Faith and Thought

A Journal devoted to the study of the inter-relation of the Christian revelation and modern research

Vol. 97 Number 3 Summer 1969

GORDON E. BARNES, M.A.

The Nature of Explanation in Biology

Biology

Biology has been variously defined; and probably no definition is completely satisfactory. But the popular, and short, description of this discipline as the Science of Life may be taken as the starting point of this discussion. The word 'science' itself means different things to different people, but biologists would insist that their science is a body of knowledge based upon, and limited by, an objective and empirical attitude to nature. It is conventional to give biology a status similar to that of the physical sciences, and to regard them all as natural sciences, as distinct from moral, social, or political sciences, in which non-objective (subjective and/or value) judgments have to be made.

If biology is an empirical study, it follows that biologists do not in fact study *life*, which is an abstraction: they study living and dead *organisms* and their constituents and products. Biology has the ultimate aim of explaining the structure and functioning of organisms in terms that permit of the widest possible generalization. This paper discusses the type of explanation which biologists employ.

Types of Descriptive Language

Any real explanation of an object or event is merely a description in terms of previous experience of other (often simpler) objects or events. The type of experience drawn upon determines the type of language employed in the explanation. Scientists generally have been very imaginative in drawing upon their past experience to develop their own descriptive languages. One can think, for example, of the use by physicists of such words as 'work', 'force', 'energy', and 'power', culled from everyday experience of society, and given a technical significance defined mathematically.

In the description of living things, several types of language have come into use, as experience in other fields has thrown light on biological problems. Among the more influential are:

(a) *Anthropomorphic language.* This is based upon obvious analogies between the behaviour of organisms and the behaviour of the human observer. It is a very ancient explanatory language; but it is still in popular use, e.g. in the statements 'the dog wants his dinner', 'he is trying to open the door', or 'he knows he should not sit on his master's chair'. In earlier periods such language was used of organisms which today would not be so described. It is well known that Wm. Paley[1] explained the cloud of jumping sand-hoppers on the sea shore as expressing feelings of joy, and saw in this behaviour a cause of thankfulness to the Creator for His beneficence to these lowly creatures. Erasmus Darwin (the grandfather of Charles) even wrote a lengthy poem on 'The Loves of the Plants'.

Such popular use of anthropomorphic language usually has psychological implications, i.e. that the organism so described has subjective experiences analogous with those of the human observer. When the biologist, however, uses anthropomorphic language (e.g. when he speaks of 'communication', or 'courtship', or 'intelligence', of animals) he is using it in a technical sense which excludes subjective aspects. He is not denying that animals have subjective experience, but merely restricting his attention, in accordance with the objective character of his science, to the overt features of the animal's behaviour which are analogous with the overt features of human behaviour.

(b) *Structure language.* This language arises from the resemblances that exist between the configuration of parts of organisms and the configuration of parts of man-made artefacts. Thus to speak of the cranium as a brain box or brain case conjures up the idea of a protective, rigid, hollow, object with a bottom, sides, and a top. Anatomical writing abounds in the use of such descriptions as 'thoracic basket', 'gastric pits', 'limb girdles', 'sacs', 'pouches', 'tissues' (tissue = something woven), 'cells', and 'sieve tubes'.

[1] Wm. Paley, *Natural Theology*, 1801.

(c) *Machine language*. The use of this language depends upon the recognition of analogies between the functioning of organs or systems and the functioning of machines. The analogies are obvious in the description of the heart as a pump, or of a bone as a lever, or of a part of the kidney as a filter. This language differs from structure language in that it involves a time factor in addition to space factors. To describe a heart as a pump involves, not only a recognition of its structure as a muscular, chambered, bag, but also an appreciation of the changes in its structure and shape with time.

(d) *Social language*. Biology uses a number of descriptive terms which normally relate to human society. Examples are 'queen', 'worker', and 'soldier', used to designate individuals playing different rôles in the organized 'colonies' of 'social' insects; animal 'populations' and plant 'communities', as used in ecology; 'dominant groups' of animals, as recognized by palaeontologists; 'genus' (= race), 'phylum' (= tribe), 'cohort', 'family', as used in taxonomy.

