleological means end-directed. To apply the word *teleological* to a goal-directed behavior or process would seem quite legitimate. I am perhaps a purist, but it bothers me to apply the word teleological, that is *end-directed,* to a stationary system. Any phenomenon to which we can refer as teleomatic or teleonomic represents a movement, a behavior, or a process that is goal-directed by having a determinable end. This is the core concept of teleological, the presence of a *telos* (an end) toward which an object or process moves. Rosenblueth et al. (1943) have correctly stressed the same point.

Extending the term teleological to cover also static systems leads to contradictions and illogicalities. A torpedo that has been shot off and moves toward its target is a machine showing teleonomic behavior. But what justifies calling a torpedo a teleological system when, with hundreds of others, it is stored in an ordnance depot? Why should the eye of a sleeping person be called a teleological system? It is not goal-directed al anything. Part of the confusion is due to the fact that the term *teleological* system has been applied to two only partially overlapping phenomena. One comprises systems that are potentially able to perform teleonomic actions, like a torpedo. The other comprises systems that are well adapted; like the eye. To refer to a phenomenon in this second class as teleological; in order to express its adaptive perfection, reflects just enough of the ok idea of evolution leading to a steady progression in adaptation and perfection to make me uneasy. What is the telos toward which the teleological system moves?

The source of the conflict seems to be that goal-directed, in a more or less straightforward literal sense, is not necessarily the same as purposive. Completely stationary systems can be functional or purposive, but the) cannot be goal-directed in any literal sense. A poison on the shelf has the potential of killing somebody, but this inherent property does not make it a goal-directed object. Perhaps this difficulty can be resolved by making a terminological distinction between functional properties of systems and strict goal-directedness, that is, teleonomy of behavioral or other processes. However, since one will be using so-called teleological language in both cases, one might subsume both categories under teleology.

R. Munson (1971) has recently dealt with such adaptive systems. In particular, he studied all those explanations that deal with aspects of adaptation but are often called *teleological.* He designates sentences "adaptational sentences," when they contain the terms *adaptation, adaptive,* or *adapted.* In agreement with the majority opinion of biologists, he concludes that "adaptational sentences do not need [to] involve reference to any purpose, final cause, or other non-empirical notion in order to be meaningful." Adaptational sentences simply express the conclusion that a given trait, whether structural, physiological, or behavioral, is the product of the process of natural selection and thus favors the perpetuation of the genotype responsible for this trait. Furthermore, adaptation is a heuristic concept because it demands an answer to the question in what way the trait adds to the probability of survival and does so more successfully than an alternate conceivable trait. To me, it is misleading to call adaptational statements teleological. “Adapted” is an *a posteriori* statement and it is only the success (statistically speaking) of the owner of an adaptive trait which proves whether the trait is truly adaptive *(=* contributes to survival) or is not. Munson summarizes the utility of adaptational language in the sentence: "To show that a trait is adaptive is to present a phenomenon requiring explanation, and to provide the explanation is to display the success of the trait as the outcome of selection" (p. 214). The biologist fully agrees with this conclusion. Adaptive means simply: being the result of natural selection.

Many adaptive systems—for instance, all components of the locomotory and the central nervous systems—are capable of taking part in teleonomic processes or teleonomic behavior. However, it only obscures the issue when one designates a system teleological or teleonomic because it provides executive structures of a teleonomic process. Is an inactive, not-programmed computer a teleological system? What "goal" or "end" is it displaying during this period of inactivity? To repeat, one runs into serious logical difficulties when one applies the term *teleological to* static systems (regardless of their potential) instead of to processes. Nothing is lost and much is to be gained by not using the term teleological too freely and for too many rather diverse phenomena.

It may be necessary to coin a new term for systems which have the potential of displaying teleonomic behavior. The problem is particularly acute for biological organs which are capable of carrying out useful functions, such as pumping by the heart or filtration by the kidney. To some extent this problem exists for any organic structure, all the way down to the macromolecules which are capable of carrying out autonomously certain highly specific functions owing to their uniquely specific structure. It is this which induced Monod (1971) to call them teleonomic systems. Similar considerations have induced some authors, erroneously in my opinion, to designate a hammer as a teleological system, because it is designed to hit a nail (a rock, not having been so designed, but serving the same function not qualifying!).

