

## Three Approaches to Biology: Part III. Organicism

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### *The Atomistic and Organismic Philosophies of Nature*

The atomistic philosophy of nature had become widely accepted by scientists by the latter part of the nineteenth century; and even today it is still taken for granted by most biologists. But whereas nineteenth century physics appeared to support it, twentieth century physics does not. By now it seems very improbable that the whole of nature could ever be explained from the bottom upwards in terms of ultimate, indivisible, eternal, material particles or 'atoms' (Greek: *a-tomos*, that which cannot be split).

The far-reaching changes in physics associated with the theory of relativity and the field concept were an important starting point for the new philosophy of nature developed by A. N. Whitehead in the 1920s. Although many aspects of Whitehead's philosophy were somewhat obscure, one of his ideas proved extremely influential in the development of the so-called organismic or holistic philosophy. He argued that enduring entities should be regarded not as material objects, but as *structures of activity*. He referred to the latter as *organisms*, using this term in a deliberately wide sense to include not only animals and plants, organs, tissues and cells, but also crystals, molecules, atoms and sub-atomic particles. In effect, Whitehead proposed a change from the paradigm of the machine to the paradigm of the organism in both the biological *and* the physical sciences: "Biology is the study of the larger organisms, whereas physics is the study of the smaller organisms".<sup>1</sup>

The organismic philosophy has now been advocated by many writers, including biologists, for over fifty years.<sup>9</sup> They all recognize in one way or another, the existence of hierarchically organized

natural systems which, at each level of complexity, possess properties which cannot be fully understood in terms of the properties exhibited by their parts in isolation from each other; at each level the 'whole' is more than the sum of its parts. These wholes, or organisms, are made up of parts which are themselves organisms at a lower level. Thus crystals, for example, are organisms made up of molecules, which are themselves organisms composed of atoms, which are in turn organisms whose parts are sub-atomic particles. At each level these wholes are governed by laws which are not fully reducible to the laws which govern the separated parts.

As a matter of fact, the organismic philosophy corresponds far more closely to the way in which science is actually carried out than the atomistic philosophy ever did. In the many different branches of the physical and biological sciences, scientists study systems at different levels of complexity, and in doing so use concepts appropriate to the systems they study.

In general, science has proceeded from the study of wholes to that of their parts, from the macroscopic to the microscopic, rather than the reverse. The classical laws of mechanics and optics were worked out before chemical atoms were identified, and before the electromagnetic nature of light was recognized. Magnets were known and laws of magnetic attraction and repulsion described before microscopic magnetic domains in iron and other ferromagnetic materials were found. The study of chemical compounds enabled the existence of elements and the laws of chemical combination to be inferred. This knowledge of the chemical properties of the atoms of the elements preceded the discovery that they were themselves composed of parts; a study of the properties of atomic nuclei preceded the identification of protons and neutrons; and these particles were only subsequently found to be decomposable into others, which were later found to fragment still further. In biology the anatomy of the organs was described before that of the tissues, which preceded the description of cells, which in turn preceded the discovery of organelles within them. The study of inheritance in whole organisms led to a prediction of genes; only later were these found to be located in the chromosomes; and the chemistry of the genetic material was worked out later still.

When the properties of wholes can be explained in terms of their parts, it is only because the properties of the parts have previously been explained in terms of the wholes. Electrons were not found first and then used to predict electricity; DNA was not discovered by molecular biologists and then used to predict genetical inheritance; microscopic magnetic domains were not found first and then used to predict the existence of magnets, the laws of quantum mechanics were not discovered first and then used to predict the properties of chemical compounds. And even after the properties of these lower-level systems have been discovered, the range of predictions that can be made is very limited. For example, to this day, the only chemical system that has been fully described in terms of quantum mechanics is the simplest of all, the hydrogen atom. It was, indeed, on the study of this system that much of quantum mechanics was based in the first place.

According to the organismic philosophy, just as the properties of an atom cannot be fully explained by a study of its parts in isolation, or those of a molecule by atoms, or those of a crystal by molecules, so the properties of a living cell cannot be fully explained in terms of its chemical constituents, nor those of a multicellular organism in terms of its cells. At each level of complexity, new properties emerge. Thus living organisms are not fully explicable in terms of the sciences of the inanimate. In this respect the organismic philosophy agrees with vitalism, but it goes beyond it in seeing this difference as part of the general scheme of things rather than as a unique discontinuity in nature.