(e) *Information theory language*. This, the latest addition to the biologist's set of tools, is derived from the remarkable similarities between control systems in organisms and biological communities on the one hand and engineering control systems and other man-made devices for collecting, transmitting, and utilizing information on the other. Thus the principles of both digital and analogue computers are finding application in neurophysiology; while the terms 'genetic code' and 'feedback' have become commonplace.

The different languages are, of course, manifestations of different ways of thinking about organisms, of different methods of investigating organisms, and of different types of problem presented by organisms. As these investigations are pursued, sooner or later there comes a stage at which previous experience in other fields fails to provide appropriate descriptive language, and then the biologist is forced to invent an *ad hoc* terminology (e.g. the reticulo-endothelial system; mitochondria; Golgi apparatus) which conveys little or nothing to the non-biologist. Again, sooner or later in different branches of biology, the investigator finds that he needs the techniques of the chemist, the physicist, or the mathematician; and accordingly then employs the descriptive languages of chemistry, physics, or mathematics (e.g. molecules, ions, electrons, potentials, probabilities). In those circumstances, the only factor which, in principle, distinguishes the biologist from the physical scientist is the nature of the material which he is investigating.

Of the above approaches (and languages), some have proved to be much more fruitful than others: anthropomorphic and social languages have very limited uses, while structure, machine, and information theory languages have been, and promise to continue to be, of very great value. The fruitfulness of the latter group results from the facts that (a) they permit of much further analysis, and (b) they allow much broader generalizations, than the former group. It is therefore the latter group which provide the framework upon which almost the whole of modern biology is built. Thus questions of structure are the concern of classical morphology and anatomy, histology, cytology, and cytochemistry (which together may be included under the term 'structural biology'); while the machine-approach is the basis of functional morphology and anatomy, ethology, physiology, biomechanics, biochemistry, and biophysics (which may be designated 'functional biology'). It is in functional biology, also, that information theory concepts are finding application.

The structural and functional aspects of biology, which are closely related by the factor of time, may together be described as mechanistic biology.

The Validity and Applicability of Mechanistic Description

For centuries mechanistic description has been highly successful in biology. Ever since Aristotle, in the fourth century B.C., laid the foundation of the structural investigation of organisms, and Harvey, Borelli, Perrault, and others, in the seventeenth century A.D., began to investigate functional aspects of organisms, mechanistic explanation has proved its worth. It has led to innumerable broad generalizations, not only between organisms, but also between living things and non-living things. In addition it has permitted a very high degree of predictability of biological phenomena. These consequences are an adequate pragmatic validation of the mechanistic approach in biology.

But, it must be asked, is this approach universally applicable? Are all types of animate activity, and all levels of organization and complexity, explicable in principle in mechanistic terms? To these questions some, the mechanists (from Democritus and Lucretius to the present day), would give the answer yes, and others, the vitalists (from Plato and Aristotle to the present century), would give the answer no. For two millenia this was a purely philosophical debate; but during the last four centuries, science has arbitrated and finally delivered its verdict in favour of the mechanists.

This has been no easy victory: and only slowly have the discoveries of science forced vitalism to retreat from one defensive position to another, until today it has little, if any, ground left to defend. Only some of the major advances of mechanistic thought can be mentioned here.