The philosophical complexity of the logical definition of *teleological* in living systems is obvious. Let me consider a few of the proximate and ultimate causes (Mayr 1961), to bring out some of the difficulties more clearly. The functioning of these systems is the subject matter of regulatory biology, which analyzes proximate causes. Biological systems are complicated steady-state systems, replete with feedback devices. There is a high premium on homeostasis, on the maintenance of the *milieu interieur.* Since most of the processes

performed by these systems are programmed, it is legitimate to call them teleonomic processes. They are "end-directed" even though very often the "end" is the maintenance of the status quo. There is nothing metaphysical in any of this because, so far as these processes are accessible to analysis, they represent chains of causally interrelated stimuli and reactions, of inputs and of outputs.

The ultimate causes for the efficiency and seeming purposefulness of these living systems were explained by Darwin in 1859. The adaptiveness of these systems is the result of millions of generations of natural selection. This is the mechanistic explanation of adaptiveness, as was clearly stated by Sigwart (1881).

Proximate and ultimate causes must be carefully separated in the discussion of teleological systems (Mayr 1961). A system is capable of performing teleonomic processes because it was programmed to function in this manner. The origin of the program that is responsible for the adaptiveness of the system is an entirely independent matter. It obscures definitions to combine current functioning and history of origin in a single explanation.

The Heuristic Nature of Teleonomic Language

Teleological language has been employed in the past in many different senses, some of them legitimate and some of them not. When the distinctions outlined in my survey above are made, the teleological *Frages-tellung* is a most powerful tool in biological analysis. Its heuristic value was appreciated already by Aristotle and Galen, but neither of them fully understood why this approach is so important. Questions which begin with "What?" and "How?" are sufficient for explanation in the physical sciences. In the biological sciences no explanation is complete until a third kind of question has been asked: "Why?" It is Darwin's evolutionary theory which necessitates this question: No feature (or behavioral program) of an organism ordinarily evolves unless this is favored by natural selection. It must play a role in the survival or in the reproductive success of its bearer. Accepting this premise, it is necessary for the completion of causal analysis to ask for any feature, why it exists, that is, what its function and role in the life of the particular organism is.

The philosopher Sigwart (1881) recognized this clearly:

> A teleological analysis implies the demand to follow up causations in all directions by which the purpose [of a structure or behavior] is effected. It represents a heuristic principle because when one assumes that each organism is well adapted it requires that we ask about the operation of each individual part and that we determine the meaning of its form, its structure, and its chemical characteristics. At the same time it leads to an explanation of correlated subsidiary consequences which are not necessarily part of the same purpose but which are inevitable by-products of the same goal-directed process.

The method, of course, was used successfully long before Darwin. It was Harvey's question concerning the reason for the existence of valves in the veins that made a major, if not the most important, contribution to his model of the circulation of blood. The observation that

during mitosis the chromatic material is arranged in a single linear thread led Roux (1883) to question why such an elaborate process had evolved rather than a simple division of the nucleus into two halves. He concluded that the elaborate process made sense only if the chromatin consisted of an enormous number of qualitatively different small particles and that their equal division could be guaranteed only by lining them up linearly. The genetic analyses of chromosomal inheritance during the next sixty years were, in a sense, only footnotes to Roux's brilliant hypothesis. These cases demonstrate most convincingly the enormous heuristic value of the teleonomic approach. It is no exaggeration to claim that most of the greatest advances in biology were made possible by asking "Why?" questions. This demands asking for the *selective* significance of every aspect of the phenotype. The former idea that many if not most characters of organisms are "neutral," that is, that is, that they evolved simply as accidents of evolution, has been refuted again and again by more detailed analysis. It is the question as to the “why?” of such structures and behaviors that initiates such analysis. Students of behavior have used this approach in recent years with great success. It has, for example, led to questions concerning the information content of individual vocal and visual displays (Smith 1969; Hinde 1972).

As soon as one accepts the simple conclusion that the totality of the genotype is the result of past selection, and that the phenotype is a product of the genotype (except for the open portions of the program that are filled in during the lifetime of the individual), it becomes one’s task to ask about any and every component of the phenotype what its particular functions and selective advantages are.