### *Organismic Theories of Morphogenesis*

Vitalism had been eclipsed by the end of the 1920s, but the problems of morphogenesis remained. A number of developmental biologists, influenced by the organismic philosophy, proposed that the wholeness and goal-directedness of living organisms should be understood not in terms of vital factors, but rather in terms of *fields*.<sup>3</sup> These morphogenetic (or developmental, or embryonic) fields not only in some way controlled and directed morphogenesis, but were

also responsible for the regulation of embryonic systems after damage, and for regeneration. Thus they were considered to have a role very similar to Driesch's vital factor, entelechy (discussed in the previous article in this series).

A new concept, related to that of the morphogenetic field, was introduced by C. H. Waddington in the 1950s: the *chreode*.<sup>4</sup> He explained this in terms of his model of the 'epigenetic landscape' (Fig.). The ball represents the developing system, and its rolling downwards the process of development. An embryonic cell or tissue is initially undetermined and capable of developing in various

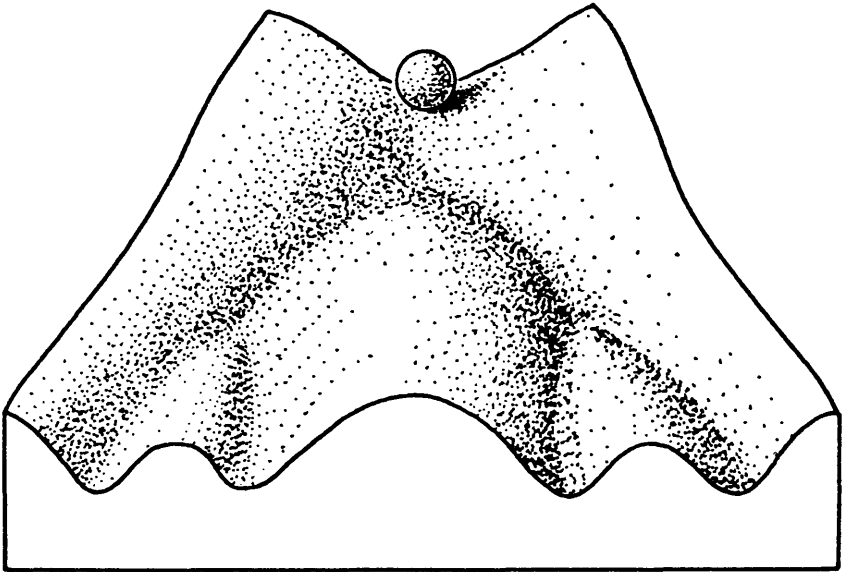


FIGURE. Part of an 'epigenetic landscape'. (After C. H. Waddington, 1957).

different ways; as embryology proceeds it becomes determined and enters into a specific developmental pathway, represented by a valley in the epigenetic landscape; this may in turn branch into further valleys, and so on. Genetic changes or environmental perturbations may push the course of development away from the valley bottom up the neighbouring hillside, but there will be a

tendency for the process to find its way back, not to the point from which it was displaced, but to some later position on the 'canalized pathway of change' from which it was diverted. This represents regulation.

These canalized pathways of change are chreodes. A chreode channels development towards a goal which it somehow contains. It thus corresponds even more closely than the concept of the morphogenetic field to Driesch's entelechy, bearing 'the end in itself'.

The main difference between these organismic concepts and Driesch's concept of entelechy was that Driesch regarded the latter as a causal factor and tried to say how it might work, whereas organicists have avoided making any such definite proposals.

Recently, the concepts of the morphogenetic field and the chreode have been developed by the mathematician René Thom as part of a comprehensive attempt to create a new mathematical formalism capable of describing morphogenesis, behaviour and language. This approach involves the construction of mathematical models in which the end or goal of a process, the final form, is represented by an 'attractor' within a morphogenetic field. Thom postulates that every object or physical form can be represented by such an attractor and that all morphogenesis "can be described by the disappearance of the attractors representing the initial forms, and their replacement by capture by the attractors representing the final forms".<sup>5</sup>

In order to develop topological models which correspond to particular morphogenetic processes, formulae are found by a combination of trial and error and inspired guess-work. If a mathematical expression gives too many solutions, restrictions have to be introduced into it; and if it is too restricted, a more generalized expression is used instead. By methods such as these Thom hopes that it should eventually be possible to develop detailed mathematical models which correspond to actual morphogenetic processes. But even so they would be essentially qualitative, and would probably not enable quantitative predictions to be made. Their main value might lie in drawing attention to formal analogies between different types of morphogenesis.<sup>6</sup>

*What are the Organismic Laws?*

One of the attractions of the organismic approach has been that it seems to provide an alternative to mechanistic reductionism, while at the same time avoiding mechanist-vitalist controversy. This is illustrated by the following statement of Waddington's, written towards the end of his career:

"Since I am an unaggressive character, and was living in an aggressively anti-metaphysical period, I chose not to expound publicly these philosophical views. An essay I wrote around 1928 on 'The Vitalist-Mechanist Controversy and the Process of Abstraction' was never published. Instead I tried to put the Whiteheadian outlook to use in particular experimental situations. So biologists uninterested in metaphysics do not notice what lies behind—though they usually react as though they feel obscurely uneasy."<sup>7</sup>

But while biologists could adopt this kind of strategy relatively unobtrusively, the explicit advocates of the organismic philosophy were more exposed to accusations of vitalism. And since vitalist theories were so commonly dismissed by mechanists as obscurantist and unscientific, most organismic theoreticians tried to avoid laying themselves open to this charge.<sup>8</sup> This is perhaps the chief reason for the vagueness and ambiguity of so much organismic writing.

However, although organicists have sought to transcend the mechanist-vitalist controversy by referring in general terms to the emergence of new laws at higher levels of complexity, the basic issue underlying this controversy has not gone away. The question remains: do these organismic laws involve any new causal factors or principles at present unrecognized by physics? If the answer is no, then it is in agreement with the assumption on which the mechanistic theory is based. This position, which is that of a number of influential organismic theoreticians,<sup>9</sup> can be described as mechanistic organicism. In so far as it states that different concepts are necessary in order to understand systems at different levels of complexity, it is in agreement with the actual practice of science, and is both unexceptionable and unsurprising.

In effect, mechanistic organicism differs so little from the straightforward mechanistic theory that it is more like a sophisticated version of the latter than an alternative to it. This is shown by the

fact that it leads to no testable predictions which differ from those of conventional mechanism.

However, there is nothing in the organismic philosophy that necessitates this adherence to presuppositions of the mechanistic theory; the question of causal factors is left open. More complex systems *may* depend only on new laws but not new causal factors: for example the understanding of a tape recorder would require a knowledge of the laws of electronics which are not required for the understanding of a simpler electromagnetic device such as an electric bell.

On the other hand, more complex systems may depend on additional causal factors which are not apparently expressed in simpler systems: for example a simple wind-up gramophone works according to purely mechanical principles, but a modern stereo system involves in addition the operation of electrical and magnetic factors. In order to understand the latter, vague notions about organismic laws would be of little help; it would first be necessary to recognize the existence of electricity and magnetism.

Similarly, the phenomena of life may involve a causal factor not so far detected in non-living systems. But whereas vitalist theories would assume that this factor was confined to the realm of life, in an organismic context this new type of causal factor would be expected to be at work not only in living organisms, but also in the inorganic realm. To return to the gramophone analogy: although the functioning of a modern stereo system depends on electricity and magnetism in a way which a wind-up gramophone does not, electromagnetism still plays a fundamental role within the latter; it is intimately involved in the atomic, molecular and crystalline structures of its components.

Vitalists proposed that a new type of causal factor, unrecognized by physics, was responsible for the ordering of morphogenesis and behaviour in living organisms. Organicists propose instead the concept of morphogenetic fields. But if this is regarded simply as a way of *talking about* the properties of physico-chemical systems, as a mere "descriptive convenience",<sup>10</sup> then it can provide little more than an ambiguous terminology. The concept of morphogenetic fields can be of value as a scientific hypothesis only if it leads to

testable predictions which differ from those of the conventional mechanistic theory. And such predictions cannot be made unless morphogenetic fields are considered to have some sort of physical existence.

### *The Hypothesis of Formative Causation*

I have recently developed a hypothesis, called the hypothesis of formative causation, which takes as its starting point the idea that morphogenetic fields are indeed physical. It is put forward in detail in a forthcoming book,<sup>11</sup> but can be summarized briefly as follows in order to illustrate the possibility of formulating a specific, testable scientific hypothesis cast within the framework of the organismic philosophy.

This hypothesis proposes that specific morphogenetic fields are responsible for the organization and form of material systems at all levels of complexity, not only in living organisms but also in crystals, molecules and atoms. These fields order the systems with which they are associated by affecting events which, from an energetic point of view, appear to be indeterminate or probabilistic; they impose patterned restrictions on the energetically possible outcomes of processes of physical change.

If morphogenetic fields are responsible for the form and organization of material systems, they must themselves have characteristic structures. So where do these field structures come from? The answer suggested is that they are derived from the morphogenetic fields associated with previous similar systems: the morphogenetic fields of all past systems become *present* to any subsequent similar system; the structures of past systems affect subsequent similar systems by a cumulative influence which acts across both space *and* time.

According to this hypothesis, systems are organized in the way they are because similar systems were organized that way in the past. For example, the molecules of a complex organic chemical crystallize in a characteristic pattern because the same substance crystallized that way before; a plant takes up the form characteristic of its



species because past members of the species took up that form; and an animal acts instinctively in a particular manner because similar animals behaved that way in the past.