The first was the realization by the sixteenth and seventeenth century medical men (particularly, Paracelsus and van Helmont) who were also interested in alchemy, that the human body could be regarded as having chemicals and chemical reactions within it. This chemical activity was, however, controlled by mystical or spiritual influences called *archaei*. In the seventeenth century also we find Descartes arguing that the body of a man or animal is purely material and operates mechanistically, with only one point of interaction (the pineal body) with mind. Although he spoke of the control of muscles by animal spirits, the latter were purely material factors flowing along the nerves. Then in the nineteenth century, organic chemists (led by von Liebig, who was a physiologist as well as a chemist) demonstrated that the same chemical elements, and often compounds, were present in both living and inanimate matter, and that they underwent the same types of chemical reactions. Nevertheless, the vitalists argued, only living things had the power to synthesize organic compounds. Admittedly, in 1828 Wöhler had synthesized artificial urea and Hennell artificial ethyl alcohol, both characteristic physiological products, but neither synthesis started from purely inorganic substances independent of vital activities. As time went on, further organic substances were synthesized, sometimes from naturally occurring inorganic substances; and towards the end of the century it was generally accepted that the synthesis of organic chemicals was not solely the prerogative of physiological processes. But again the vitalists had an answer. It may be possible, they said, to synthesize organic chemicals in the laboratory, but it cannot be done there as efficiently as living organisms do it: laboratory syntheses usually require high temperatures, and other special energy conditions, which organisms manage without: it seems likely therefore that vital processes are exempt from the operation of the laws of thermodynamics which govern inanimate matter. Once more, however, the vitalists' claims were refuted by scientific discoveries. At the end of last century the development of biological calorimetry by Atwater and others demonstrated that the first law of thermodynamics applied with the same rigour to physiological activity as to non-living systems. And lastly, the appreciation this century of the significance of homeostatic functions and of biochemical information storage (the genetic code) removed, in principle, those problems which were an embarrassment to the second law of thermodynamics.

Vitalism has taken many forms, represented by the concepts of *élan vital*, life force, *anima sensitiva*, *archaei*, soul, spirit, entelechy (all falling into Gilbert Ryle's category of 'the ghost-in-the-machine'); but all have, within biology, yielded to the advance of mechanism. So today, whatever the philosophical or religious views of a biologist may be, he is a mechanist in the laboratory.

But why should vitalists feel it necessary to fight a defensive action for four centuries? There must be some important aspects of life which they have been concerned to safeguard. These aspects are, in fact, (a) subjective experience (i.e. awareness, and responsibility), and (b) the directiveness of organic activities. Now these are both facts which no one would want to deny. Were the vitalists right, therefore, in denying the universal applicability of mechanistic description in biology in order to leave room for the recognition of subjective and directive aspects of life? Or can we accept that a complete description in mechanistic terms of all biological phenomena (i.e. objective aspects of life) would still permit such recognition?

Is it necessary to deny the Universal Applicability of Mechanistic Description?

In order to answer this question, it will be necessary to examine briefly the logical basis of our approach to other organisms, which ultimately depends upon the knowledge we have of ourselves.

Each one of us is apparently a unity; we think and speak in terms which imply a unity. Whatever aspect of his person a man is talking about, he still speaks of 'I' or 'me' or 'my', etc. Thus the man may say 'I am standing' and 'I am thinking': he does not normally say, or think, 'this body is standing' or 'this mind is thinking'. He may, in order to specify a part of his body or a function of his mind, say 'my finger' or 'my imagination', and thus mentally divide himself; but nevertheless the unity is still implied in the word 'my'. The principle of Occam's razor, therefore, would have us each regard himself as a unity unless there is some fact which demands another view. I know of no such fact; and believe that it is unnecessary, and therefore unwarranted scientifically, to regard myself as a 'ghost-in-a-machine'.

But, although I am a unity, I have two ways of learning about myself, one through my sensory system, and the other through introspection. The first informs me of the material or objective aspects of my being (aspects which other observers can detect as well as, or maybe better than, I can), while the second provides me with knowledge of my *psyche*, or subjective aspects of my person (aspects which other observers can judge, often extremely unreliably, only by inference from their observations of my overt behaviour). These two ways of learning about myself lead to descriptions in two different types of language: (a) the language of structure and function, and (b) the language of mind. Each language deals with an abstraction: neither is capable of giving a complete description of my activities, but the two together can give as complete a description as it is possible for me to achieve. Nevertheless, the two languages must not be confused: they are logically independent; that is, a statement in one language cannot be deduced from a statement in the other. In other words, the descriptions are complementary.

If now I turn my attention to another human being or to a member of another animal species, I have two languages available for describing the behaviour of that organism, (a) the language of structure and function, which I have earlier called mechanistic language, and (b) the language of mind, or psychological language. Both of these languages are valid as descriptive languages, but they are again complementary. This implies, therefore, that even if it were possible to give an exhaustive description in mechanistic language of another individual's behaviour, that description would not preclude another description in terms of subjective experience; and *vice versa*. So the vitalists need not have worried on this score.