It is now quite evident why all past efforts to translate teleonomic statements into purely causal ones were such a failure: A crucial portion of the message of a teleological sentence is invariably lost in the translation. Let us take, for instance the sentence: "The Wood Thrush migrates in the fall into warmer countries *in order to* escape the inclemency of the weather and the food shortages of the northern climates." If we replace the words "in order to" by "and thereby," we leave the important question unanswered as to *why* the Wood Thrush migrates. The teleonomic form of the statement implies that the goal-directed migratory activity is governed by a program. By omitting this important message, the translated sentence is greatly impoverished as far as information content is concerned, without gaining in causal strength. The majority of modern philosophers are fully aware of this and agree that "cleaned-up" sentences are not equivalent to the teleological sentences from which they were derived (Ayala 1970; Beckner 1969).

One can go a step further. Teleonomic statements have often been maligned as stultifying and obscurantist. This is simply not true. Actually, the nonteleological translation is invariably a meaningless platitude, while it is the teleonomic statement which leads to biologically interesting inquiries. …

From the time of the Greek philosophers until the middle of the last century, a controversy existed between a teleological and a purely causal mechanical explanation of the world.

Sometimes one, sometimes the other, of these two views seemed to be victorious. Or else one could deal with the problem as was done by Kant and be a strict mechanist with respect to inanimate nature but a teleologist in the treatment of the world of life. One of the reasons why Darwin was attacked so vigorously was that his theory of seIection made a belief in cosmic teleology unnecessary. It was their unshakable belief in teleology that induced Karl Ernst von Baer and other of Darwin's contemporaries to attack the theory of selection so temperamentally. Indeed, the belief in a teleological force in nature was so firmly anchored in the thinking of many that even among the evolutionists this belief had more followers in the first 80 years after 1859 than did Darwin's theory of selection.

As Max Delbruck has emphasized so rightly, teleonomic and adaptational phenornena have a history and cannot be explained directly through a strictly causal mechanical explanation, as is possible for processes in inanimate nature.

Conclusions

(1) The use of so-called teleological language by biologists is legitimate; it neither implies a rejection of physicochemical explanation nor does it imply noncausal explanation.

(2) The terms *teleology* and *teleological* have been applied to highly diverse phenomena. An attempt is made by the author to group these into more or less homogeneous classes.

(3) It is illegitimate to describe evolutionary processes or trends as goal-directed (teleological). Selection rewards past phenomena (mutation, recombination, etc.), but does not plan for the future, at least not in any specific way.

(4) Processes (behavior) whose goal-directedness is controlled by a program may be referred to as *teleonomic.*

(5) Processes which reach an end state caused by natural laws (e.g., gravity, first law of thermodynamics) but not by a program may be designated as *teleomatic.*

(6) Programs are in part or entirely the product of natural selection.

(7) The question of the legitimacy of applying the term *teleological* ***to*** stationary functional or adaptive systems requires further analysis.

(8) Teleonomic (that is, programmed) behavior occurs only in organisms (and man-made machines) and constitutes a clear-cut difference between the levels of complexity in living and in inanimate nature.

(9) Teleonomic explanations are strictly causal and mechanistic. They give no comfort to adherents of vitalistic concepts.

(10) The heuristic value of the teleological makes it a powerful tool in biological analysis, from the study of the structural configuration of macromolecules up to the study of cooperative behavior in social systems.

POSTSCRIPT

There have been numerous developments in the analysis of the meaning of *teleological* since this essay was first published (1974). I will not deal with all those papers and books in the purely philosophical literature in which the four meanings of teleological are still merrily intermingled. Instead, I will call attention to two aspects of the problem which require comment.

Aristotle has been traditionally misinterpreted as a cosmic teleologist. Modern students of Aristotle are in agreement that he was not (Gotthelf 1976; Nussbaum 1978; Sorabji 1980; Balrne 1981). As already understood by Delbruck (1971), Aristotle's concept of the *eidos,* in the context of ontogenetic development, is in some respects remarkably similar to the modern concept of the genetic program. What the standard histories of philosophy write about Aristotle's teleology is unfortunately largely wrong, and must be ignored. I myself misinterpreted Aristotle before I became acquainted with the modern literature.