The hypothesis is concerned with the *repetition* of forms and patterns of organization; the question of the *origin* of these forms and patterns lies outside its scope. This question can be answered in several different ways, but all of them seem to be equally compatible with the suggested means of repetition.

A number of testable predictions can be deduced from this hypothesis which differ strikingly from those of the conventional mechanistic theory. Two examples will suffice. The first concerns the inheritance of form, which according to the hypothesis of formative causation depends *both* on recognized genetic factors *and* on a direct influence from similar past organisms. The larger the number of similar past organisms, the greater should be this influence. Thus, for instance, in first-generation hybrids produced by crossing plants of two varieties, A and B, the form of the variety which has had the largest number of past individuals should generally tend to be dominant. If both varieties have had similar numbers of past individuals, the hybrids should generally be of intermediate form. Now if hybrid seeds produced in such crosses are kept in cold storage while very large numbers of one of the parental types, say B, are grown, and then if these seeds are taken out of storage and sown, the form of the resulting plants should resemble the parent B type more strongly than in the original hybrids, even though they were grown from identical seeds. Thus in the hybrids the dominance of one parental form over the other should change even though the genetic constitution of the seeds remains the same.

The second example involves changes in the rate of learning of new patterns of behaviour. If an animal, say a rat, learns to carry out a new task, which can be specially devised for the purpose of this experiment, there should be a tendency for all subsequent similar rats (of the same breed, reared under similar conditions, etc.) to learn more quickly to carry out the same pattern of behaviour. The larger the number of rats that learn to perform the task, the easier should it be for any subsequent similar rat to learn it. Thus, for instance, if thousands of rats were trained to perform a new task in a

laboratory in London, similar rats should learn to carry out the same task more quickly in laboratories everywhere else. If the speed of learning of rats in another laboratory, say in New York, were to be measured before and after the rats in London were trained, the rats tested on the second occasion should learn more quickly than those tested on the first. The effect should take place in the absence of any known type of physical connection or communication between the two laboratories.

Such a prediction may seem so improbable as to be absurd. Yet, remarkably enough, there is already evidence from laboratory studies of rats that the predicted effect actually occurs.

This hypothesis leads to an interpretation of many physical and biological phenomena which is radically different from that of existing theories, and enables a number of well-known problems to be seen in a new light. Its value will be uncertain until some of its predictions have been tested experimentally. But for the time being, it may serve to show that a specific organismic hypothesis is at least conceivable.

## Notes

1. A. N. Whitehead: *Science and the Modern World*, Chapter 7. Cambridge University Press (1926).
2. E. g. J. H. Woodger: *Biological Principles*. Kegan Paul, London (1929); L. von Bertalanffy: *Modern Theories of Development*. Oxford University Press (1933); L. L. Whyte: *The Unitary Principle in Biology and Physics*. Cresset Press, London (1949); W. M. Elsasser: *Atom and Organism*. Princeton University Press (1966); A. Koestler: *The Ghost in the Machine*. Hutchinson, London (1967); I. Leclerc: *The Nature of Physical Existence*. Allen and Unwin, London (1972).
3. This concept was first put forward independently by P. Weiss and A. Gurwitsch in the 1920s. A systematic statement of Weiss' view can be found in his *Principles of Development* (Holt, New York, 1939). For a discussion of the influence of organismic ideas on Weiss and other experimental embryologists, see D. J. Haraway: *Crystals, Fabrics and Fields*. Yale University Press (1976).
4. C. H. Waddington: *The Strategy of the Genes*. Allen and Unwin, London (1957).
5. R. Thom: *Structural Stability and Morphogenesis*, p. 320. Benjamin, Reading, Mass. (1975).
6. R. Thom: From a model of science to a science of models. *Theoria to Theory*, 10, 287-302 (1977).
7. In C. H. Waddington (ed.): *Towards a Theoretical Biology II*, pp. 72-81. Edinburgh University Press (1969).

8. For example, W. M. Elsasser in his *Physical Foundations of Biology* (Pergamon Press, London, 1958) proposed that new 'biotonic' laws were required in the realm of biology, but he later withdrew this suggestion (in *Atom and Organism*) because he did not want to be mistaken for a vitalist.
9. e.g. L. von Bertalanffy: *General Systems Theory*. Allen Lane, London (1971), and W. M. Elsasser, op. cit.
10. C. H. Waddington in Waddington (ed.), op. cit., pp. 238, 242.
11. A. R. Sheldrake: *A New Science of Life: the Hypothesis of Formative Causation*. Blond and Briggs, London (1981).