Now although both of these languages are valid means of description, the biologist *qua* biologist uses only the mechanistic one – for very good reasons. He cannot observe the organism's subjective experience, and any psychological inference he may draw from its behaviour is bound to be highly speculative. It is often difficult to appreciate the subjective experience of other human beings, where there is a firm basis of analogy for psychological inferences; but the further an organism is removed in structure from man the more uncertain are any inferences concerning its *psyche*. Furthermore, such inferences cannot be tested by observation or experiment; they are therefore not part of empirical science.

If, then, it be accepted that the biologist is allowed only mechanistic description, is there any danger that his explanation of behaviour would negate responsibility? If, for example, it ever became possible to offer an exhaustive explanation of human behaviour in terms of sensory input, stored information, synaptic switching, and motor impulses, so that a man's behaviour could be completely predicted by an observer, would this imply that choice of action played no part in that man's behaviour? The answer is no: responsible action is action chosen in the light of one's knowledge and of one's appreciation of existing circumstances; we should therefore expect it to be, in principle, predictable. Thus we find two parallel and complementary descriptive languages available to explain human behaviour: 'sensory input' in one is complementary to 'appreciation of existing circumstances' in the other; 'stored information' in one to 'knowledge' in the other; 'synaptic switching' in the first to 'choice' in the second. The mechanistic language of the biologist does not therefore thwart the psychological language of the ethicist. In fact, MacKay[2] has argued that a fully-mechanistic view of man, although permitting prediction by an observer, at the same time implies freedom of choice on the part of the actor observed.

As for the directiveness of organic activities, the progress in mechanistic explanation during this century has now made vitalistic theories superfluous. The discovery of the genes and their work, recent insights into the nature of the genetic code, the concept of the cerebral engram, and the discovery of various neural and chemical feed-back mechanisms, together go far towards explaining the goal-seeking activity that vitalism was invoked to explain.

There appears then to be no good reason for denying the universal applicability of mechanistic description.

The Validity of Teleological Description in Biology

The operation of a machine may be explained in two ways, causally and teleologically. The first describes the mechanisms involved; the second the purpose of the operation. We have already seen that mechanistic description is equally valid for organic activity; but to what extent is the biologist justified in using teleological description?

In the case of a man-made machine, there may be a book of instructions issued by the manufacturer and indicating the machine's purpose; but even when no manufacturer's instructions are available we assume that an orderly-working human artefact has some purpose, although we may not know what it is. But when the biologist examines a living organism or a working part of it, whatever his personal philosophy may be,

[2] D. M. MacKay, *Freedom of Action in a Mechanistic Universe* (Eddington Memorial Lecture, 1967).

he does not, as an empirical scientist, invoke the concept of a Designer or Maker. Thus the main justification of a teleological description of a man-made machine does not apply in the biologist's description of a living organism.

But another possible reason for using teleological language stems from my own self-awareness. I know that, in my own behaviour, purposes or goals are very important controlling factors. May it not be that other organisms similarly have goals? It would be possible for an observer, by watching me carefully, to recognize at least some of the goals of my behaviour. It is conceivable that a biologist similarly could recognize, quite objectively, such goals in other organisms, without attempting to infer anything about their psychological state. To use Braithwaite's terminology, the biologist may recognize goal-directed behaviour, but not goal-intended behaviour.[3]

Now goal-directed activity is universally discernible in living systems; it is, in fact, probably the most characteristic feature of life. It can be recognized by (a) its persistence until the end-state is reached, (b) the adaptability of the routes by which the end-state is reached, and (c) the presence of negative feed-back devices stimulated by departures from the end-state. Such goal-directed activity is found, not only in the behaviour of individuals, but also at all physiological levels, and at the level of the community. Goal-directed activity, then, is a biological fact.