The other aspect to be discussed is the reaction of one philosopher to my use of the concept *program, in* 1977 the late Ernest Nagel, distinguished philosopher at Columbia University, published an essay "Teleology revisited: goal directed processes in biology," the first part of which consisted of a rather adverse critique of my treatment of teleology.

Not surprisingly, Nagel questioned particularly those of my proposals that he considered to be in conflict with the logical-positivist tradition. This is not the place for a detailed analysis of Nagel’s propositions and criticisms, particularly since we both agree in a total rejection of cosmic teleology and of non-empirical explanations. He is worried about the predictability of teleonomic explanations and about the logical structure of sentences as used by evolutionary biologists. Most of all, however, Nagel, who was perhaps the most consistent reductionist among recent philosophers, is critical of the concept *program.* He finds my definition of program unacceptable, because historically evolved genetic programs do not exist in the inanimate world. Their recognition would automatically concede that not all biological phenomena can be reduced (without residue) to physical processes.

In order to invalidate the claim that programs, as defined by me, are a special property of the world of life, Nagel attempts to demonstrate the existence of programs in the inanimate world. He suggests that the radioactive decay of a chunk of uranium could be considered also to be controlled by a program. This claim is simply wrong. Radioactive decay is controlled by laws and not by any particular program; it obeys the same laws any time anywhere. Programs are highly specific and often unique. The importance of the concept *program* is increasingly being recognized. I refer in particular to Beniger (1986).

The objective of my own analysis (see above) had been to show that such a heterogeneous aggregate of phenomena as was discussed by philosophers under the label "teleological" could never be elucidated simply by logical analysis, as had been tried by so many philosophers (including Nagel 1961). The first step in my analysis had been to sort these phenomena and processes into homogeneous classes. 1 recognized four of such classes, three

of which have a sound empirical basis. By contrast, there is no evidence for the existence of a fourth class, cosmic teleology, as had already been shown by Darwin (see Essay 14). One further class, that of teleomatic processes (see above), is of no special interest to philosophers of biology.

Nagel agrees with the biologist that this leaves two classes of phenomena in the biological realm to which the term *teleological* has been applied: *goal-directed activities,* called by me teleonomic, and *functional activities* of organs or structures, called by me the activities of adapted systems. Unfortunately, in his account, he frequently confounds the two, leaving him at times greatly puzzled. He refers to the "goal" of certain endocrine tissues co maintain levels of blood sugar, and to the "function" of the kidneys to eliminate waste products from the blood.

Actually, the two processes are equivalent, and endocrine tissues, being "systems," have no goal. In his account of the goal of a rabbit's flight from a hound, he gets hopelessly entangled and winds up with the statement: "Survival itself ' does not appear to have any function." This ignores that in the genetic as well as somatic program of rabbits, numerous subprograms exist dealing with predator thwarting. And if these did not have any survival value their origin would not have been favored by natural selection.

Nagel's arguments are largely based on the principles of the "received view." He is reluctant to accept programs until they are fully reduced to "the components and structures of DNA molecules." For him, as logician, it is, for instance, apparently important whether or not the words *goal-directed* occur in the explanation. He is trying by every means to avoid the adoption of the *concept program* because through such an avoidance "explanations of goal-directed processes in biology are in principle possible, whose structure is like the structure of explanations in the physical sciences in which teleological notions have no place." In other words, Nagel would translate the sentence, "The turtle swims to the shore to lay her eggs" into the sentence, "The turtle swims to the shore and lays her eggs." Then, we would be back precisely to the point where Pittendrigh (1958) found himself when he introduced the term *teleonomic* in order to restore meaning to a biologically meaningless sentence.

In the end Nagel, ruefully but honestly, comes to the conclusion that "none of these conclusions concerning the character of explanations of goal and function ascriptions shows that the laws and theories of biology are reducible to those of the physical sciences" (p. 300). He also agrees with the nonvitalistic biologists, from Aristotle to the present, "that teleological concepts and teleological explanations [except cosmic teleology—E.M.] do not constitute a species of intellectual constructions that are inherently obscure and should therefore be regarded with suspicion" (p. 301).