But what exactly does this statement mean? It could mean either that a particular activity *A always leads to* end-state *B*, or that activity *A* occurs *in order to lead to* end-state *B*. The difference can be illustrated by simple analogies. A cork, fallen into a tank of water, will bob up and down until it comes to rest at a mean position. If it is disturbed it will again oscillate until it comes to rest at the same flotation level. Similarly, a thermostatically-controlled immersion heater will switch its heating current on and off, thus tending to maintain a constant temperature of the water in the tank. Both of these mechanisms are goal-directed, but in the case of the cork we should say merely that the activity always leads to the end-state, while in the case

[3] R. B. Braithwaite, *Scientific Explanation*, 1964, ch. 10.

of the thermostat we could say that its activity is in order to produce the end-state. The difference in principle between the two systems is that one, the thermostat, has been 'programmed', while the other has not.

Now could it be said of living systems that they have been programmed in any way? If it can, then the biologist is justified in using the teleological 'in-order-to' type of description. I suggest that the theory of natural selection does offer some justification. On this theory, behavioural and physiological mechanisms have been selected in the past, and are therefore present now, because they adapt their possessors to their environments. Thus muscle cells are present in many animals, not just because these cells can contract, but because, and only because, their contraction is useful (i.e. of adaptive significance) to the animal. Now it seems to me that to say that muscle cells are present only because their contraction is useful comes very close to saying that they are present *in order to* contract. It appears to be logically equivalent to saying that the thermostat is present in the tank in order to control the temperature of the water. In this way, it may be said that natural selection 'programmes' living systems. Hence a teleological 'in-order-to' description could validly be employed by the biologist, provided it is in terms of goal-direction and not goal-intention. But, whether or not a biologist actually uses teleological descriptions in his research publications, there is little doubt that he uses teleological thinking in the planning of his research work. And it is certainly intellectually satisfying to be able to supplement a description of a piece of biological mechanism with an account of its biological significance.

Having used the word 'teleological' in the foregoing discussion, I ought to point out that this use is a departure from the traditional concept of teleology. The latter arises from the recognition of mind and purpose (either of the Creator or of man): it is concerned with goal-intention, and is independent of the notion of causality. The teleology here described is concerned solely with goal-direction, is independent of mind or purpose, and arises out of the concept of causality. For this teleology is merely a short cut obviating the use of an involved causal description. For if I say 'This muscle is here in order to impart a lateral movement to the jaw', what I am really implying is something like 'Among the ancestors of this species there occurred a mutation which changed the position of this muscle in such a way that they were better able, by lateral movements of the jaw, to masticate the available food, and therefore had a better chance of survival or a higher reproduction rate, with the result that they eventually ousted the non-mutant form, and continued until the present day to reproduce forms with the muscle arranged like this'. This is a purely causal explanation.

So, although both forms of teleology enable us to make statements about organisms in terms of a goal, they rest upon entirely different logical bases. Traditional teleology depends upon the recognition of mind, and is therefore not a part of empirical science: the teleology discussed in this paper is mechanistic, and therefore, in principle, open to experimental test. To avoid confusion, this type of teleology, which I believe has its place in biology, might be designated 'pseudoteleology'.

Conclusions

The conclusions of this paper may be summarized as follows:

(1) The most successful type of explanation in biology is that which employs mechanistic description of living systems. This type of description depends upon the recognition of the fact that the same causal laws that describe non-living matter apply equally to living matter. In those areas (e.g. physiology of the mammalian cerebral cortex) where mechanistic description has not been so successful, the difficulty apparently lies, not in the invalidity of the method of approach, but in the complexity of the explicanda.

(2) There is therefore no reason to doubt that, in principle, it may be capable of giving an exhaustive account of living things, i.e. that the structure and function of all living things may be reduced to chemical and physical principles.

(3) Such an exhaustive account, however, does not invalidate or exclude other descriptions (e.g. psychological, theological, ethical, aesthetic) of the same phenomena. But such descriptions, being non-objective, are not part of biology as an empirical natural science.

(4) Teleological descriptions may be valid: but it is important to distinguish between those (of the classical type of teleology) which are in terms of goal-intention, and which are not part of empirical science, and those (pseudoteleological) which are in terms of goal-direction and can be regarded as scientific.