There has been one recent development in my thinking that might facilitate a certain degree of rapproachment between the traditional philosopher and the modern evolutionary biologist. It deals with the properties of programs. I recognized two kinds of programs, *closed ones* that are entirely coded in the DNA of the genotype, and *open programs* that can incorporate additional information. Although this is a useful classification for certain purposes, particularly for the discrimination between innate and learned behaviors, it fails to meet the

needs of many explanations in developmental biology. Here, it is more informative to speak *genetic* and *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.

All adapted systems of an organism can be considered to be somatic programs. If this were accepted, then one could call the functional activities of adapted systems teleonomic activities.

The recognition of somatic programs is important in behavioral biology, but it is even more important in developmental biology, where many larval or embryonic structures seem to serve as somatic programs for the later stages of development. This has been understood by embryologists since Kleinenberg (1886) and probably earlier. Most of the embryonic structures that have been cited as evidence for recapitulation, like the gill arches of tetrapod embryos, are presumably somatic programs. They cannot be removed by natural selection without seriously interfering with the subsequent development.

As I have said elsewhere in this volume, acceptance of the term *program* from informatics is not anthropomorphism. There is a strict equivalence of the "program" of the information theorist and the genetic and somatic programs of the biologist.

I am rather amused to notice that Nagel's rebuttal of my ideas has been cited with approval in several recent papers in philosophical journals, but not one of these philosophers descended to discuss or even list the paper of the biologist whom Nagel had criticized.

NOTES

This essay is adapted from a paper which first appeared in *Boston Studies in the Philosophy of Science* under the title "'Ideological and teleonomic: a new analysis."

1. This is quite evident from the following explanatory comment I have received from Professor Pittendrigh by letter (dated February 26, 1970):

> You ask about the word 'teleonomy'. You are correct that I did introduce the term into biology and, moreover, I invented it. In the course of thinking about that paper which I wrote for the Simpson and Roe book (in which the term is introduced) I was haunted by the famous old quip of Haldane's to the effect that 'Teleology is like a mistress to a biologist: he cannot live without her but he's unwilling to be seen with her in public'. The more I thought about that, it occurred to me that the whole thing was nonsense—that what it was the biologist couldn't live with was not the illegitimacy of the relationship, but the relationship itself. Teleology in its Aristotelian form has, of course, the end as immediate, 'efficient', cause. And that is precisely what the biologist (with the whole history of science since 1500 behind him) cannot accept: it is unacceptable in a world that is always mechanistic (and of course in this I include probabilistic as well as strictly deterministic). What it was the biologist could not

escape was the plain fact—or rather the fundamental fact—which he must (as scientist) explain: that the objects of biological analysis are organizations (he calls them organism and, as such, are end-directed. Organization is more than mere order; order lacks end-directedness; organization *is* end-directed. [I recall a wonderful conversation with John von Neumann in which we explored the difference between 'mere order' and 'organization' and *his* insistence (I already believed it) that the concept of organization (as contextually defined in its everyday use) always involves 'purpose' or end-directedness.]

I wanted a word that would allow me (all of us biologists) to describe, stress or simply to allude to—without offense—this end-directedness of a perfect respectable mechanistic system. Teleology would not do, carrying with it the implication that the end is causally effective in the current operation of t machine. Teleonomic, it is hoped, escapes that plain falsity which is anyhow unnecessary. Haldane was, in this sense wrong (surely a rare event): we can live without teleology.

The crux of the problem lies of course in unconfounding the mechanism evolutionary change and the physiological mechanism of the organism abstract from the evolutionary time scale. The most general of all biological 'ends', 'purposes' is of course perpetuation by reproduction. *That* end [and all subsidiary 'ends' of feeding, defense and survival generally] is in some ser effective in causing natural selection; in causing evolutionary change; but not causing itself. In brief, we have failed in the past to unconfound causation the historial origins of a system and causation in the contemporary working the system. ....

You ask in your letter whether or not one of the 'information' people didn’t introduce it. They did not, unless you wish to call me an information bloke. It is, however, true that my own thinking about the whole thing was very significantly affected by a paper which was published by Wiener and Bigelow with the intriguing title 'Purposeful machines'. This pointed out that in the then newly-emerging computer period it was possible to design and build machines that had ends or purposes without implying that the purposes were the cause the immediate operation of the machine.

2. For more recent treatments of Aristotle's teleology, see Nussbaum (1978); Sorabji (1980); Baime (1980); and, most of all, Gotthelf (1976).